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PLANKTON, HYDROLOGY AND MARINE FOULING AT HEARD ISLAND

by

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1. PLANKTON AT HEARD ISLAND, 1949 -52

by E.H.M. Ealey.

INTRODUCTION.

In the early years of exploration in the Antarctic seas, plankton samples were collected haphazardly. In this way, much new material became available to the descriptive morphologists and many new species were described.

When commercial whaling was begun in the Antarctic, it became desirable to know the distribution of the main food organism of whales, Euphausia superba Dana, and to understand the physical and biotic factors influencing its distribution. The Discovery Committee undertook the investigation of the hydrology of the Southern Ocean and of the plankton community it contained. A considerable amount of work was done by this organization over several years from its base at South Georgia. Observations of the seasonal cycle of the plankton community over a complete year at any one place were not made, but a reasonable picture of such cycles was built up as a result of observations extending over a period of years. These observations made in the South Georgia region were supplemented by results from circumpolar cruises and by work done by the antarctic expeditions and whaling cruises of other nations.

Although this present work is limited in extent, it is the first plankton investigation carried out at any one locality south of the Antarctic Convergence throughout a full year.

In December 1947 the Australian National Antarctic Research Expeditions established a research station on Heard Island (53°01'S., 73°23'E.). During the second year of occupation (1949) a programme of biological research was begun; this included plankton investigations, which were continued until 1952. Continuous records over these four years were not achieved, as the programme was interrupted in 1950 and 1952 by damage to the craft used for collecting samples. Thus there are records from March 1949 to July 1950 and from March 1951 to August 1952. After 1952 the biological programme was reviewed and to avoid risking men and small craft in the Heard Island waters, the plankton tows were omitted.

It was planned to operate two planktological and hydrological stations in order to correlate seasonal fluctuations of the plankton with changes in environment. Chittleborough (See the second part of this Report) carried out hydrological observations during 1949 and such data as

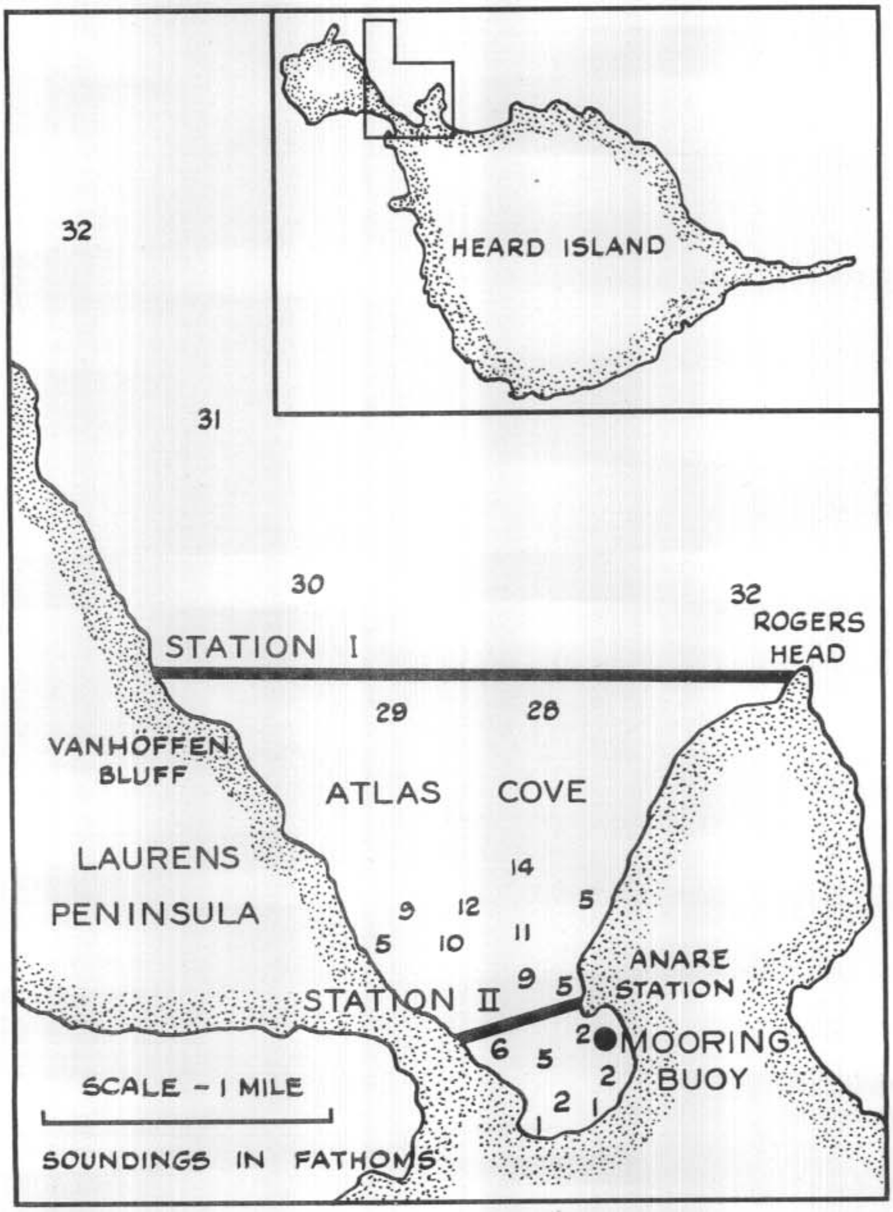

FIG. 1. MAP OF ATLAS COVE, HEARD ISLAND, SHOWING THE POSITIONS OF STATION 1 AND STATION 11

were collected after this year did not differ significantly from his results. Preserved water samples were not considered sufficiently reliable to warrant their collection after 1949. Station I, lying in Atlas Roads in about 60 metres of water, was under oceanic influence. Station II was situated in the shelter of Atlas Cove in four to ten metres of water and within the area of run-off from glaciers and melting snow (See Figure 1).

METHODS

Collection of samples. In 1949 three nets ("Discovery" type nets N70 and N50 and a 50 cm. stramin net) were hauled as surface horizontal tows at a speed of 1-2 knots for 15 minutes by a 25-foot cutter powered by a 10 h.p. two-cylinder diesel engine. (Later in the year, when the cutter became unserviceable, a dinghy powered by an outboard motor was substituted and found capable of hauling the nets at a similar speed.) Cutters of the same type were used in 1950-52. The N70 stramin net was of little value and was not used after 1949.

A new method of plankton volume determination. As volume estimates of the exceedingly common copepod, Drepanopus pectinatus Brady, were considered more important than counts of total numbers, a comparatively accurate method was devised to measure their volume after other organisms had been removed from each N70 sample. The mothod has been described (Ealey 1954) but it is useful to repeat it here.

Sheard (1947) showed that volume measurements of plankton allowed to settle in a graduated cylinder are quite inaccurate. He redescribed and tested a technique of obtaining plankton volumes by a displacement method, in which a known volume of plankton and liquid was filtered — the original container being washed out with known volumes of water. The volume of the filtrate was measured and subtracted from the original total volume to give the volume of plankton.

The new method is based on the displacement principle but a simpler technique is used. A plain glass tube some 40 cm. long with an external diameter of 3 cm. is used in conjunction with a 250 c.cm. graduated cylinder of internal diameter slightly less than 3.5 cm. Silk gauze, finer than that used in the net which took the samples, is tied over one end of the plain glass tube. Before plankton volumes can be measured, the difference in volume caused by the presence of the tube inside the graduated cylinder must be determined. It is a simple matter to make a graph showing this difference by plotting the readings given by several different volumes of water in the cylinder with the tube in position and without. There is an obvious linear relationship.

The sample to be measured is poured into the glass tube. When most of the water has drained away, air is blown through until water ceases dripping from the tube. The tube and plankton samples are then plunged into the cylinder containing 100 ml. of water. When the plankton is well mixed with water and no bubbles remain, a reading is taken of the level inside the tube. The graph is used to find the real increase in volume which approximately equals the volume of the plankton sample. The tube is removed from the cylinder and drained for a few seconds before the compact mass of plankton in the bottom is allowed to slide out of the tube and back into the original container. The whole process can be carried out in six minutes.

Methods of analysis. The age-sex composition of the Drepanopus population was determined by counting 400-500 specimens from each N70 sample and expressing the ratio as a percentage. All zooplankton were counted except such very small copepods as Microstella norvegica (Boeck), Oithona sp., Oncoea sp. and juvenile Metridea spp.

The phytoplankton were not counted but the volume of each N50 sample was measured by the old displacement method (Sheard 1947) and the proportion of zooplankton and detritus, to the phytoplankton roughly determined. A drop of each sample was then examined under the microscope, the relative abundance of each organism being judged and checked twice. Occasional back checks showed this method was sufficiently accurate to indicate major fluctuations. The symbols used to indicate these changes are described in Tables 6 and 7.

Stomach contents of about 100 plankton-feeding birds have been examined. The stomachs had been injected with formalin so that many of the organisms found in them were in such good condition that specific identification was possible.

OCEANOGRAPHY OF THE HEARD ISLAND REGION

Hydrology. This section is based on results obtained by Chittleborough (See the second part of this Report) and biologists of other years.

(i) Salinity. Chittleborough showed the salinity at Station II fluctuated much more than at Station I. He was able to correlate these fluctuations with air temperature changes which in turn governed the rate of flow of glacier water into the cove. A slight increase in salinity with depth is suggested by his results. It is possible that the glacier water caused the lowered surface salinities and at times it may have caused the plankton to keep below the surface, thus being responsible for some of the strangely unproductive plankton hauls. The surface salinities for 1949 may be summarised as follows:-

SURFACE SALINITY (%) 1949

Station	Minimum	Maximum	Mean	Number of Observations
I	33.89	34.04	33.94	9
II	32.92	34.04	33.75	23

(ii) Oxygen. The amount of dissolved oxygen at Station II was more influenced by wave action and the underlying algal belt and was consequently usually higher than at Station I. Chittleborough found oxygen concentration to vary with the amount of sunshine each day, rather than each week. His results showed a seasonal fluctuation. The high values from August to December coincided with increased phytoplankton growth and were followed by a drop in the summer due in part at least, to the increase in zooplankton. However, much of the fluctuation could be correlated with sea temperature changes. The dissolved oxygen in surface water, for 1949, is summarised below:-

DISSOLVED OXYGEN (ml. per litre) IN SURFACE WATER, 1949.

Station	Minimum	Maximum	Mean	Number of Observations
I	7.00	7.60	7.31	9
II	7.20	8.14	7.70	24

PERCENTAGE SATURATION, 1949.

Station	Minimum	Maximum	Mean	Number of Observations
I	89.5	99.0	94.4	9
II	91.0	102.0	97.9	23

(iii) Phosphate and nitrate. Chittleborough recorded higher values of both these nutrient salts at Station II than at Station I. While the concentrations of the salts were never low enough to limit phytoplankton growth, slight seasonal fluctuations were suggested by his data. After September, when the diatom growth began, the values showed some decrease but signs of recovery appeared in February. The surface phosphate phosphorous and nitrate nitrogen for 1949 (from preserved samples) are summarised below.

PHOSPHATE P. (mg./M^3)

Station	Minimum	Maximum	Mean	Number of Observations
I	34	50	40.8	9
II	29	56	41.9	18

NITRATE N. (mg./M^3)

Station	Minimum	Maximum	Mean	Number of Observations
I	373	554	444	9
II	463	666	586	17

Sea temperature. Chittleborough showed that the sea temperature at the inshore station was more affected by air temperature fluctuations than that at Station I.

The following figures show the range of values for 1949:-

OBSERVED RANGE OF SURFACE TEMPERATURES (°C.)

Station	Minimum	Maximum	Mean	Number of Observations
I	1.08	2.70	2.03	9
II	0.05	3.37	1.52	27

Observations at Station I were discontinued after 2 July in 1949. Records made in 1950 show that the sea temperature at that station had dropped to 0.1°C. on 2 September. In 1949 the minimum temperature at Station II occurred about the end of August; therefore it can probably be said that sea temperatures begin rising at Station I and II before October.

Records of sea temperatures taken during A.N.A.R.E. relief voyages over the period 1949-1955 show that in the region between longitudes 70°E. and 119°E., the Antarctic Convergence lies between latitudes 48¾° and 51¾°S. during the months January-March inclusive. At all times of the year Heard Island is south of the Convergence which passes approximately through Iles de Kerguelen.

The range of the apparent mean positions of the ice edge due south of Heard Island has been shown by Mackintosh and Herdman (1940) Pl.LXIX to be between 67°S. in March and 58°S. in September-October approximately. Plate LXXV of their paper shows records of pack ice at:-

56°0'S. 77°E. on 15 October, 1934
57°30'S. 73°E. on 28 November, 1935
57°0'S. 76°E. on 1 December, 1935

During the winter of 1948 suspected ice blink was reported as having been seen from the island and in August of that year snow petrels, Pagadroma nivea, were recorded (Gilchrist, 1952). R.R.S. "Discovery II" made a summer record of pack-ice at 65°08'S., 90°00'E. in February, 1951, and a winter record of 57°54'S., 98°24'E. in this sector. During the circumpolar cruise of this vessel, pack-ice was discovered south of Heard Island at 59°15'S., 64°08'E. and 56°50'S., 80°42'E. These latter records would place August limit of the pack at about 300 miles south of Heard in 1951. There is reason to believe that pack ice would reach Heard Island under certain conditions of wind and temperature.

Probable currents. Heard Island lies in the region of the West Wind Drift. This surface current caused by the south-westerly winds must strike the western and southern shores of the island, flowing around its northern end and along the south-easterly spit. The direction in which this spit lies and the position of shoals in the area suggest that the current in that region has resumed its north-easterly direction of flow. That a small craft which sank close inshore early in 1949 at the northern tip of the island was washed well into Atlas Cove suggests that sometimes, at least, currents wash into Atlas Cove. However, it appears from plankton records that the Cove may be a backwater from which oceanic water is excluded for long periods. After the winter of 1949 there was no sign of calanid copepods in the summer hauls at Station II (Station I was not visited after July that year), and very few were recorded in 1950 although they were numerous at Station I. On the other hand in 1951 these oceanic copepods were sometimes more abundant at Station II than Station I.

Tidal currents also occur in Atlas Cove twice in every 24 hours, although a gale may cause a tide to remain high for some time.

Turbulence. Evidence of wave turbulence bringing water from the deeper layers is provided by the plankton. Occasionally species that are indicators of deeper water have been taken. The chaetognath *Sagitta maxima* (Conant) seldom recorded above 250 metres has appeared during three separate periods. In two hauls in June and July of 1950 it occurred and again in August 1951. On the latter occasion one of the few records of the copepods *Pleuromanna robusta* (F. Dahl) and *Metridea lucens* Boeck, was made. *S. maxima* was again taken during December-January 1951-52 together with *Euchaeta biloba* (Farran), a typical copepod inhabitant of the intermediate water layer, while numerous larvae of *Euphausia vallentini* Stebbing were present during this period as well.

PHYTOPLANKTON SPECIES OCCURRING AT HEARD ISLAND

BACILLARIOPHYCEAE (1)

DISCINEAE

Coscinodiscus spp. The seasonal variations of only one species of this genus (*Coscinodiscus concinnus*)

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(1) Some species of diatoms are not mentioned in this Report. They are listed however in a systematic paper by E. Manguin (1954).

have been followed. Speaking generally of the genus, the largest numbers were recorded during March and April in all years. After the winter decline there was some increase from October to December.

Coscinodiscus concinnus Wm. Smith. This diatom is considered by Hendey (1937) to be plentiful in temperate and sub-tropical seas; but it was also quite common at Heard Island. It was one of the dominant species of the autumnal increase and was one of the first diatoms to reach its peak. Tables 5 and 6 show the main period of growth to be from September to December with the peak being reached in late October and early November.

Hyalodiscus sp. During 1949 not many cells of this genus were collected at any one time, except in a sample taken in May, and in 1950 the species was usually not present in N50 samples although it did appear in all hauls done in June and July 1950. There is only one record of Hyalodiscus in 1951, in July.

Asteromphalus robustus Castrocane. This was almost always taken in small numbers, except during November and December when the numbers increased. There were more during November and December 1949 than in these months of 1951.

BIDDULPHINEAE

Eucampia balaustium Castracane. Occasional fragments of this species were identified throughout each year and during the latter part of the period of main increase it was an important form in the net plankton. In 1949 most were recorded in November, but it was still present in December and during the following January. By contrast, in 1951 there were only a few isolated pairs of frustules in November, numerous chain forms in December, and odd fragments in early January 1952.

Hart (1942) places Eucampia in his ecological Group III which implies that its "relative importance" is greatest from the beginning to the peak of the main increase. It can be seen from Tables 5 and 6 that this was not the case at Heard Island.

Triceratium arcticum var. kerguelensis Castracane. A few of this species appeared in most samples and sometimes chains of up to four or five frustules were noted. The frustules which composed these chains were smaller than single ones.

Biddulphia spp. Members of this group were never important in the Heard Island phytoplankton. Chain forms occurred now and then and a small but definite increase in numbers was recorded in December 1951.

Isthmia enervis Ehrenberg. A few specimens of this large diatom were collected.

Chaetoceros atlanticus Cleve. This diatom is considered to be the most important member of Hart's ecological Group IV in the northern region of the Antarctic. Our data agrees with this view but his contention that the greatest relative importance of this group is "from the peak of the main increase through summer and autumn" is not supported by our results (Tables 5 and 6). In 1949 and 1951 much cell division was noted in October; the peak appeared to be reached in November after which numbers declined. Except for occasional short chains this form was not found during the other months.

Chaetoceros atlanticus var. neapolitana (Schroder) Husted. This variety was not as numerous as the above species. Its spring increase did not begin until after the type form began increasing in October. In November it reached its peak but there was no record of it after December in any year. Its appearance at Heard Island in moderate abundance is interesting in view of the fact that it prefers temperate and sub-tropical water (Hendey, 1937).

Chaetoceros dichaeta Ehrenberg. This appeared only in the spring and was never common. In 1949 it was sampled in October, November and December, but in 1941, apart from a few short chains late in November, it occurred only in December.

Chaetoceros concavicornis Mangin and Castracane. These two chaetocerids could not be distinguished from one another by the author. One or both species were taken in March, April, May, October and November of 1949 and 1951. They were never numerous.

Chaetoceros peruvianus Brightwell. This species occasionally occurred.

Chaetoceros dicladia Castracane. This diatom was recorded by Castracane (1886) as frequenting the seas around Heard Island and Iles de Kerguelen. Always present in our samples, it was the most common chaetocerid, the seasonal fluctuations coinciding with those of Coscinodiscus concinnus. It was one of the dominant species of the autumnal increase, after which empty cells and resting spores were found. However, at all times of the year occasional resting spores of Ch. dicladia were noted. Spring growth began in October and this reached the peak of its increase early in November in 1949 and 1951. Whereas in 1949 there still appeared to be some active cell division until the end of the year, in 1951 large numbers of resting cells were produced in mid-December and many frustules were quite empty. In late December of the same year (1951) water suspected of coming from deeper layers contained mostly empty cells and few resting forms, and in January 1952 only a few fragments of frustules represented the species.

Chaetoceros Lawii Manguin. This diatom became suddenly abundant around the peak of the main phytoplankton increase in 1949 and 1951. It disappeared just as suddenly in mid-December and was not recorded at other times of the year.

SOLENIINAE

Rhizosolenia antarctica Karsten. Small numbers of this species were noted in some spring samples.

Rhizosolenia alata Brightwell. The species, Sensu stricta, was noted only during the period of main increase in 1949 but in 1951 very small numbers appeared at the time of the autumnal increase as well as during the main increase when it was quite an important form reaching a peak in early December. A few cells were collected as late as the end of January 1952.

Rhizosolenia alata fo. indica (Perag.) Ostenfeld did not occur in the autumn and it reached its spring peak earlier than the above species. Otherwise its time distribution was similar. Its relative abundance at Heard Island is interesting as Hendey (1937) found it to be more common in tropical and sub-tropical waters.

Rhizosolenia alata fo. inermis (Cast.) Hust was taken in April 1951 but not in the autumn of other years. This form was important at the time of maximum increase, appearing in large numbers in mid-November and early December. It did not occur after December.

Rhizosolenia crassa Schimper ex Karsten. Hendey (1937) considers Rh. crassa to be a typically antarctic diatom sometimes abounding in the waters of South Georgia, South Sandwich Islands and Bouvetoya. Large numbers appeared occasionally at Heard Island in 1949 and it was plentiful in March but most abundant in April when big rafts consisting of large and small frustules were found (Figure 2). A similar, but not so great, autumnal fluctuation took place in 1951. There was insufficient material from 1950 for trends to be noted. Rh. crassa was not seen in autumn 1952. Odd cells were taken in most months of 1949 and some increase was noted in late October and November. In the spring of 1951 some dividing chains appeared but the diatom was not numerous and it was not seen between its autumn increase and spring of this year.

Rhizosolenia curvata Zacharias. The occurrence of this subantarctic species at Heard Island although not in abundance is significant. Hart (1937) considers "that the occurrence of this species on the antarctic side of the Convergence is a good indication that mixing of surface waters is in progress or has recently taken place". Judging by this criterion there is only occasional evidence of mixed water in Atlas Cove in 1949 and none in early 1950. Rh. curvata appeared once in April 1951 but was continuously present during October and November of that year. There was apparently some horizontal mixing during those months.

Rhizosolenia Chunii Karsten. This was recorded at Heard Island only during the spring months.

Rhizosolenia hebetata (Bailey) Gran fo. Bidens Heiden and Kolbe. This cold water species was sampled on several occasions. It was more important in the spring of 1949 than 1951 but it was never common.

Rhizosolenia hebetata fo. semispina (Hensen) Gran was represented in small numbers during each autumnal period of increase and throughout the main phytoplankton increase, reaching its peak between mid-November and early December.

Rhizosolenia simplex Karsten. This diatom was present in small numbers throughout the period of main increase in 1951.

Rhizosolenia styliformis Brightwell. This was never as common as Rh. crassa during the autumnal increase,

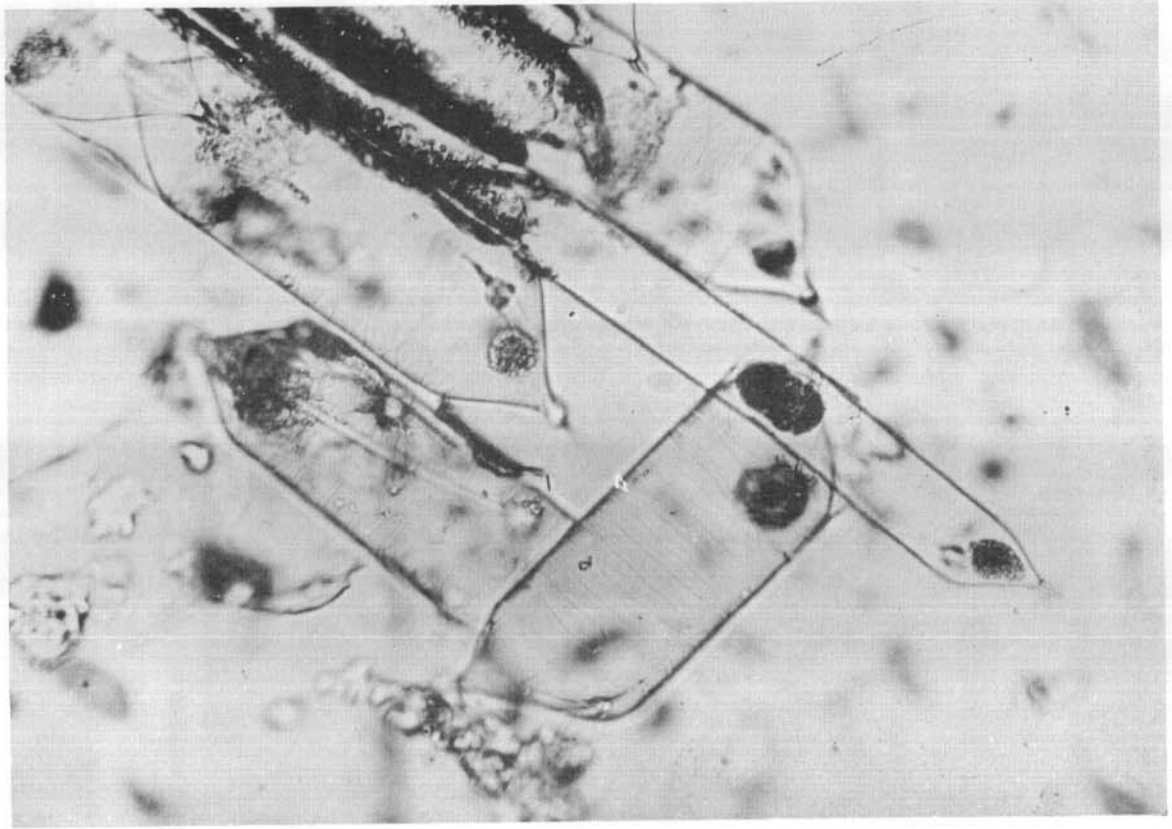

FIG. 2. RHIZOSOLENIA CRASSA SCHIMPER CLUMPED TOGETHER TO FORM A RAFT. x200.

but was more common during the spring increase. However, it was never a very important species.

Dactyliosolen antarcticus Castracane. This species was always taken in the N50 net but in winter months it was represented by only a few solitary cells. In 1949 it was a dominant species in the main phytoplankton increase, reaching a peak in November, but in sprint 1951 although numerous it did not attain such relative importance. In 1951 a peak in its increase was noted in early December. At Heard Island the greatest relative importance of this diatom was not in the autumn as Hart (1942) suggested it should be, to conform with his ecological Group II to which it belongs, but in the spring.

Corethron criophilum Castracane. Apart from a spring increase the type phase of this species occurred in very small numbers. In 1949 and 1951 it was present from October to December, being most numerous in November. A peak was attained in mid-November 1951, but most of the specimens were very small and may have been the "hystix" phase. As in the case of *D. antarctica*, *C. criophilum* was of no importance in the autumn.

Corethron criophilum fo. inerme Hendey was not as abundant as the type and was seldom seen other than in the spring. Moderate numbers were recorded in November and December of both 1949 and 1951. Terminal bristles were present in a few cases. This agrees with the findings of Hart (1942).

ARAPHIDINEAE

Fragillariopsis antarcticus (Castracane) Hustedt. Small chains appeared occasionally but the species was abundant only during the period of main increase when it was a dominant form in 1949 and in 1951. In 1949 it was most common in November and had almost died out in December. In 1951 small chains of 4-5 cells were noted in October with both the number and length of the chains increasing during November and reaching a peak in December but declining suddenly in January 1952. This is the only representative of Hart's Group I and on the whole its fluctuations are in accordance with his generalizations.

Thalassiothrix longissima Cleve and Grunow, var. *antarctica* Grunow. This was the most abundant diatom of the main increase. It reached its peak in November of 1949 and was so prevalent in 1951 that it interfered with the sorting of the N70 samples. It was still found in the following January but was not so plentiful. Its great abundance at the time of main increase fits in with Hart's Group II to which it belongs, but it was not observed during the autumnal increase nor at any other time of the year.

Rhabdonema adriaticum Kutzing. Single frustules of this diatom were taken on a few occasions during 1949 and 1950, but in 1951 it appeared in most net samples when short chains of two or three cells were found. In October some 7-cell chains were collected and a peak in its growth came in mid-October after which its numbers declined, although it was found consistently in every haul until January.

MONORAPHIDINEAE

Achnanthes kerguelensis Castracane was more frequent in 1949 than in other years. It was never abundant but it was more numerous at the inshore station and appeared there more often. A. kerguelensis was first recorded near Heard Island - off Iles de Kerguelen - by Castracane (1886).

Cocconeis spp. Members of this genus were sometimes taken, usually in samples from the inshore station.

BIRAPHIDINEAE

Pleurosigma directum Grunow occurred occasionally, with larger numbers appearing in the spring.

DINOFLAGELLATA

Goniaulax monocantha Pavillard. This was recorded only once, in December 1951.

PERIDINIALES

Ceratium pentagonum Gourret 1883 fo. robustum Cleve. Although this was present in almost all N50 samples, it was quite prominent in the autumnal period of increase, reaching its maximum in June and showing some increase in spring, though never abounding at that time. There were no hauls made in March, or April, or after July in 1950, but it was prevalent in May when they were resumed, and most numerous in June. Its abundance in June was not repeated in 1951 and 1952 in which years it was commonest in April. C. pentagonum was not important during the period of main phytoplankton increase in 1951 but it reached a peak in January of the following year.

Peridinium depressum Bailey. This species was the most common of the genus in our plankton. It was always associated with *C. pentagonum* in its seasonal fluctuations (Tables 5 and 6) although their relative abundance was not always the same.

Peridinum oblongum (*Aurivallius*) Cleve 1900. This was noted only in 1949 when it was present in most samples.

The time distribution of the other species of *Peridinium* in the Heard Island samples is dealt with in more detail by Wood (1954) but the records are summarised as follows:-

OCCURRENCE OF VARIOUS SPECIES OF PERIDINIUM, 1949-1952

Species of *Peridinium*	1949	1951	1952
P. punctulatum Paulsen	May, December	December	
P. roseum Paulsen	April, May, December	March, April	May
P. pyriforme Paulsen	June, November, December	December	
P. leonis Pavillard	June, November, December	December	
P. c.f. *breve* Paulsen	July, October, November, December, January(1950)	April, December	January
P. crassipes Kofoid	December	April	
P. granii Paulsen	December		January
P. oceanicum Vanhoffen	October		
P. conicordes Paulsen		December	
P. subinerme Paulsen		April	January
P. turbinatum Manguin		December	January
P. brevipes Paulsen		December	January
P. ovatum (Pouchet) Schutt		December	January
P. pellucidum (Bergh) Schutt		December	
P. curtipes Jorgensen		December	

ZOOPLANKTON SPECIES OCCURRING AT HEARD ISLAND

COELENTERATA

SIPHONOPHORA

Pyrostephos vanhoffeni Moser. The nectophores of one or two individuals of this species were found intermittently in our nets throughout each year. Sometimes large numbers were washed into the shallows of Atlas Cove during a gale. Occasionally Cape petrels, Daption capensis Linne, could be seen picking these pale pink animals from the sea. These birds seemed to concentrate on a definite area and could be seen feeding mainly on P. vanhoffeni, suggesting that the latter was concentrated in some places.

MEDUSAE

Cosmetirella davisi (Browne). This Leptomedusan was only taken in summer hauls and never in large numbers. It was not found before January in any year and specimens taken as late as May in 1950 appeared to be dead and decaying.

Desmonema chierchiana Vanhoffen. Specimens of this large reddish medusa were never taken in the nets but were occasionally found washed up on the beaches usually in the winter months.

CTENOPHORA

Callianira antarctica Chun. In 1949 and 1950 occasional specimens were taken during the winter months, yet in 1951, when many more hauls were done, none was recorded until November.

POLYCHAETA

Tomopteris carpenteri Quatrefages. Individuals sometimes appeared in the samples throughout each year in small numbers, the largest number being sixteen taken in June 1951. Large numbers were occasionally found in the shallows after a storm, over 50 being taken with a hand net on 17 July, 1949.

Autolytus charcoti Grairer. This species was not taken in our plankton nets but three specimens were captured on 31 August, 1949, with a hand net. They were swimming on the surface near the shore and had large numbers of eggs attached to them. Perhaps this species becomes planktonic for a short while at this time of the year during its breeding season.

Autolytus gibber Ehlers. Only three of this species was taken by our nets — one in September, 1949, one in October 1949 and one in August 1951. The specimens taken in August and September were epitokous.

Autolytus simplex Ehlers. This did not occur in 1949 or 1950 samples, but in 1951 six male epitokes were netted in August and three non-breeding forms in October. Of these latter one came from Station I and was the only example of *Autolytus* to be taken from the outer station.

Pelagobia longicirrata Greef. At Heard Island this tiny polychaete appeared only in the summer and autumn months and in small numbers. A specimen was also found in a surface sample collected by R.R.S. "Discovery II" off Iles de Kerguelen in September.

Phalacrophorus c.f. *pictus* Reibisch. This species occurred in small numbers in the summer months.

Nerinides sp. Chaetosphere and spionid larvae, presumably of this genus, were noted during the summer months.

Maupasia sp. One was identified from a sample taken in November 1951.

CRUSTACEA

COPEPODA

The following copepods were identified in the Heard Island plankton:-

> *Calanus simillimus* Giesbrecht, *Calanus propinquus* Brady, *Calanoides acutus* (Giesbrecht), *Rhincalanus gigas* Brady, *Drepanopus pectinatus* Brady, *Euchaeta antarctica* Giesbrecht, *Euchaeta biloba* Farran, *Metridia lucens* Boeck, *Metridea curticauda* Giesbrecht, *Pleuromamma robusta* (F. Dahl) form *antarctica* Steur., *Oithona similis* Claus., *Microstella norvegica* Boeck.

In 1949 no calanoids were taken after July. This cannot be due to the loss of the N70 net as the small stramin net had always sampled some of these species at the same time as they were present at only average abundance in N70 net hauls. In fact, very few Calanus simillimus were taken when N70 nets were again in use in 1950, until July. This suggests that hydrological conditions in Atlas Cove from spring to autumn, 1949-1950, were different from those of other years.

Calanus simillimus Giesbrecht. Of the larger copepods this species was the most abundant. In one 15-minute tow over four hundred were taken. During the later summer and autumn the bulk of the population consisted of juveniles (Table 1). There were comparatively few adult males and females and the gonads of the latter were undeveloped. In 1951 individuals were taken from August to October only occasionally, probably because the population in the area had migrated to the deeper warm layer (Mackintosh, 1937). Early in November 1951 adult females were quite numerous. A few had spermatophores attached but were not oviferous; the majority had well developed ovaries and oviducts full of eggs while some had distended oviducts but these did not contain eggs. The latter females were probably spent. Oviferous females were still being taken in the middle of December though there was a larger proportion of spent females. Males were encountered only occasionally and these had well developed testes. Turbulence is considered to have occurred before the end of December and adult individuals were taken before the end of January only occasionally when juveniles comprised the main population.

Several hundred C. simmillimus were taken in a 40-minute surface haul done by R.R.S. "Discovery II" off Iles de Kerguelen on 1 September, 1951. The ovaries of the females were in a similar condition to those taken at Heard Island in October. In fact, it was noted that in some cases development was even more advanced.

Vervoort (1951) states that large numbers of this species taken at 51°11'S., 11°17'E. in December showed no signs of breeding. Although this position is at a lower latitude than Heard Island, it is much further south of the Antarctic Convergence than Heard Island. These observations suggest that the breeding season of C. simillimus is progressively later the further south of the Convergence it is found.

Calanus propinquus Brady. This species was never found in large numbers at Heard Island and those present were mostly juvenile (Table 2). This observation agrees with that of Mackintosh (1934) who stated that "specimens taken near the Antarctic Convergence are mostly immature". Of the few adults the great majority were females. Several of these taken in November 1951 had well developed ovaries; perhaps these were stragglers from a spawning stock well to the south of the island. The females taken in late December from upwelled water had expanded empty oviducts, and appeared to be spent. Members of this scuthern breeding stock were probably the progenitors of the comparitively large number of juveniles sampled in March of 1950 and 1951. Ottestad (1932) found these animals spawning in the north eastern Weddell Sea during November and December.

Several juveniles taken in December 1951 appeared to be in the last copepodite stage but there is not sufficient evidence to suggest when or where the spawning which produced them took place.

Calanoides acutus (Giesbrecht). A typically antarctic species, this was second in abundance only to Calanus simillimus. Adult males were never found, and adult females did not occur from March to July. No Calanoides were taken in August, September or October (Table 3). Mackintosh (1937) in his Table VI shows them as confined to the deeper water layers in September though rising to the surface in October. Ottestad (1932) considered C. acutus to begin spawning in the Weddel Sea during late November and early December. However, Heard Island results suggest that the stock sampled by our nets in early November had already started spawning. This suggestion is supported by the few adult females taken during December which appeared to be spent, and by the large number of very small juveniles occurring in middle and late December.

Rhincalanus gigas Brady. Although it has been shown by Mackintosh (1937) that this copepod occurs in considerable numbers on each side of the Antarctic Convergence, very few specimens, none of them males, were collected in our nets (Table 3). This is no doubt because the bulk of the species remains below the 50-metre level (Hardy and Gunther, 1935). During the years of our investigations almost all the specimens taken in autumn and winter were juveniles. Ommanney (1936) shows in his Fig. 6 that this species begins rising to the surface in November in the Falkland Island sector. The largest number taken at Heard Island was 40, 25 of which were adults, mature or approaching maturity (Ommanney, 1936; Fig.17) in early November 1951. Some of the adults taken in December were also mature, but the numbers are far too small to postulate a breeding season for the region. However, nauplii of Rhincalanus sp. were noticed in the middle of December 1951.

Drepanopus pectinatus Brady. Although this species has been shown by Hardy and Gunther (1935) to make vertical migrations, this copepod was by far the most numerous in our hauls (daylight). Around South Georgia it was found most abundantly over the continental shelf and in the Heard Island area its distribution is probably similar. Our largest samples were taken at the inshore station. However, at the off-shore station the animals would be distributed throughout 60 metres during the daylight while turbulence may have prevented any effective vertical migration at the shallow inshore station.

Sufficient hauls were done in 1949 and 1951 to outline the breeding season of Drepanopus, and the 1950 and 1952 hauls support the conclusions. The system used to analyse the population of the species is described in the section on "Methods". Almost identical results were obtained from Stations I and II so that Figure 3 showing the seasonal variations of the percentages of males, females and juveniles for Station II in 1951 may be taken as being representative of Station I and of other years.

It can be seen from Figure 3 that the adult males and females began to increase with a corresponding decrease in juveniles in July. At this period large numbers of shed skins in the samples suggested large-scale moulting during July and August. As early as June occasional males were seen, but the highest percentage occurred in August (40% in early August, 1952, and 33% in late August, 1951). Such high percentages were not found in 1949, although there was a marked increase during August in this year.

In June, also, adult females with spermatophores attached to their abdomens and occasional oviferous females were found. The number of adult females with spermatophores attached (Figure 4) increased with the high proportion of adult males. September records are inadequate. The highest percentage of females taken was in October and November of 1949 and 1951, a large proportion of the October samples being oviferous and many actually extruding eggs, (Figure 5). Several gravid females were dissected and each contained between 28 and 32 eggs. Numerous eggs, similar to Drepanopus eggs, and nauplii were found in the N50 samples collected during October. Many eggs occurred singly but clumps of as many as 18 appeared, most of which were in various stages of division. The November N50 samples also yielded numerous eggs but there were more nauplii that month.

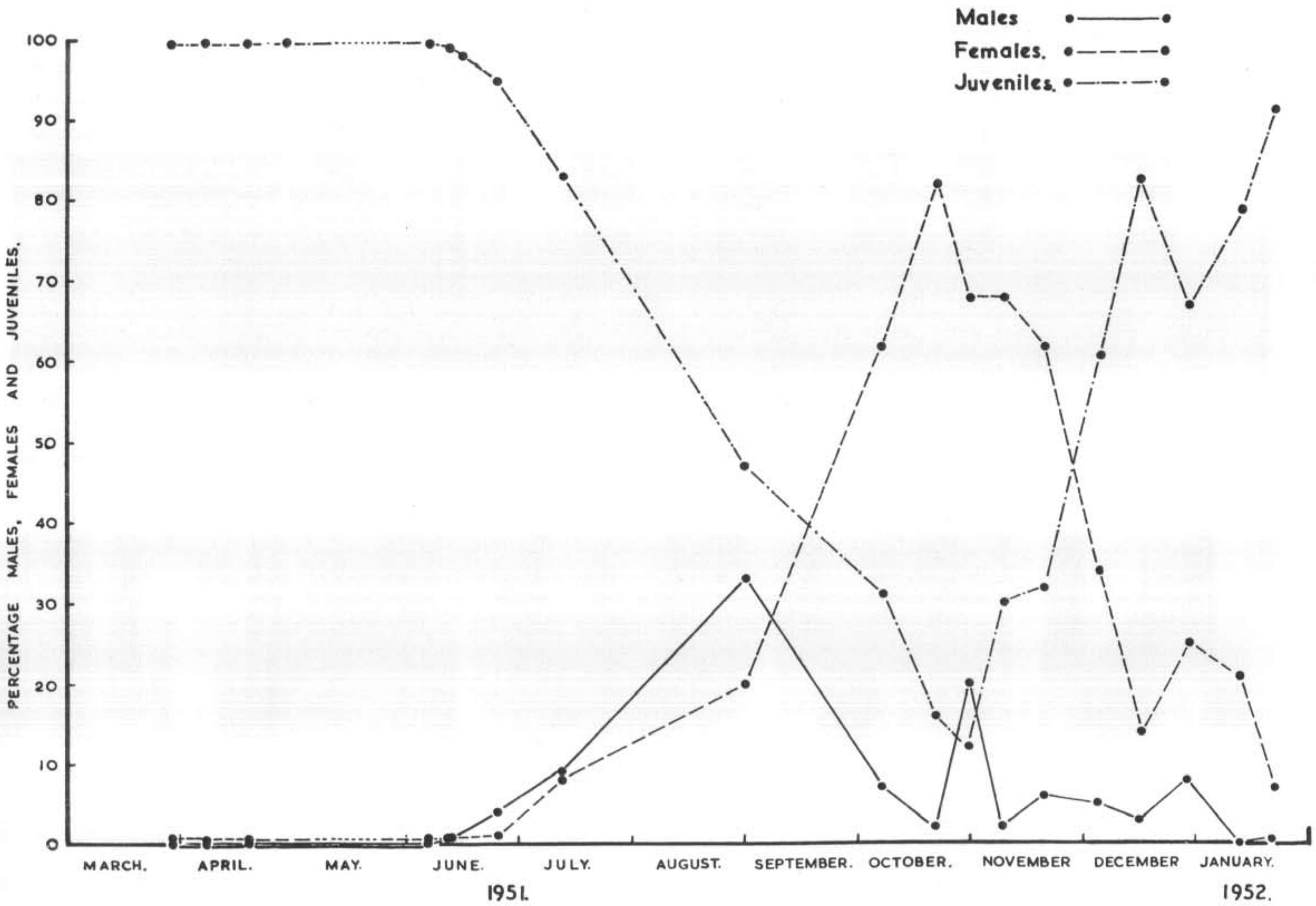

FIG 3.

BREEDING CYCLE OF DREPANOPUS PECTINATUS
BRADY, 1951–52

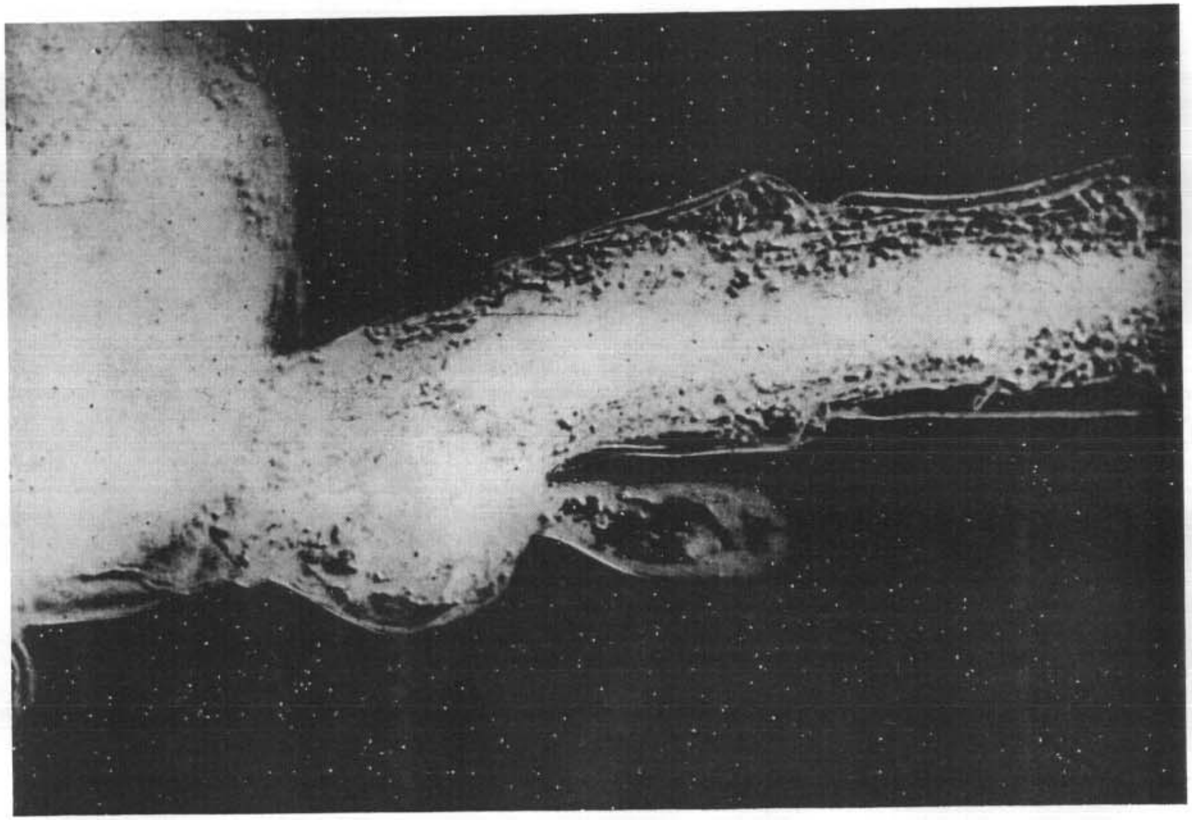

FIG 4.

DREPANOPUS PECTINATUS BRADY SHOWING SPERM SAC ATTACHED TO ABDOMEN OF FEMALE. x500

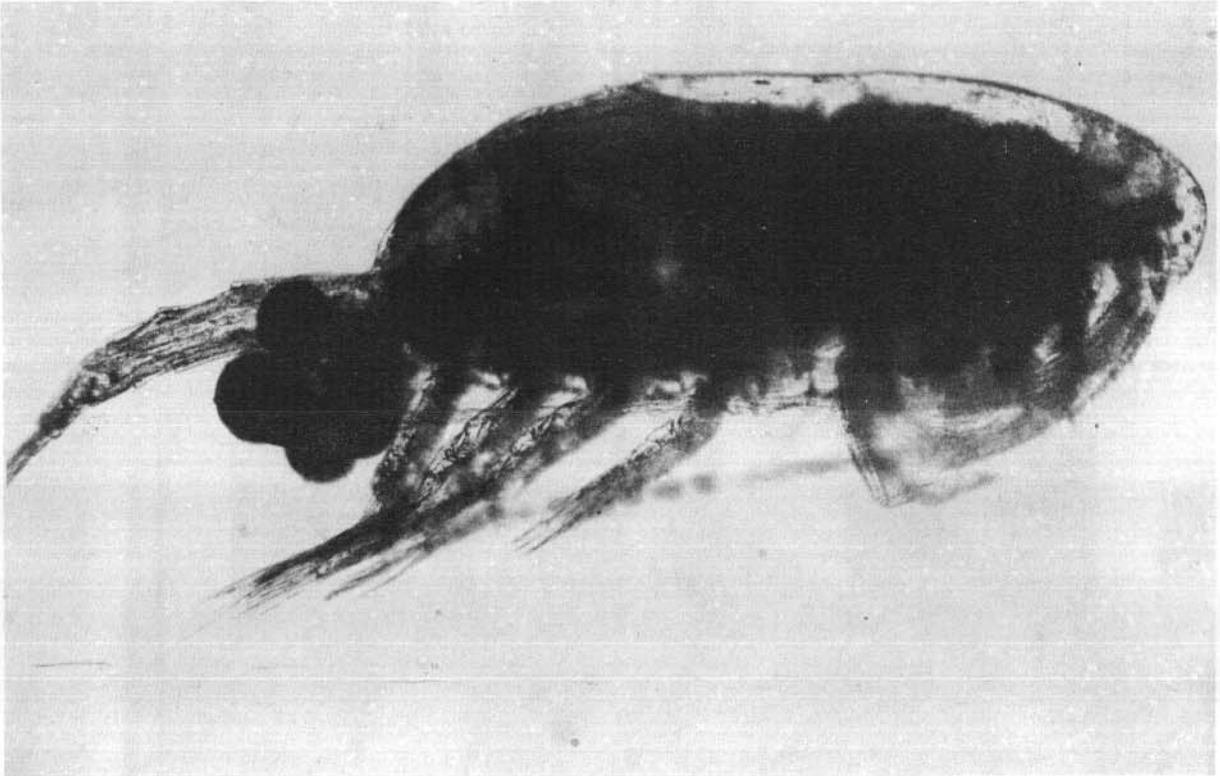

FIG. 5. *DREPANOPUS PECTINATUS* BRADY SHOWING FEMALE EXTRUDING EGGS. x150.

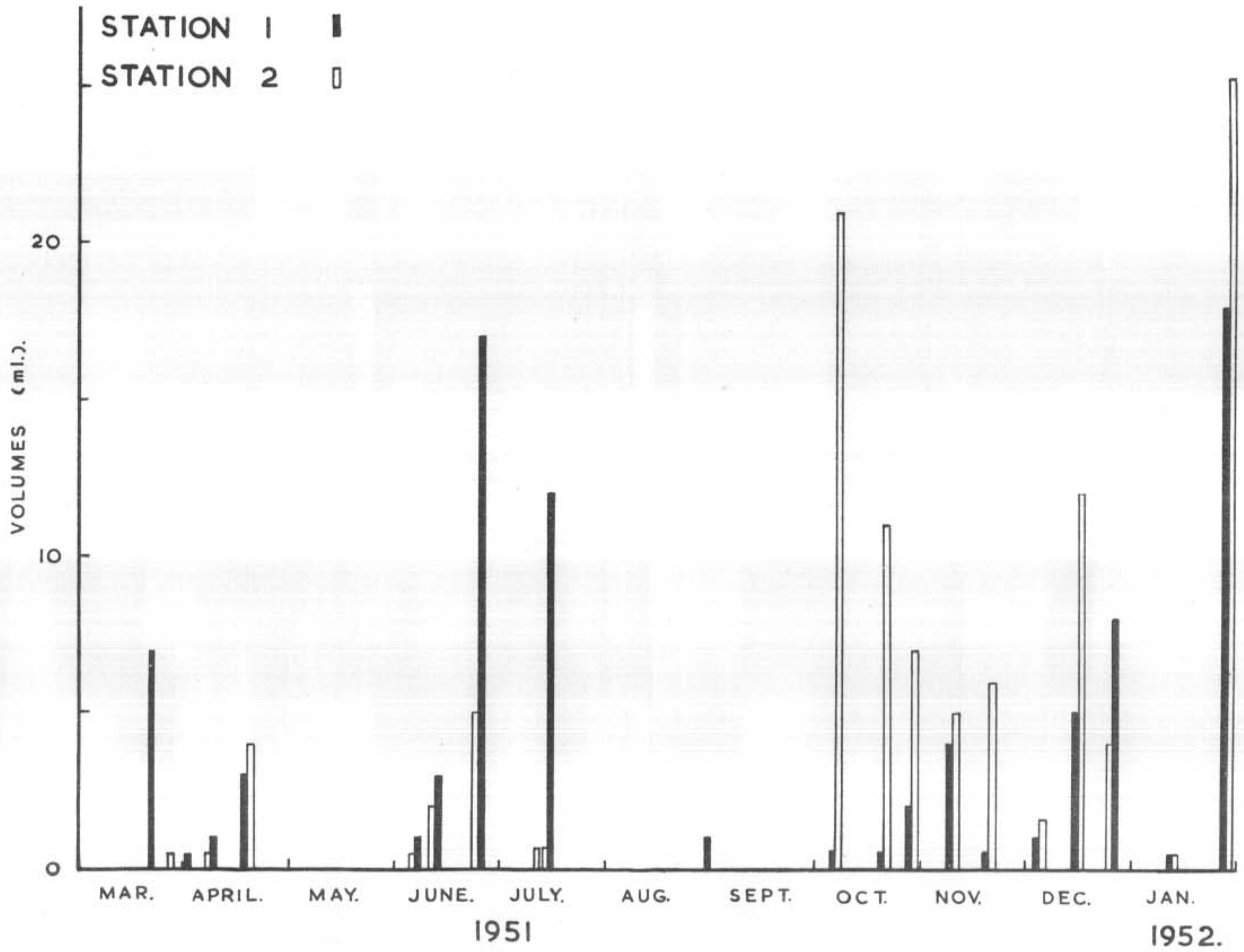

FIG. 6. DISPLACEMENT VOLUMES OF DREPANOPUS PECTINATUS BRADY, 1951–52.

It may be significant that from March to July 1951, the volumes of Drepanopus at Station I (off-shore) were almost always greater than at Station II whereas after October the reverse was the case (Figure 6). Similar results were obtained in 1949 before Station I was abandoned in June of that year. It can also be seen that the volumes of Drepanopus decreased at Station II as they increased at Station I during October and November 1951. No records are available for September, but perhaps the maturing population moves into shallow water to breed and disperses seaward towards the end of the season.

In December and January some adult males and oviferous females were still present but the bulk of the population consisted of juveniles. There were no records for February but by March the population was almost entirely juvenile.

Euchaeta antarctica Giesbrecht. This species was only taken in small numbers, perhaps because our hauls were done in daylight. Hardy and Gunther (1935) have shown this species (referred to by them as Pareuchaeta antarctica) to make active diurnal migrations. E. antarctica has occasionally appeared in the stomach contents of Pelecanoides georgicus Murphy and Harper and Pelecanoides urinatrix (Gmelin). On two occasions 200 individuals were found in a single bird stomach, which seems to support the claim of Hardy and Gunther that the species is patchy in its distribution.

Insufficient specimens were taken to provide observations on the breeding season of this copepod. However, it was noted that adult males were seen only in July, August (net samples) and January. Adult females carrying spermatophores, one with three attached to its abdomen, occurred in net samples from June to November and in a bird's stomach in January. Females carrying egg sacs occurred in July and October. Occasional juveniles were taken in net hauls from January to July and in October over 200 well advanced juveniles were found in a bird's stomach.

In one instance when a large number of what appeared to be Euchaeta, almost completely digested, were extracted from a Pelecanoides stomach, spermatophores from the same stomach showed no signs of being digested.

Euchaeta biloba (Farran). This species was taken only at the end of December 1951, when an adult female and 26 juveniles appeared in a surface sample.

Vervoort (personal communication) found this species only in samples from the B.A.N.Z.A.R. Expedition which came from the intermediate water layer, but they were not taken in the Heard Island region.

At Heard Island the occurrence of the deep water chaetognath, Sagitta maxima, in the samo sample as E. biloba and the marked difference in the state of the diatoms taken by the N50 nets, suggest that turbulence took place during late December 1951 and probably early January 1952.

Metridia lucens Boeck. Adult females and juveniles were collected sporadically, mainly between May and August. In December 1951, numerous small juveniles of Metridia which may have belonged to this species were collected.

Metridia curticauda Giesbrecht. A single adult female, taken in July 1950, is the only record of this species at Heard Island.

Pleuromamma robusta (F. Dahl) form antarctica Steur. This species was recorded only twice at Heard Island — in May 1949 and July 1951. In each case it was a juvenile female.

Oithona similis Claus. This species was usually prevalent throughout each year but breeding data and variations in numbers were not noted.

Microstella norvegica (Boeck). Found throughout the year, this species was more abundant in the samples from the inshore station.

AMPHIPODA

Pontogeneia c.f. chosroides Nicholls. This kelp-inhabiting gammarid was collected in our nets in small numbers throughout each year, the largest haul in July 1951 being 48, There appears to be no definite breeding season since females with eggs attached to their oostegites occurred in April 1949 and April, July, August and December 1951. Females carrying young were never netted but they were found in the stomachs of the Arctic tern, Sterna macrura Naum, in Novembor and December 1951.

Tryphosella barbatipes (Stebbing). This was not taken in our nets although two well-preserved large specimens were found in the stomach of a fulmar prion, Pachyptila crassirostris. It has previously been recorded off Iles de Kerguelen.

Hyale hirtiplana (Dana). This occurred only three times in our samples.

Euthemisto antarctica (Dana). This hyperiid was rarely seen in our samples but it seems to be preyed upon by birds more than any other plankton crustacean in the region. From June onwards it appeared in the stomach contents of Eudyptes chrysocome Forster, Eudyptes chrysolophus (Brandt), Pygoscelis papua Forster, Pelecanoides georgicus, and Pachyptila crassirostris Matthews. Other petrels besides prions no doubt eat it also. In January and February huge numbers (sometimes over 500 in a single prion) were present in the stomachs of these birds. Pachyptila crassirostris containing E. antarctica were always captured at dusk, the state of their stomach contents showing that they had eaten them during the day. In view of the fact that Hardy and Gunther (1935) showed this amphipod (referred to by them as Parathemisto gaudichaudi Guerin) made active diurnal migrations, the presence of such large numbers in bird stomachs suggests that swarms probably surface during the day during these months.

Primo macropus Guerin. Only an occasional juvenile was sampled.

Hyperia galba Montagu. This oceanic hyperiid was not netted at Heard Island but was identified amongst the stomach contents of two Pachyptila crassirostris killed in September 1951. Large numbers of this species were extracted from the stomachs of the penguins Eudyptes chrysocome and Pygoscelis papua in February 1950.

Hyperia spinigera Bovallius. Juveniles only of this oceanic species were caught in our nets although a number of adult males and females were washed ashore at the end of August 1952. Although specimens (some of them adult) were found in the stomachs of a few Pachyptila crassirostris, Pachyptila desolata, Pelecanoides sp. and Pygoscelis papua, they were in very small numbers, which suggests that H. spinigera is either not preferred by these birds, is inaccessible to them or is not plentiful in the Heard Island area.

Hyperiella antarctica Bovallius. This was much commoner than H. spinigera. Usually juveniles were taken in our hauls and in October and November 1951 many tiny ones were present which suggested a recent spawning. H. antarctica was frequently identified in bird stomachs; in September 1951 on occasions as many as 300 individuals were taken from Pachyptila crassirostris stomachs. Other birds which prey on this animal are Pachyptila desolata, Pelecanoides georgicus and Pelecanoides urinatrix.

Vibilia armata Bovallius. Several specimens were collected from time to time and several were found in Pachyptila crassirostris stomachs.

EUPHAUSIACEA

Euphausia vallentini Stebbing. Except during December-January 1951-52, when large numbers of larvae were sampled in water thought to have come from the intermediate layer, only occasional specimens (all juvenile) were collected. Hardy and Gunther (1935) and Sheard (1953) consider this species to be a characteristic inhabitant of the warmer subantarctic water. The mature stock of E. vallentini which produced our immature specimens were no doubt located some distance north of Heard Island.

Thysoanessa vicina Hanson. Adults and juveniles, in small numbers, occurred throughout each year. In October 1949 swarms were washed into the shallows of Atlas Cove. Many were dead or dying, which suggested they were spent breeding swarms. A haul of 50 individuals was made in August 1952 when the net is recorded as having passed through "a peculiar patch of water". A few specimens were found in stomachs of Pelecanoides georgicus and in December 1951 large numbers were extracted from two Sterna macrura stomachs. Daption capensis have been seen to pick these animals out of the seas.

ISOPODA

Cerceis sp., usually taken in samples from the inshore station, did not occur frequently. Specimens were found in stomachs of Sterna vittata Gmelin and Larus dominicanus Lichenstein, both of which feed mainly along the shore line. A large specimen was also found inside a cormorant, Phalancrocorax atriceps King.

CUMACEA

Ekdiastylis horridus (G.O. Sars) was found twice only. It has already been recorded at Iles de Kerguelen (Nicholls, personal communication).

MYSIDACEA

Boreomysis rostrata Illig. Occasionally juveniles of both sexes were collected in our nets, the only adult (a male) being taken in July 1950. In September 1951 the remains of this species were found in a Pachyptila crassirostris stomach. Heard Island specimens were considered by Mrs. O. Tattersal (personal communication) to be almost identical with the form of B. rostrata from the Straits of Magellan.

DECAPODA

Parapasiphaea sp. The remains of a member of this genus were regurgitated by a giant petrel, Macronectes giganteus (Gmelin), but it was not possible to make a specific identification because some digestion had taken place.

MOLLUSCA

PTEROPODA

Clio sulcata (Pfeffer). A few of these were found in the winter only (1949 and 1950) and autumn only (1951). Hooks, sacs and other remains appeared in stomachs of Pachyptila crassirostris during June and July 1951, but rarely after August. These molluscs are also eaten by Pachyptila desolata and Daption capensis.

Limacina balea Moller. This species occurred in large numbers at the end of January 1952; otherwise only occasional specimens were collected.

Spongiobranchia australis d'Orbigny. This species was commonest during 1949. Early in July of that year many were taken with a hand net. They were probably washed into the shallows by a storm. In other years only a few were sampled.

CHAETOGNATHA

Eukrohnia hamata (Mobius). Varying numbers and sizes of juvenile E. hamata were nearly always present in our samples, but adults were never taken. The species was most abundant from March to June, a few specimens only being collected in the winter when presumably they sink to deeper levels (Mackintosh, 1937). They seemed to have regained the surface in November 1951 when our biggest haul, 26, was netted. Like the calanoid copepods, already discussed, no increase was recorded between October and December in 1949.

Sagitta gazellae Ritter-Zahony. This species occurred spasmodically throughout each year, the largest collection being 25 in December 1951. Quite large specimens were sometimes washed ashore, some measuring 80 mm. in length being found along the drift line. No adults were recorded.

A large immature animal, caught in July 1950, had recently eaten 14 individuals of the copepod *Drepanopus pectinatus*.

Sagitta maxima (Conant). This species was taken on isolated occasions and its appearance was presumed to indicate the presence in Atlas Cove of water from deeper layers. It was recorded in June and July 1950, in August 1951 when *Pleuromamma* occurred in the same haul, and in December-January 1951-52 concurrently with *Euchaeta biloba* and larvae of *Euphausia vallentini*

CHORDATA

TUNICATA

Ihlea magellanica Apstein. This large salp appeared only in one haul, during October 1949, but in January 1953 several were washed up on the beach. Some were taken in a haul by M.V. "Tottan" 35 miles due east of Heard Island in February 1953, and again in early March at 48°44'S., 76°05'E. where the sea temperature was 5°C.

PISCES

Notothenia sp. Ova and larvae belonging to this group of teleosts were found in all years. Most were probably produced by *Notothenia corriiceps* Richardson and *Notothenia cyanobranchia* Richardson which abound in the shallows of Heard Island. From July onwards eggs were collected in the samples and sometimes found washed up on the shore. Eggs taken in early October 1951 were well developed. Larvae first appeared in late October and, in various stages of development, continued to be present in hauls until the following January.

SEASONAL VARIATIONS AND ASSOCIATIONS

Phytoplankton variations. Hart (1942) has divided the Southern Ocean into three biogeographical regions, describing the "Northern Region" as being between the Antarctic Convergence and a line 330 miles south of it extending all round the world except for special areas. Heard Island lies in the middle of this region and our results show that the times of phytoplankton fluctuation agree with those suggested by Hart for his "Northern Region".

Period of Main Phytoplankton Increase

Unfortunately in 1949 only five hauls were made between September and December, but Table 5 indicates that growth had begun by October. A sudden burst of cell division seems to have occurred in early November as the volume of the sample taken on November 11, 1949, was four times the volume of those of October and December. There is some evidence to show that hydrological conditions in Atlas Cove during part of 1949 may not have been typical of the surrounding ocean. Nevertheless the succession of species is worth noting. The Conscinodiscus population was dominant until August when a further increase in C. concinnus was noted. This species and Ch. discladia reached a peak in October during which active cell division was noted in Ch. atlanticus, Dactyliosolen, Thallassiothrix and Fragillariopsis. These attained maximum growth in November, with the exception of Ch. atlanticum which reached its peak in December. Eucampia balaustium suddenly appeared in November in profusion. Apart from the much smaller volume of the December sample there was also a decrease in dividing stages. Other species undoubtedly reached their growth peaks during November but our material was inadequate and our methods not sufficiently accurate to detect them. Growth had certainly slackened by January in 1950 when the dinoflagellate Peridinium depressum attained its maximum.

There are no early summer records for 1950.

Unfortunately no samples were taken in September 1951 but some diatom growth was in progress by October (Table 6). As in 1949 C. concinnus reached its peak growth late in October; there was evidence of a small peak in Rhabdonema adriaticum in the middle of the month; and Ch. dicladia showed much cell division late in October. These species would fall into Hart's Group III.

Although he places all *Coscinodiscus* sp. in Group V, perhaps the fluctuations of *C. concinnus* warrant its better inclusion in Group II of the neritic diatoms. Pre-maximum abundance of these three species agrees with Hart's findings for the Group. Hart considered diatoms of Group I to be most numerous at the time of the peak of the main increase. *Dactyliosolen*, *Thalassiothrix*, *Corethron* and the three phases of *Rh. alata* belong to this Group and these reached their peaks in November or early December (Table 6), during which period the peak of maximum growth was considered to have occurred at Heard Island. *Ch. atlanticus* attained its point of maximum growth in November but was not relatively important after that, as suggested by Hart for members of Group IV. *Eucampia balaustium* reached its peak in December and was not even present in the samples when other neritic diatoms of Group III to which it nominally belongs were abundant. In late December and early January the plankton samples were a yellowish colour instead of grey-green and contained many broken frustules and empty cells. Turbulence is considered to have brought water from deeper layers to the surface during this period.

Samples were not collected during the spring of 1952.

The Autumnal Increase

A definite increase in numbers occurred in several species during March and April, decreasing in May of the four years.

In 1949 *C. concinnus*, *Ch. dicladia*, *Rh. styliformis* and *Rh. crassa* showed increasing growth in March and reached a peak in April dominated by the latter species. A sample collected in April was examined by Hart who considered that "the general facies of the sample reminded" him "strongly of the solenoid community" he "found between South Georgia and the Falkland Islands in the Convergence region. It definitely had a more northerly appearance than most of the material from South Georgia" (Hart, personal communication). There was also an increase in the numbers of *Ceratium* during April and May leading to a peak in June.

Samples were not available for March and April, of 1950 but a sample in May suggests that an increase in the same species had occurred. *Ceratium* also behaved similarly.

In 1951 the same species increased but *Ch. dicladia* was more abundant than *Rh. crassa*. A slight increase in *Dactyliosolen* was also noted in April of this year. *Ceratium* and *Peridinium depressum* both increased noticeably in April but there was no winter maximum of the former in 1951.

Rh. crassa was not even recorded in autumn 1952 but the usual fluctuation in *C. concinnus* and *Ch. dicladia* occurred. *Ceratium* and *P. depressum* behaved as in 1951.

The seasonal cycle of the phytoplankton at Heard Island may be summarised as follows: Post-winter growth began in September, increasing in October to reach a maximum in November and December. A decline began in January which in the case of most species continued to the low winter values. A secondary increase in several species occurred in March and April but the decline towards winter values of these species in May was not necessarily as rapid as suggested by Hart (1942).

Zooplankton variations. The plankton of late summer and autumn was always dominated by huge copepod swarms of juvenile *Drepanopus* that had hatched the previous spring. In 1949 and 1950 juvenile calanids were present only in small numbers during this period but in 1951 and 1952 they were the most numerous. Few amphipods occurred in our samples at any time, but examination of bird stomach contents showed numerous juveniles (especially *Euthemisto*) to be in the region at this time. The small medusan *Cosmetirella* was recorded during this period and the tiny polychaetes *Pelagobia*, *Phalacophorus* and *Nerinides* also appeared only during the months of late summer and autumn. The largest numbers of the chaetognath, *Eukrohnia hamata*, (juveniles) were recorded from March to June but occasional examples occurred through the winter.

As sea temperatures dropped towards the winter level the abundance of organisms dwindled noticeably. Because of its swarming habit the actual volumes of *Drepanopus* are not very significant. However, during June the highest volumes were always taken at the shore station (I) which suggested a movement to deep water. Mackintosh (1937) showed that *C. acutus*, *R. gigas* and *E. hamata* sought deeper water in the winter months. Tables 1, 2, 3 and 4 show that the calanid copepods certainly became scarce in our surface hauls as did most other organisms until November. It appears that in the winter months some of the local fauna produce their eggs. Breeding forms of *Autolytus* were taken between July and

September. The amphipod Pontogeneia was most frequently found with eggs in July and fish ova were first recorded in the plankton in July. The pteropod, Clio sulcata, was collected only in June and July of 1949 and 1950. Although a few occurred earlier than this in 1951 none was taken in the winter, but it appears from the bird stomach contents that this mollusc was quite numerous in the surrounding ocean in July 1951, as was the hyperiid amphipod, Euthemisto. Bird stomachs taken in September show that quite large numbers of the hyperiid, Hyperiella antarctica, had been eaten in that month.

The situation in Atlas Cove in spring 1949 was not considered typical of the surrounding ocean; but in 1951 diatom growth had commenced in that region and was reaching its climax in November when the larger copepods appeared in the plankton in breeding condition. No doubt they and the larvae they produced grazed on the phytoplankton. Large volumes of Drepanopus, predominantly oviferous females, occurred in October while the percentage of juvenile Drepanopus began increasing rapidly in November. During these months, measured volumes of this species were always larger at the inshore station than at the offshore station. Fish larvae were present from October but were in highest numbers in December when they were probably feeding on the other abundant zooplankton.

The summer months of January, February and March are characterized by the dominance of juveniles of all the breeding species noted in the spring.

DISCUSSION

Heard Island plankton and the oceanography of the region. Extensive work has been done in the past on the distribution of the plankton species found in the antarctic and subantarctic waters. Mackintosh (1934), discussing the distribution of the macroplankton of the Atlantic Sector of the Antarctic, attempts to distinguish individual communities whose constitutions are dependent on the hydrological and geographical features of the environment. Therefore by considering some of the species found in Heard Island plankton some idea of the nature and origin of waters surrounding the island can be obtained. It must be remembered that all hauls were made at the surface in daylight so that we can only compare our results with those of other workers with reservations.

Mackintosh divided the plankton into four main groups and it is of interest to note in which of his groups (Table III of his paper) the Heard Island species are found.

1. Warm-Water Species. Except close to the shore the sea temperature at Heard Island seldom, if ever, exceeds 3°C. It is not surprising then that *Euphausia vallentini* described as being "practically confined to water above 3°C." was rarely taken.

Of his "typical warm-water species" only two were noted: *Pleuromamma robusta* was rare while *C. simillimus* was the mostcommon calanid in our hauls.

Four out of five of Mackintosh's "warm-water species sometimes found in colder regions" occurred in our plankton. Except for the widespread *E. hamata*, chaetognatha were not common; neither were copepods such as *Euchaeta*, although the diurnal migrations of the latter may have upset our records.

Limacina balea was numerous at times and bird stomachs revealed that *Euthemisto* could be found in large numbers somewhat further offshore than were our stations.

2. Widespread Species. The species of this group with "a slight preference for warmer water" all occurred in Heard Island plankton: *Primo macropus* was rare but *Spongiobranchia* and *Thysanoessa* sometimes appeared; the copepod, *R. gigas* was frequently present, always in small numbers which may have been due to its preference for oceanic water and sub-surface layers.

None of the "neutral species" was recorded.

All of the "species with a slight preference for cold water" were found. *Vibilla armata* (referred to by Mackintosh as *V. antarctica*) was rarely seen, but among the calanids moderate numbers of *C. propinquus* were usually present. *C. acutus* was second in abundance only to *C. simillimus*. It can be seen from Mackintosh's table that although *C. simillimus* occurs in largest numbers in water above the 3°C. isotherm, the abundance of both species is roughly similar in the summer temperature range that would include Heard Island.

3. Cold-Water Species. Although Heard Island is almost always south of the 3°C. isotherm, only three out of nine "species which may occur in large numbers anywhere south of the 3° summer isotherm" were recorded at Heard Island. *Clio sulcata* (referred to as *Cleodora*)

was never common although it was usually present in winter.

Pyrostephos vanhoffeni was almost always present.

None of the "species typical of the coldest regions" were recorded and of course the 4th category, Neritic Ice Edge species, did not occur.

It can be seen from these remarks that the Heard Island macroplankton is similar in some respects to the community which Mackintosh describes north of South Georgia; but it is by no means identical with it.

Hendey (1937) lists "typical" warm-water and cold-water species of diatoms. His divisions are much broader than those of Mackintosh (1934) who refers to warm and cold-water species of the antarctic regions only, whereas Hendey refers to tropical and sub-tropical waters by the term "warm" and antarctic waters by the term "cold". However, it is interesting to note which diatoms in these two categories are found at Heard Island.

A species marked "X" is important in Heard Island plankton.

Warm-water Species (Hendey)	Cold-water Species (Hendey)
X *Chaetoceros atlanticus*	X *Eucampia balaustium*
Chaetoceros dichaeta	*Chaetoceros dichaeta*
X *Rhizosolenia alata*	*Rhizosolenia habetata* fo. *bidens*
R. habetata fo. *semispina*	X *Rhizosolenia crassa*
R. habetata fo. *styliformis*	*Rhizosolenia curvata*
X *Corethron criophilum*	*Rhizosolenia styliformis*
	X *Dactyliosolen antarctica*
	X *Corethron criophilum*
	X *Fragillaropsis antarctica*

The fact that species typical of warm and cold-water floras are important in Heard phytoplankton indicates that Heard Island is in an intermediate position. It is not only within the geographical boundary of the Northern region of the Antarctic described by Hart (1942) but it has been shown here that the fluctuations of its phytoplankton are almost typical of that region.

Heard Island is generally surrounded by antarctic surface water but the occasional presence of Rhizosolenia curvata indicates that some mixing with subantarctic water may take place. Indicators of deeper water, e.g. Sagitta maxima and Euchaeta biloba, appearing in surface hauls suggest that wind and wave turbulence may bring water from the intermediate layer to the surface near Heard Island.

The rarity or absence of some oceanic species suggests that both Station I and II were under a strong neritic influence. This is supported by the large numbers of some oceanic amphipods found in bird stomachs, apparently eaten well offshore, compared with the very few taken in our net samples. In fact, results from 1949 and 1950 indicate that there was very little oceanic influence during parts of those years.

Productivity of the region. Examination of birds' stomach contents has shown that amphipods, especially Euthemisto, are an important factor in the diet of Heard Island plankton-feeding birds (Table 7). In comparison, the role of the euphausids is relatively unimportant, whereas, further south they, particularly Euphausia superba Dana, are "key industry" organisms (Hart, 1942).

The amount of plankton consumed by birds in the Heard Island region alone must be enormous. A penguin's stomach has been found to contain 200-300 gm. or 4,000-6,000 amphipods, while over 500 Euthemisto have been taken from individual prion's stomachs. Considering the huge numbers of birds known to breed on Heard Island the seas in the region must be highly productive.

TABLE 1

SEASONAL VARIATION IN NUMBERS OF <u>Calamus simillimus</u>

	Jan.			Feb.			Mar.			April			May			June			July			Aug.			Sept.			Oct.			Nov.			Dec.		
1949																																				
Adult males								O	O			A			O		O	O	O		O		O			O		O		O		O		O		
Adult females								O	O			A			A		A	A	A		O		O			O		O		O		O		O		
Juveniles								A	A			B			A		A	A	A		O		O			O		O		O		O		C		
1950																																				
Adult males			O						O					O	O		O		O	O	A															
Adult females			A						A					O	O		A		B	B	B															
Juveniles			O						A					A	A		A		B	B	B															
1951																																				
Adult males								A	O	A	A	O				O	O	A	O	O				O				O	O	O	O	B		O	O	A
Adult females								A	A	A	B	A				A	B	C	A	A				A				O	A	A	D	D		A	B	O
Juveniles								B	B	A	D	O				B	C	C	A	B				A				O	O	O	A	A		O	A	A
1952																																				
Adult males	O	A										O										O														
Adult females	O	A										B		A								A														
Juveniles	A	C										D		C								A														

<u>Legend</u>

No. of individuals	Symbol
0	O
1-10	A
11-50	B
51-100	c
More than 100	D

Where no symbols are shown no hauls were done.

TABLE 2

SEASONAL VARIATION IN NUMBERS OF *Calanus propinquus*

	Jan.			Feb.			Mar.			April			May			June			July			Aug.			Sept.			Oct.			Nov.			Dec.		
1949																																				
Adult males								0	0			0			0		0	0	0				0			0		0		0		0		0		
Adult females								0	0			A			A		0	A	A				0			0		0		0		0		0		
Juveniles								A	A			A			A		A	A	0				0			0		0		0		0		0		
1950																																				
Adult males			0						0		0	0		0	0		0		0	0	A															
Adult females			A						A					0	0		A		B	B	B															
Juveniles			0						A					A	A		A		B	B	B															
1951																																				
Adult males								0	0	0	A	0				0	0	0	0	0				0				0	0	0	0	0		0	0	0
Adult females								0	A	0	A	0				0	A	A	A	A				A				0	0	0	A	A		0	0	A
Juveniles								B	B	A	B	A				0	A	A	0	A				0				0	0	0	0	0		0	B	A
1952																																				
Adult males	0	0										0		0								0														
Adult females	0	0										A		A								0														
Juveniles	A	B										A		A								0														

Legend

No. of individuals - Symbol
0 - 0
1-10 - A
11-50 - B
51-100 - C
More than 100 - D
Where no symbols are shown no hauls were done.

TABLE 3

SEASONAL VARIATION IN NUMBERS OF Calanoides acutus

	Jan.			Feb.			Mar.			April			May			June			July			Aug.			Sept.			Oct.			Nov.			Dec.		
1949																																				
Adult females							0	0				0			0		A	0	0		0		0			0		0		0		A		0		
Juveniles							A	A				A			A		A	0	A		0		0			0		0		0		0		0		
1950																																				
Adult females			0				A	0						0	0		0		0	0	0															
Juveniles			A				B							0	A		A		A	0	A															
1951																																				
Adult females							0	0		0	0	0				0	0	0	0	0				0				0	0	0	B	A		0	A	A
Juveniles							B	B		0	A	A				A	A	B	A	A				0				0	0	0	B	A		0	D	D
1952																																				
Adult females		0										0		0								0														
Juveniles		B	D									A		A								0														

Legend

No. of individuals	Symbol
0	0
1- 10	A
11- 50	B
51-100	C
More than 100	D

Where no symbols are shown no hauls were done.

TABLE 4

SEASONAL VARIATION IN NUMBERS OF <u>Rhincalanus gigas</u>

	Jan.			Feb.			Mar.			April			May			June			July			Aug.			Sept.			Oct.			Nov.			Lec.		
1949																																				
Adult females							A	O				O			A				O		O		O			O		O		O		O			O	
Juveniles							A	O				A			A				A		A		O			O		O		O		A			O	
1950																																				
Adult females			O					O						O	O		A		A	A	O															
Juveniles			A					A						O	A		A		A	A	A															
1951																																				
Adult females							A	O		O	A	O				O	O	A	A	O				O				A	A	A	B	A		A	A	A
Juveniles							O	A		A	A	A				A	A	A	A	A				A				A	A	O	B	A		A	A	A
1952																																				
Adult females		A	A									A		A								O														
Juveniles		A	A									A		A								A														

<u>Legend</u>

No. of Individuals - Symbol
0 - 0
1-10 - A
11-50 - B
51-100 - C
More than 100 - D

Where no symbols are shown no hauls were done.

TABLE 5

SEASONAL VARIATIONS OF SOME HEARD ISLAND DIATOMS - March - August, 1949

	March			April			May			June			July			August		
Fragilariopsis antarctica		X	X			O			X		X	O	O		X		O	
Rhizosolenia alata		O	O			O			O		O	O	O		O		O	
Rh. alata fo. indica		O	O			O			O		O	O	O		O		O	
Rh. alata fo. inermis		O	O			O			O		O	O	O		O		O	
Rh. crassa		XX	XX			P			XX		X	X	X		X		O	
Rh. curvata		O	O			X			O		X	X	X		O		O	
Rh. habetata fo. semispina		X	X			O			O		O	O	O		O		O	
Rh. styliformis		X	XX			XX			XX		O	O	O		O		O	
Dactyliosolen antarctica		X	X			O			X		X	O			X		O	
Corethron criophilum		O	O			X			X		X	O			O		O	
Thalassiothrix longissima		O	O			O			O		O	O			O		O	
Coscinodiscus concinnus		XX	XX			XX			XX		X	X	X		X		X	
Eucampia balaustium		O	O			O			O		O	O	O		O		O	
Chaetoceros dicladia		XX	XX			XX			XX		O	O	O		O		O	
Rhabdonema adriaticum		O	X			O			O		O	O	O		O		X	
Chactoceros atlanticus		O	O			O			O		X	O	O		O		O	
Ch. atlan. var. neopolitana		O	O			O			O		O	O	O		O		O	
Ceratium pentagonum		X	XX			XX			XX		PX	XX			X		X	
Peridinium depressum		X	X			X			XX		PX	XX	X		O		O	

Legend

O - was not recorded though a haul was done.
X - was recorded at this time.
XX - large numbers were noted at this time.
PX - very large numbers - probably peak in growth.

TABLE 5 (Contd.)

SEASONAL VARIATIONS OF SOME HEARD ISLAND DIATOMS - September 1949 - January 1950

	September	October		November	December	January
Fragilariopsis antarctica	X	X	XX	PX	XX	X
Rhizosolenia alata	O	O	X	XX	X	O
Rh. alata fo. indica	O	O	O	X	X	O
Rh. alata fo. inermis	O	O	O	X	X	O
Rh. crassa	O	X	X	X	X	X
Rh. curvata	O	X	O	X	O	O
Rh. habetata fo. semispina	O	O	X	X	X	O
Rh. styliformis	O	X	X	X	X	O
Dactyliosolen antarctica	X	X	XX	PX	XX	X
Corethron criophilum	O	X	X	XX	X	O
Thalassiothrix longissima	O	O	XX	PX	XX	O
Coscinodiscus concinnus	XX	XX	PX	XX	X	X
Eucampia balaustium	O	O	O	PX	XX	O
Chaetoceros dicladia	O	XX	PX	XX	XX	X
Rhabdonema adriaticum	O	X	X	O	O	O
Chactoceros atlanticus	O	X	XX	XX	PX	X
Ch. atlan. var. neopolitana	O	O	XX	XX	XX	
Ceratium pentagonum	O	X	X	X	X	X
Peridinium depressum	O	O	O	O	X	XX

Legend

O - was not recorded though a haul was done.
x - was recorded at this time.
XX - large numbers were noted at this time.
PX - very large numbers - a probable peak in growth.

TABLE 6

SEASONAL VARIATIONS OF SOME HEARD ISLAND DIATOMS - March - August, 1951

	March			April			May			June			July			August		
Fragilariopsis antarctica		X	X	O	X													
Rhizosolenia alata		X	O	X	O					O		O		O				O
Rh. alata fo. indica		O	O	O	O					O		O		O				O
Rh. alata fo. inermis		O	O	X	O					O		O		O				O
Rh. crassa		XX	XX	PX	XX					O		O		O				O
Rh. curvata		O	O	O	X					O		O		O				O
Rh. habetata fo. semispina		X	X	O	X					O		O		O				O
Rh. styliformis		X	X	X	O					O		O		O				O
Dactyliosolen antarctica		X	X	X	X					O		O		X				O
Corethron criophilum		X	X	X	X					O		O		O				O
Thalassrothrix longissima		O	O	O	O					O		O		O				O
Coscinodiscus concinnus		XX	XX	XX	PX					X		O		X				O
Eucampia balaustium		O	O	X	O					O		O		O				O
Chaetoceros dicladia		XX	XX	PX	PX					X		O		X				X
Phabdomena adriaticum		O	X	X	X					X		X		X				X
Chaetoceros atlanticus		O	O	O	O					O		O		O				O
Ch. atlan. Var. neopolitana		O	O	O	O					O		O		O				O
Ceratium pentagonum		X	X	XX	XX					X		X		X				O
Peridinium depressum		X	X	XX	X					X		X		O				O

Legend

O	- was not recorded though a haul was done.
X	- was recorded at this time.
XX	- large numbers were noted at this time.
PX	- very large numbers - a probable peak in growth.

TABLE 6 (Contd.)

SEASONAL VARIATIONS OF SOME HEARD ISLAND DIATOMS - September 1951 - January 1952

	Sept-ember			October			Novem-ber			Decem-ber			January		
Fragilariopsis antarctica				X	X	X	X	XX		XX	PX	XX		X	X
Rhizosolenia alata				X	X	X	X	X		PX	X	X		O	X
Rh. alata fo. indica				O	X	O	X	PX		X	X	X		X	X
Rh. alata fo. inermis				O	O	O	O	PX		XX	X	X		O	O
Rh. crassa				O	O	X	X	X		O	X	X		O	O
Rh. curvata				X	X	X	X	X		X	X	X		O	X
Rh. habetata fo. semispina				X	X	X	X	XX		XX	X	X		X	X
Rh. styliformis				O	O	X	X	X		X	X	X		O	X
Dactyliosolen antarctica				X	XX	X	X	X		PX	X	X		X	X
Corethron criophilum				O	X	X	X	PX		XX	X	X		O	O
Thalassrothrix longissima				O	O	O	O	X		XX	PX	XX		X	XX
Coscinodiscus concinnus				X	XX	PX	PX	X		X	X	X		X	X
Eucampia balaustium				O	O	O	O	X	X	X	PX	X		X	O
Chaetoceros dicladia				O	XX	XX	PX	XX		XX	X	X		O	O
Phabdomena adriaticum				X	PX	X	X	X		X	X	X		X	X
Chaetoceros atlanticus				X	XX	X	X	PX		X	X	X		X	
Ch. atlan. var. neopolitana				O	X	X	X	X		X	X	O		O	
Ceratium pentagonum				X	X	X	X	X		X	X	X		X	
Peridinium depressum				O		X	X	X		X	X	XX		XX	

Legend	
O	- was not recorded though a haul was done.
X	- was recorded at this time.
XX	- large numbers were noted at this time.
PX	- very large numbers - a probable peak in growth.

TABLE 7

PLANKTON ORGANISMS IDENTIFIED FROM STOMACH CONTENTS OF SOME HEARD ISLAND BIRDS

<u>Legend</u> - + - recorded at least once.
++ - sometimes recorded in large numbers.

	Number of Birds Examined:									
	6	11	38	5	15	11	8	7	6	25
Species of Bird:	Eudyptes chrysocome	Pygoscelis papua	Pachyptila crassirostris	Pachyptila desolata	Pelecanoides urinatrix	Pelecanoides georgicus	Larus dominicanus	Sterna vittata	Sterna macrura	Chionis minor
Species of Plankton										
Euchaeta antarctica					+	++				
Euthemisto antarctica	++	+	++			++				+
Pontogeneia c.f. chosroides								+	+	
Tryphosella barbatipes			+							
Hyperiella antarctica			++	+	++	+				
Hyperia galba	++	+	+							
Hyperia spinigera		+	+	+	+			+		
Vibillia armata			+							
Cerceis sp.							+			+
Thysoanessa vicina						+				+
Boreomysis rostrata			+							
Clio sulcata			++	+						

SUMMARY

The positions of the plankton stations and the objects and limits of the investigations are outlined. Methods of collecting and analysing the samples are described and a new method of determining displacement volumes of N70 samples is given. The oceanography of the Heard Island region is briefly discussed.

Details are given of relative importance, associations and fluctuations of each species identified from the Heard Island plankton. Some breeding data on the calanid copepods is included and the seasonal cycle of Drepanopus pectinatus Brady is indicated. The period of main phytoplankton increase occurred in late November and an autumnal increase was noted in some members of the phytoplankton. This is considered to be usual for the northern region of the Antarctic.

The Heard Island plankton community is compared with that of the South Georgia region and the oceanographical position of Heard Island is discussed in relation to the plankton community. The Heard community is fairly typical of plankton found just south of the Antarctic Convergence. Its composition is modified by local species and some of its fluctuations are modified by local conditions.

The importance of amphipods as "key industry" organisms and the relative unimportance of euphausids in the region is shown by the analysis of the stomach contents of local plankton-feeding birds.

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Polychaeta - Dr. O. Hartman, University of Southern California.

Medusae - Dr. P.L. Kramp, Zoology Museum, Copenhagen.

Cumacea - Dr. Nicholls, W.A. Museum, Adelaide.

Amphipoda)
Isopoda) - Dr. K. Sheard, C.S.I.R.O. Division of Fisheries, Perth, W.A.
Decapoda)

Copepoda - Dr. W. Vervoorts, University of Leiden, Holland.

Pisces - Mr. L. Munro, C.S.I.R.O. Fisheries Division, Cronulla, N.S.W.

Etenophora - Miss P. Ralph, Zoology Department, Victoria University College, Wellington.

Mysidacea - Miss O. Tattersall, British Museum, London.

Dinoflagellata - Mr. F. Wood, C.S.I.R.O. Division of Fisheries, Cronulla, N.S.W.

Diatoms - Mr. E. Manguin, Laboratoire de Cryptogamie de Muséum National d'Histoire Naturelle, France.

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2. HYDROLOGY AT HEARD ISLAND, 1949.

by R.G. Chittleborough

INTRODUCTION

Heard Island (53°01'S., 73°23'E.) lies about 180 miles south of the Antarctic Convergence. The surrounding surface water is of the cold, poorly saline type known as antarctic surface water. Deacon (1933) states that Iles de Kerguelen lies just on the Convergence and Mackintosh (1946) shows the Convergence passing through Iles de Kerguelen; Sverdrup (Howard and Sverdrup 1940) suggests the Convergence is one or two degrees south of Deacon's estimate.

Hydrological observations south of the Antarctic Convergence have been made by research vessels from Britain (Deacon 1933, 1937, Clowes 1934, 1938, Mackintosh 1946), Australia (Howard and Sverdrup 1940, Mawson 1940), Norway (Mosby 1934), Germany (Brennecke 1921) and other countries. But with the exception of some work in the South Atlantic region, the hydrological observations of these expeditions have been for short periods only (usually the summer months).

In December 1947, the Australian National Antarctic Research Expeditions established a research station on Heard Island. During the second year of occupation (1949) a biological programme was begun. In the marine research, plankton investigations were carried out by E.H.M. Ealey while hydrology and the settlement of marine organisms on exposed surfaces were investigated by the author.

The station on Heard Island provided an opportunity of obtaining regular records throughout the year of the hydrological conditions in this northern region of antarctic surface water. It is evident however, that coastal water at Heard Island is at times strongly influenced by local conditions, especially glacial streams and the coastal algal belt.

HYDROLOGICAL PROGRAMME AND STATIONS

It was hoped that a station over a depth of at least 100 metres of water, far enough offshore to minimise the effects of summer glacial streams from the island, could be visited every fortnight over a period of twelve months, for sampling at the surface and at depths of 50 and 100 metres. Variations in the temperature, salinity, oxygen, phosphate phosphorus and nitrate nitrogen content of this antarctic surface water were to be recorded throughout the year. At the same time the condition of the inshore water was to be investigated in conjunction with research upon the settlement of organisms on exposed surfaces.

For the marine research a 25-foot naval cutter powered by a 10 h.p. diesel engine was used. Later, when the cutter became unserviceable, a 14-foot dinghy powered by an outboard motor was used.

The hydrological programme commenced in March 1949. It soon became obvious that it was unsafe to attempt to reach the 100-metre line in the cutter with any regularity. In one month, sixteen days of gale force winds were recorded and storms often reached the island with little warning.

A station was thereford established at the mouth of Atlas Roads (See Station I on Figure 1) over approximately 60 metres of water, samples being taken at the surface and at depths of 25 and 50 metres.

An inner station (Station II) was established about 400 yards offshore in Atlas Cove over 9 metres of water, so that only surface samples were taken.

A buoy from which experimental plates were hung was moored 100 yards from the shore in the more sheltered part of the cove close to the mooring buoy (See Figure 1) and here temperature, salinity and dissolved oxygen were regularly recorded. During the year, three twenty-four hour surveys were carried out from the cutter at the mooring buoy.

Station I was abandoned early in July as defects in the cutter's engine made it dangerous to venture out to the outer part of Atlas Roads. Sampling at Station II and alongside the buoy was continued regularly from March 1949 until February 1950 using the dinghy and outboard motor.

The salinity and oxygen samples were titrated on the island (the former by titration with standard silver nitrate solution and the latter by the Winkler method). It was not possible to carry out phosphate and nitrate estimations at the station, so samples were preserved and returned to Australia for estimateion by the hydrological section of the Division of Fisheries, C.S.I.R.O. (For methods of determination see Rochford, 1951). Phosphate samples were preserved by the addition of two drops of chloroform per 100 ml. of water and nitrate samples with 1 ml. of saturated mercuric chloride per 100 ml. of sea water. It is known that dissolved phosphates and nitrates increase to some extent in preserved samples stored for several months, but as it was not possible at the time to perform these analyses on the island, it was expected that at least some variation of these nutrients could be recorded from preserved samples.

TEMPERATURE.

Air temperatures at the meteorological station (14.6 feet above mean sea level) are shown in Figure 7 in weekly averages. The mean weekly air temperature was 0.6°C., with a maximum of 4.6°C. and a minimum of -3.9°C.

The surface water temperatures at Stations I and II and at the buoy are shown in Figure 8. As can be seen from Figures 7 and 8, the water at Station I, further away from the island, was affected less by local fluctuations of air temperature. Variation of temperature with depth was not marked, 25 and 50 metre temperatures being very close to each other, while surface temperatures were higher when the air temperature was higher, and lower than deeper water when the air temperature dropped lower than that of the water.

Because of insufficient winter temperature records at Station I, the mean surface temperature may be slightly high, but after allowing for this the recorded range and mean are well below those given by Deacon (1933) who states that the temperature of the antarctic surface water at the Convergence ranges from 3°C. in summer to 1°C. in winter. Conditions on the island have the effect of lowering the water temperatures in winter, this being most marked at the two inner stations (Station II and the buoy). The nearer the shore the greater the fluctuations in temperature. Diurnal variations of surface temperature are discussed in the section on "Twenty-four hour surveys".

Station II temperatures for November (1.0 to 1.2°C.) are surprisingly close to Howard's (1940)

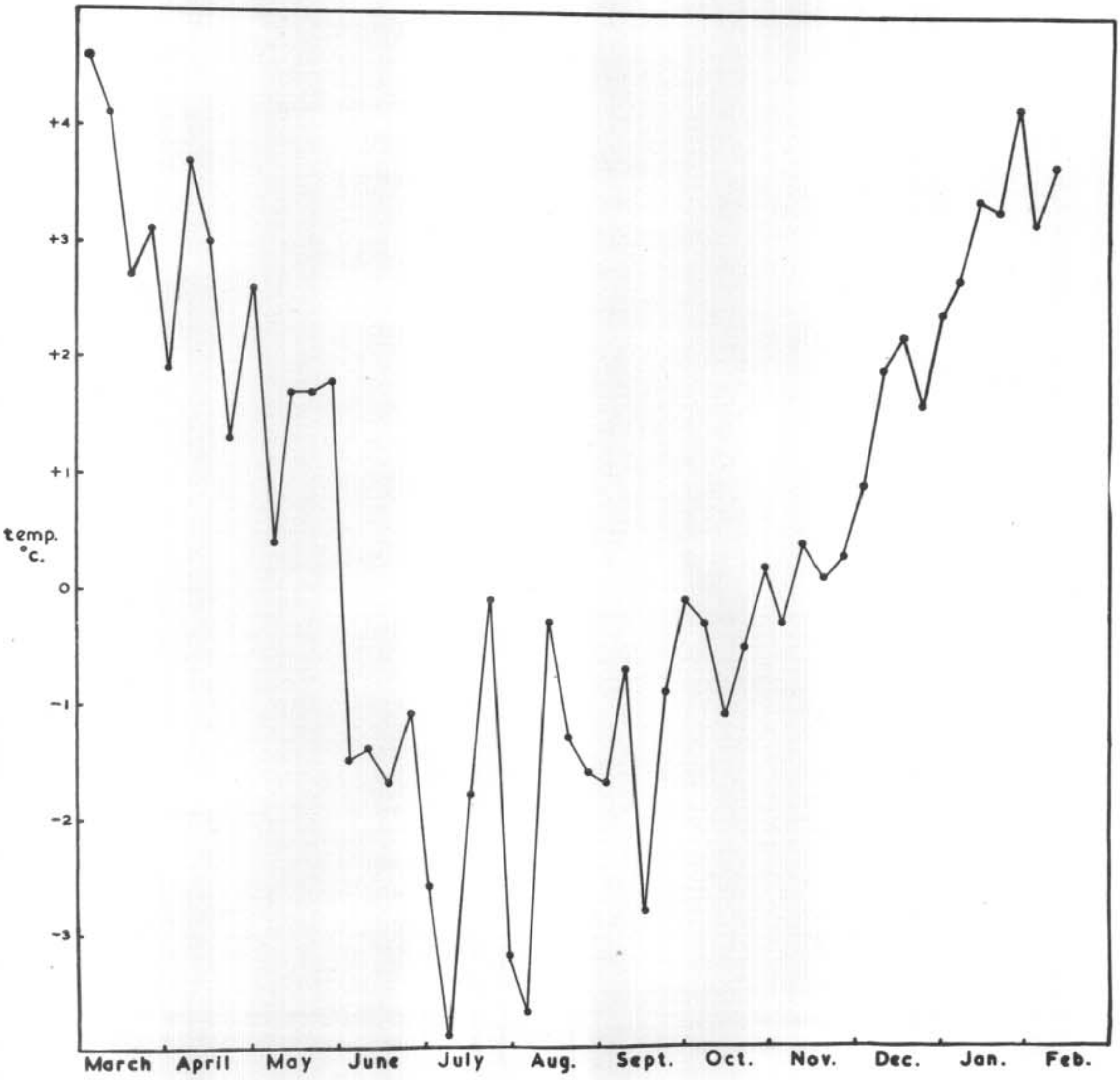

FIG. 7. AIR TEMPERATURES, HEARD ISLAND, MARCH 1949 – FEBRUARY 1950

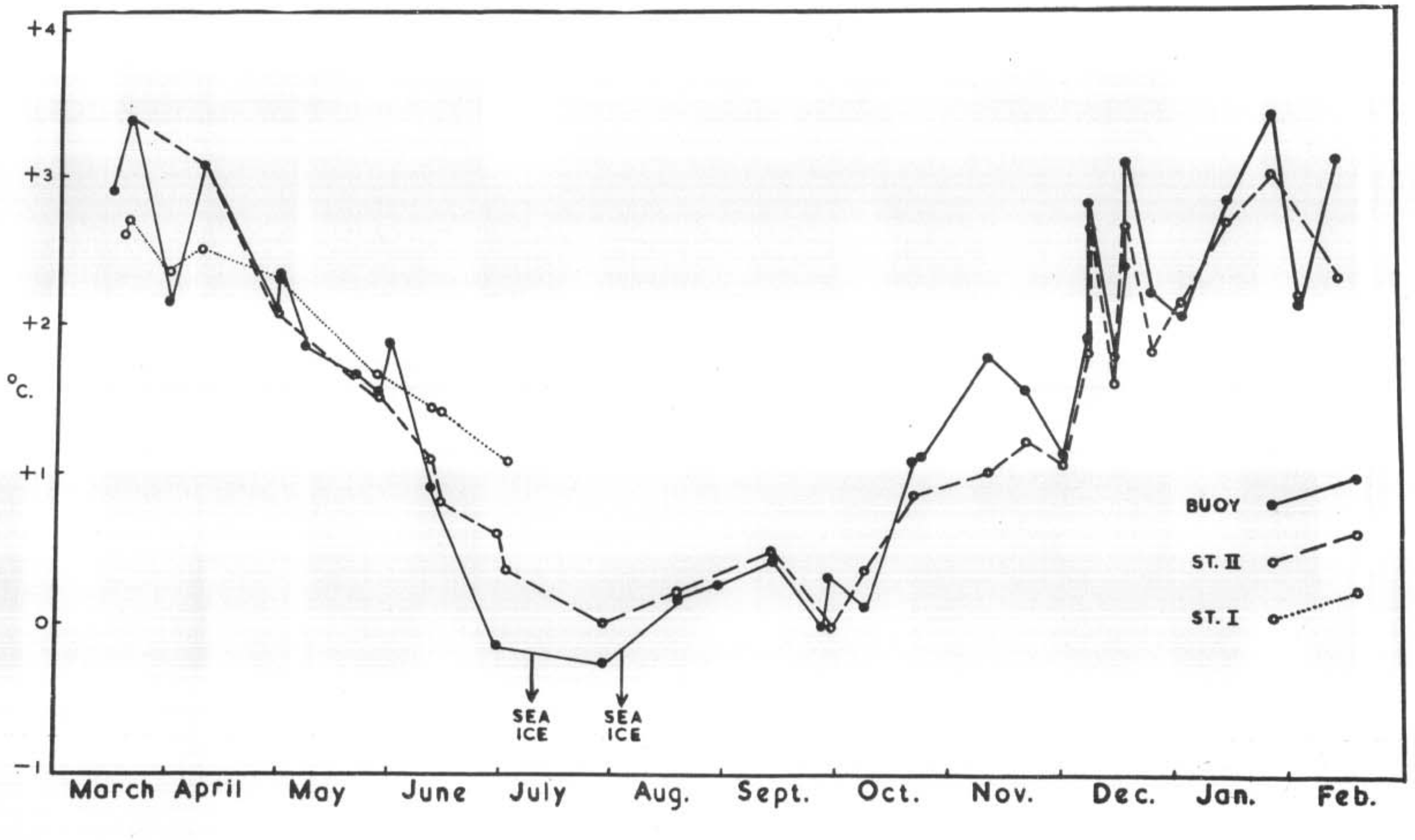

FIG. 8. SURFACE WATER TEMPERATURES, HEARD ISLAND, MARCH 1949 – FEBRUARY 1950.

temperatures (0.86 to 1.24°C.) for surface water in Corinthian Bay, Heard Island, in November 1929.

WATER TEMPERATURES AT STATION I, 1949

Depth	18 March	19 March	31 March	9 April	30 April	27 May	11 June	2 July
Surface	2.60°C	2.70	2.35	2.51	2.30	1.90	1.43	1.08
25m.	2.50	2.50	2.37	2.43	2.30	1.95	1.43	1.11
50m.	-	2.54	2.37	2.41	2.31	1.95	1.49	-

OBSERVED RANGE OF SURFACE TEMPERATURES

Station	Maximum	Minimum	Mean	Number of Observations
I	2.70	1.08	2.03	9
II	3.37	-0.05	1.52	27
Buoy	3.41	-1.8	1.58	36

Sea ice in Atlas Cove. Sea ice began forming in Atlas Cove on two occasions in 1949, 9 July and 3 August, as a result of very low air temperatures on the preceding days (See Figure 7).

On 9 July a small area near the shore about 30 yards wide began freezing. It lay in the most protected part of the cove, and appeared as a soft mush of flat crystals. It began to disappear soon after sunrise. At 9 a.m. the temperature of the shore water was -1.6°C. Its chlorinity was 18.62°/oo. Using Sverdrup 's (1942) formula $\Delta \vartheta_f = -.0966cl - .0000052cl^3$, its initial freezing point would be -1.83°C.

On 3 August a much larger area, over 100 yards wide, began to freeze, this time extending to the fouling

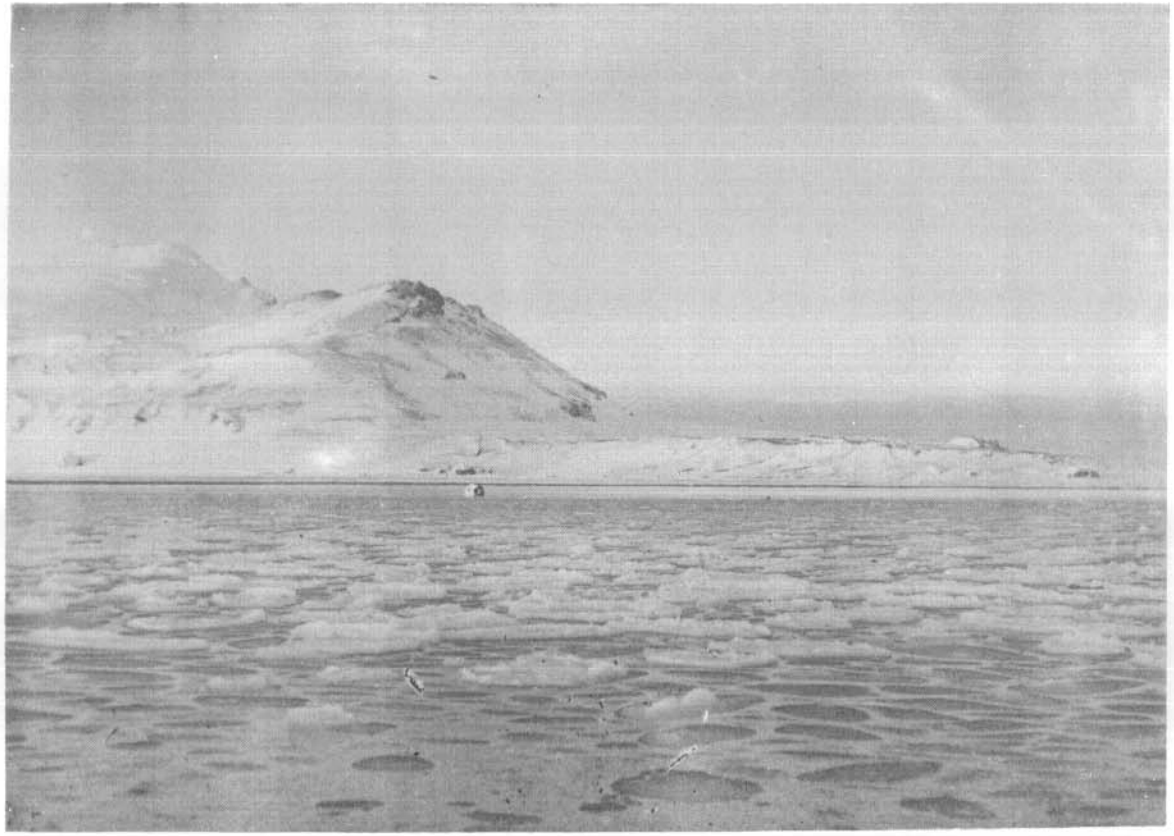

FIG. 9. SEA ICE ON ATLAS COVE, 3rd AUGUST 1949.

and mooring buoys. With a chlorinity of 18.30°/oo, this water should begin freezing at -1.84°C. The small thermometer used showed the shore water to be at -1.8°C. On this occasion, the mushy ice had begun to form soft pancakes (See Figure 9). This ice persisted until late in the morning, when rising wind and temperature scattered and melted it.

SALINITY

Surface salinities at the three stations are shown in Figure 10. They are summarised below:-

SALINITY (°/oo) RANGES AND MEANS

Station	Maximum	Minimum	Mean	Number of Observations
I	34.04	33.89	33.94	9
II	34.04	32.92	99.75	23
Buoy	33.95	32.45	33.55	29

Station I was least affected by variable island conditions and approached nearest the ocean conditions in this locality. Though relatively few values are available, the surface mean fits in with the generalisation by Sverdrup (1942, p. 609), Howard and Sverdrup (1940, p. 112) and Deacon (1933, p. 176) that surface salinity in this locality is less than 34.00°/oo.

The table on the next page shows that at Station I there was a slight tendency for salinity to increase with depth, though 25 and 50 metres values were very close together, as might be expected with such a short distance between samples.

Salinities progressively decreased and became more variable as the coast was approached (Figure 10). No correlation was found between salinity and rainfall, but salinity showed an inverse relationship to air temperature (Figures 7 and 10) which governed the flow of glacial water into the sea. In winter, with permanent freezing conditions when almost no glacial water

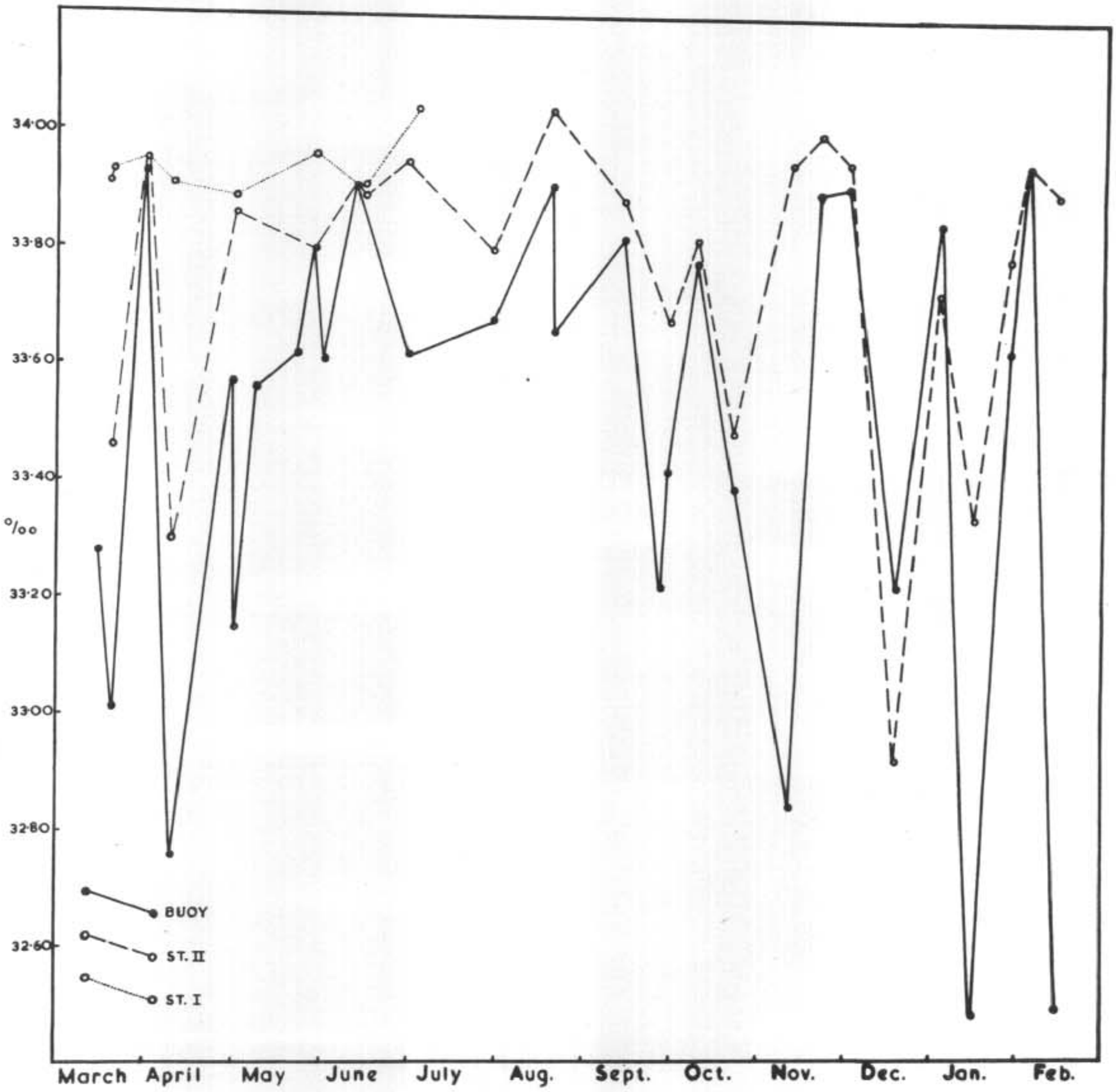

FIG. 10. SALINITY, HEARD ISLAND, MARCH 1949 – FEBRUARY 1950.

was being added to the sea, the mean salinity of the inshore water rose (though not to the level of the offshore water) and fluctuations were smaller.

SALINITIES (°/oo) AT STATION I, 1949

Depth	18 March	19 March	31 March	9 April	30 April	27 May	11 June	2 July
Surface	33.91	33.93	33.95	33.91	33.89	33.96	33.91	34.04
25m.	33.96	33.91	34.07	34.05	33.89	33.98	34.05	34.00
50m.	-	33.98	34.00	34.11	33.87	33.96	34.04	-

In summer, fluctuations of the glacial streams with air temperature were reflected in the wide variations in salinity at inshore stations. With a salinity gradient increasing seawards, the salinity at Station II or the buoy was partly effected by the tide, the degree depending on the steepness of the gradient. This is shown in the twenty-four hour surveys at the buoy (See section on "Twenty-four hour surveys").

The November salinities for Station II compare well with the range of 33.55°/oo to 34.00°/oo recorded by Howard (1940) for five days in Corinthian Bay, Heard Island, in November 1929.

DISSOLVED OXYGEN

The dissolved oxygen in surface waters expressed as ml. per litre is shown in Figure 11. These values converted to percentage saturation are shown in Figure 12. They are summarised below:--

DISSOLVED OXYGEN (°/oo saturation) RANGES AND MEANS

Station	Maximum	Minimum	Mean	Number of Observations
I	99.0	89.5	94.4	9
II	102.0	91.0	97.9	23
Buoy	102.0	91.0	98.2	28

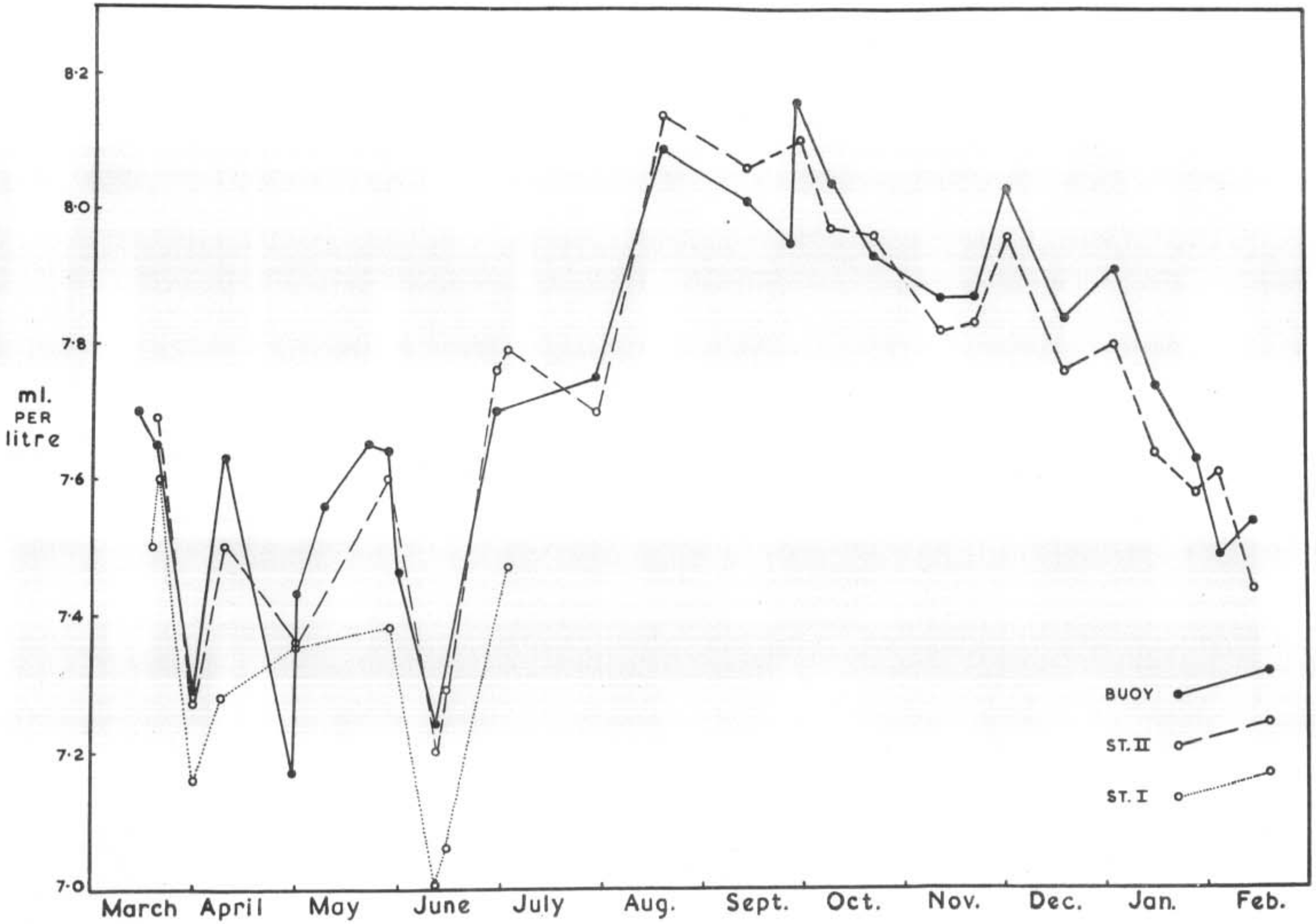

FIG. 11. OXYGEN (ml/L) HEARD ISLAND, MARCH 1949 – FEBRUARY 1950.

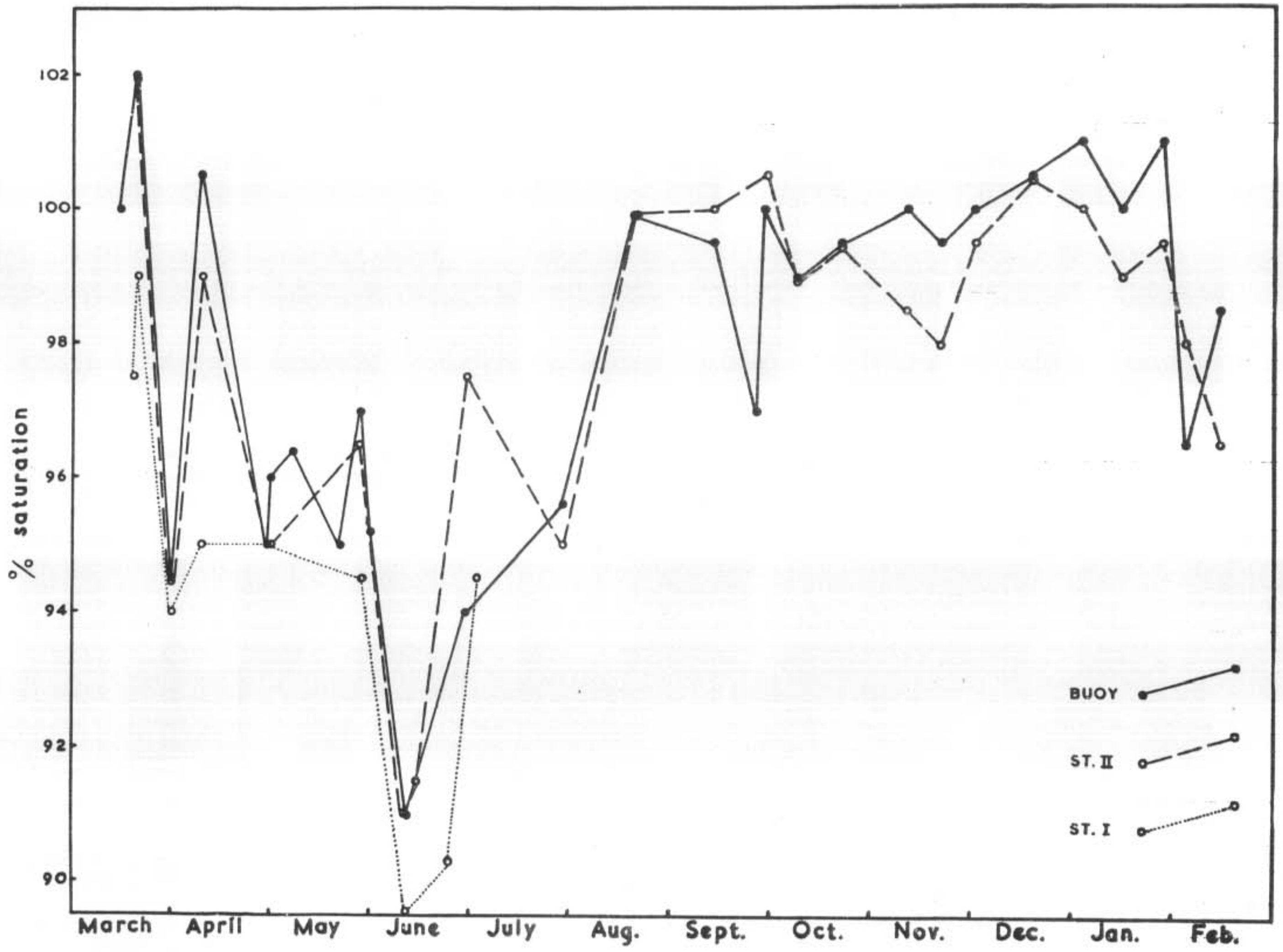

FIG. 12. OXYGEN (%SATURATION) HEARD ISLAND MARCH 1949 – FEBRUARY, 1950.

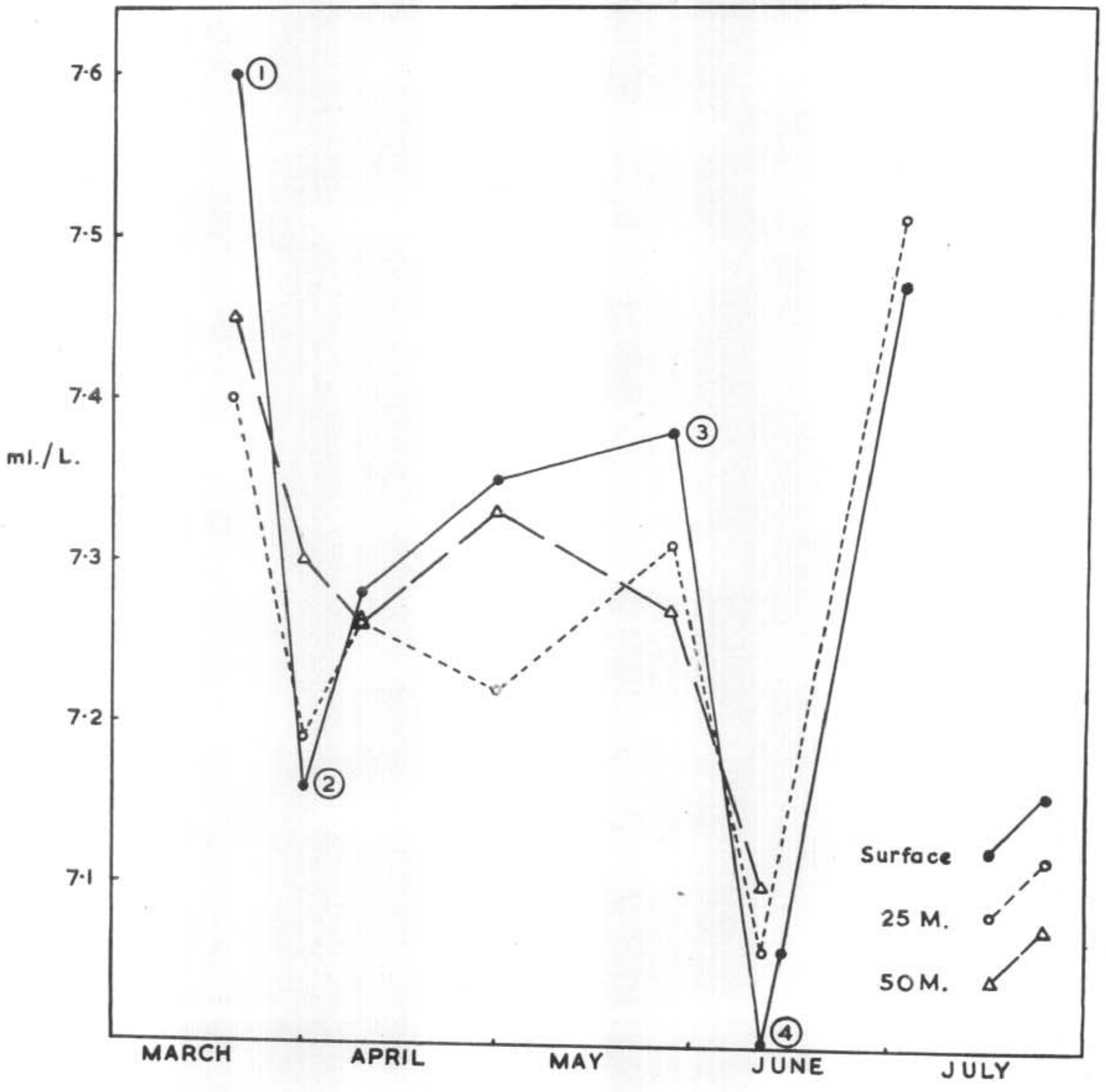

FIG. 13. OXYGEN (ml/L) STATION 1, HEARD ISLAND, MARCH – JULY 1949.

DISSOLVED OXYGEN (ml. per litre) RANGES AND MEANS

Station	Maximum	Minimum	Mean	Number of Observations
I	7.60	7.00	7.31	9
II	8.14	7.20	7.70	24
Buoy	8.16	7.17	7.71	28

It can be seen that oxygen in the surface water decreases further away from the coastal algal belt (though Station II is still too close to be much lower than at the buoy). The oxygen concentration shows no correlation with the amount of sunlight each day (See section on "Twenty-four hour surveys").

Station I, farthest from the coastal algal belt, showed the lowest concentration of oxygen. The values recorded are set out below:-

DISSOLVED OXYGEN (ml. per litre) AT STATION I, 1949

Depth	18 March	19 March	31 March	9 April	30 April	27 May	11 June	2 July
Surface	7.50	7.60	7.16	7.28	7.35	7.38	7.00	7.47
25m.	7.50	7.40	7.19	7.26	7.22	7.31	7.06	7.51
50m.	-	7.45	7.30	7.26	7.33	7.27	7.10	-

The variation of oxygen concentration in the upper 50 metres was small (Figure 13) and there are too few records to draw many conclusions, but it appears that when the air temperature (Figure 7) was greater than or equal to surface temperature at Station I (Figure8), oxygen concentration decreased with increasing depth (① and ③ of Figure 13). When the air temperature fell below the surface temperature, the surface water cooled and sank, so that there was an inversion, and oxygen concentration increased with depth (② and ④ of Figure 13). Photosynthesis then being less (lower temperature and less sunlight), the absolute values of oxygen concentration were less than before.

At Station II and the buoy, surface oxygen concentrations both followed similar courses throughout the year (Figures 11 and 12) although oxygen generally tended to be slightly lower at Station II. The oxygen concentration varied inversely with the water temperature (compare Figures 8 and 11), in agreement with Harvey (1945). The solubility of oxygen rose as the water temperature fell in winter, so that oxygen concentration rose, falling again as solubility decreased with higher summer temperatures, though this fall was delayed by photosynthesis of algae and diatoms in December.

When the oxygen concentrations are converted to percentage saturation (Figure 12), most of the effects of water temperature and salinity changes are removed and increases due to photosynthesis can be seen. If the sharp peaks caused by temporary bursts of sunshine at the times of some samplings are ignored, a decrease of oxygen can be seen in winter, rising again with plant increases in summer. At the buoy the water was supersaturated in December and January, just after the diatom and algal maxima. Then in February, as the plant decrease became pronounced, oxygen fell below the saturation point. (For correlation between oxygen and photosynthesis, see the third part of this Report).

PHOSPHATE AND NITRATE

The surface phosphate phosphorus and nitrate nitrogen from Stations I and II are summarised below:-

PHOSPHATE PHOSPHORUS (μg./L.)

Station	Maximum	Minimum	Mean	Number of Observations
I	50	34	40.8	9
II	56	29	41.9	18

NITRATE NITROGEN (µg./L.)

Station	Maximum	Minimum	Mean	Number of Observations
I	554	373	444	9
II	666	463	586	17

Phosphate values agree well with the range of 33-60µg. phosphate phosphorus per litre recalculated from Deacon (1933) for antarctic surface water, the range of 28-52 g. phosphate phosphorus per litre recalculated from Clowes (1938) at South Georgia, and the range reported by Howard (1940), but nitrate appears to be very high. Nitrate values may be high due to increase during the long storage period before the estimations were made (in spite of the preservation with mercuric chloride). However, dissolved nitrate was higher nearer the shore (Station II) than offshore (Station I).

The values obtained for Stations I and II are shown in Figures 14 and 15. The recording of 371µg. nitrate nitrogen per litre at Station II on September 13 has been omitted, as it is obviously a case where the preservative failed.

Nitrate nitrogen and especially phosphate phosphorus values at Station I were erratic and showed little correlation with depth; nitrate nitrogen at Station I showed a tendency to fall from March to June.

At Station II, nitrate showed a tendency to follow a seasonal cycle with concentration falling in spring and summer and showing signs of a slight recovery in early February.

Station II phosphate phosphorus (Figure 14) showed the seasonal cycle best. A concentration of 56µg. phosphate phosphorus per litre in September fell rapidly to 29µg. at the end of January, rising again in February and March and reaching 52µg. per litre in April. This compares well with Clowes' (1938) values for South Georgia, where a concentration of 52µg. phosphate phosphorus per litre in September fell rapidly

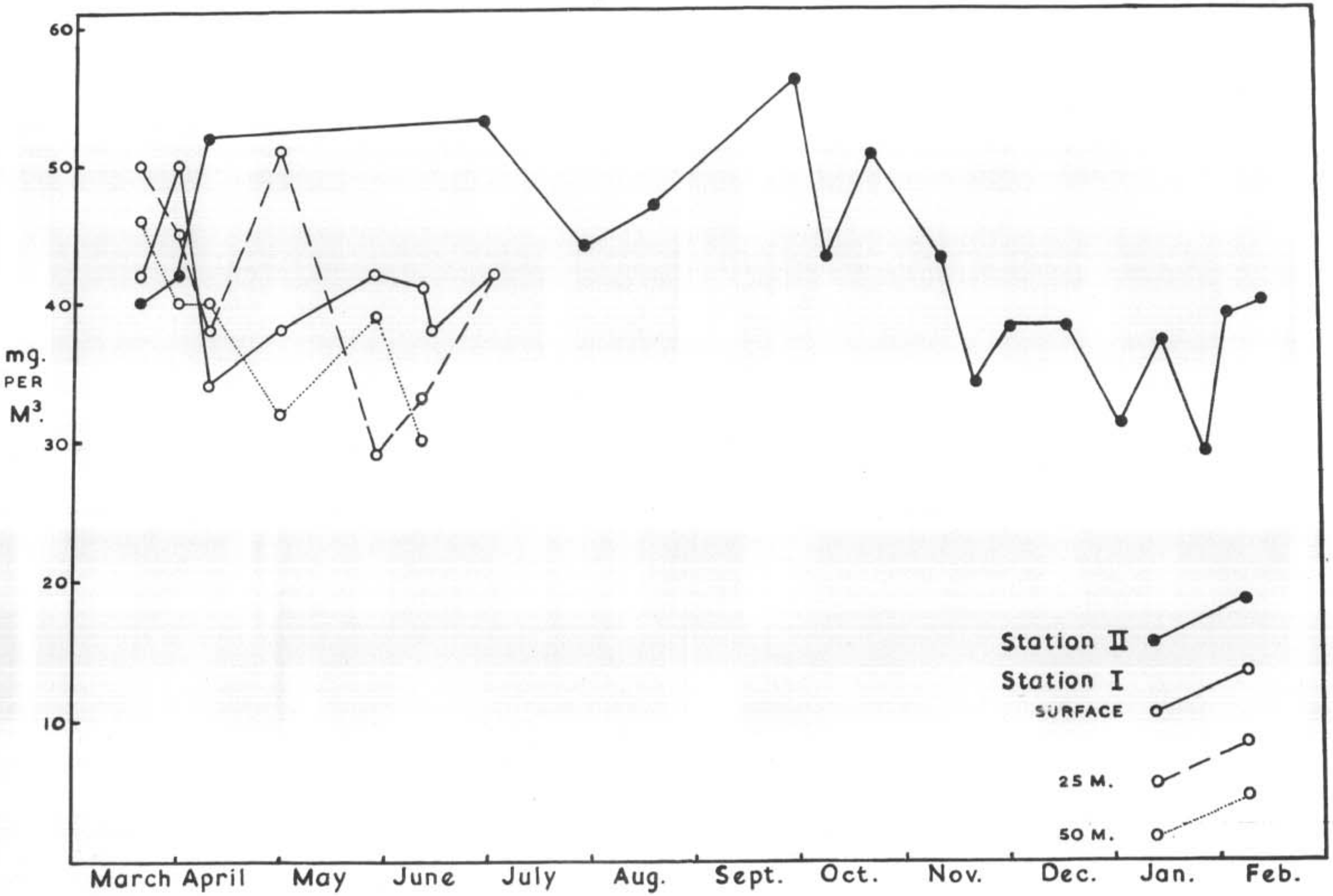

FIG. 14. PHOSPHATE P(mg/M3) HEARD ISLAND, MARCH 1949 – FEBRUARY 1950.

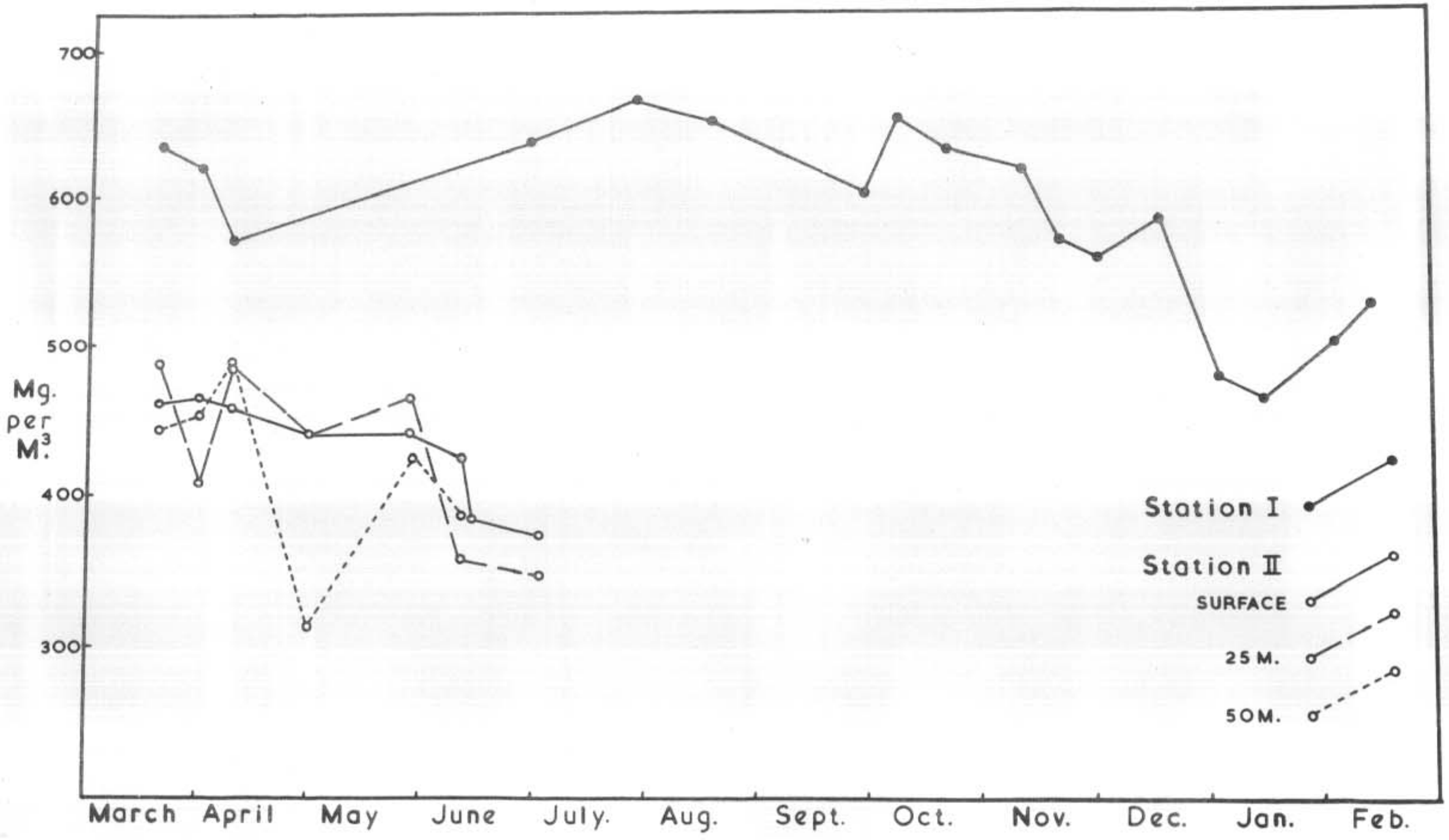

FIG 15. NITRATE N(mg/Me) HEARD ISLAND, MARCH 1949 – FEBRUARY 1950.

to 28µg. by the end of December, rising only slightly in January, but rising more rapidly in February and March when it again reached 52µg. per litre. Clowes records a slight drop in phosphorus in April-June, but lack of sufficient records prevents checking this at Heard Island.

The significance of the seasonal cycle in nutrients is discussed in the third part of this Report.

TWENTY-FOUR HOUR SURVEYS

The results of three twenty-four hour surveys carried out from the cutter moored at the mooring buoy are summarised in the following table. They are graphed in Figures 16, 17 and 18.

Tides. A tide gauge was in operation at Atlas Cove during part of 1948 but was returned as unserviceable at the end of that year. From the records available, the Hydrographic Branch of the Navy has calculated the following mean heights above the zero of that gauge.

TIDE	HEIGHT
Mean High Water Mean Low Water	3.23' 1.59'
Mean High Water Springs Mean Low Water Springs	3.54' 1.28'
Mean High Water Neaps Mean Low Water Neaps	2.92' 1.90'
Indian Spring High Water Indian Spring Low Water	4.34' 0.48'
Mean Higher High Water Mean Lower Low Water	3.79' 1.03'
Mean High Water Diurnal Spring Mean Low Water Diurnal Spring	3.21' 1.61'
Mean Sea Level	2.41'
Mean Ordinary Range	1.64'
Mean Spring Range	2.26'
Mean Neap Range	1.02'

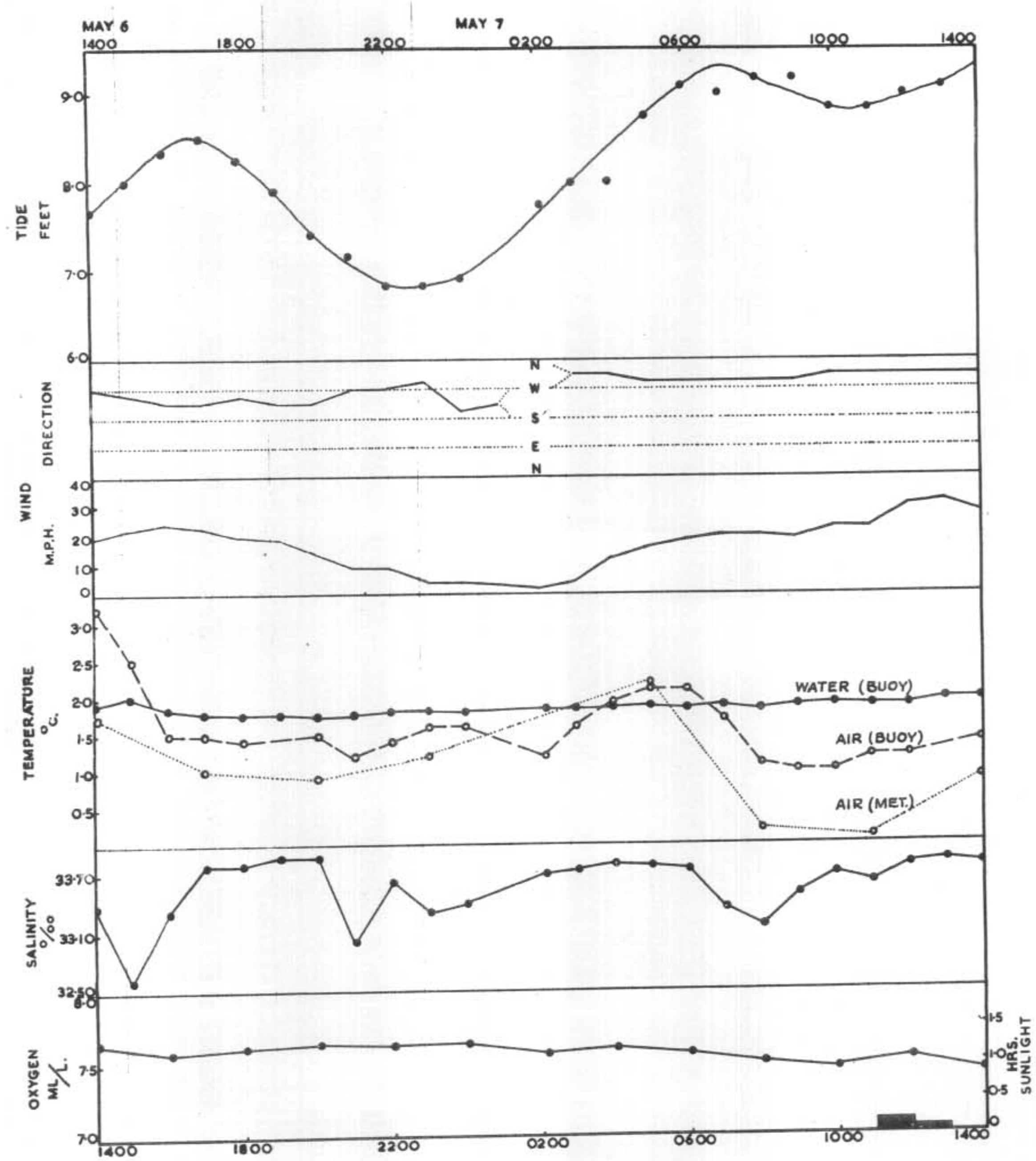

FIG. 16. TWENTY–FOUR HOUR SURVEY, MAY 6–7, 1949.

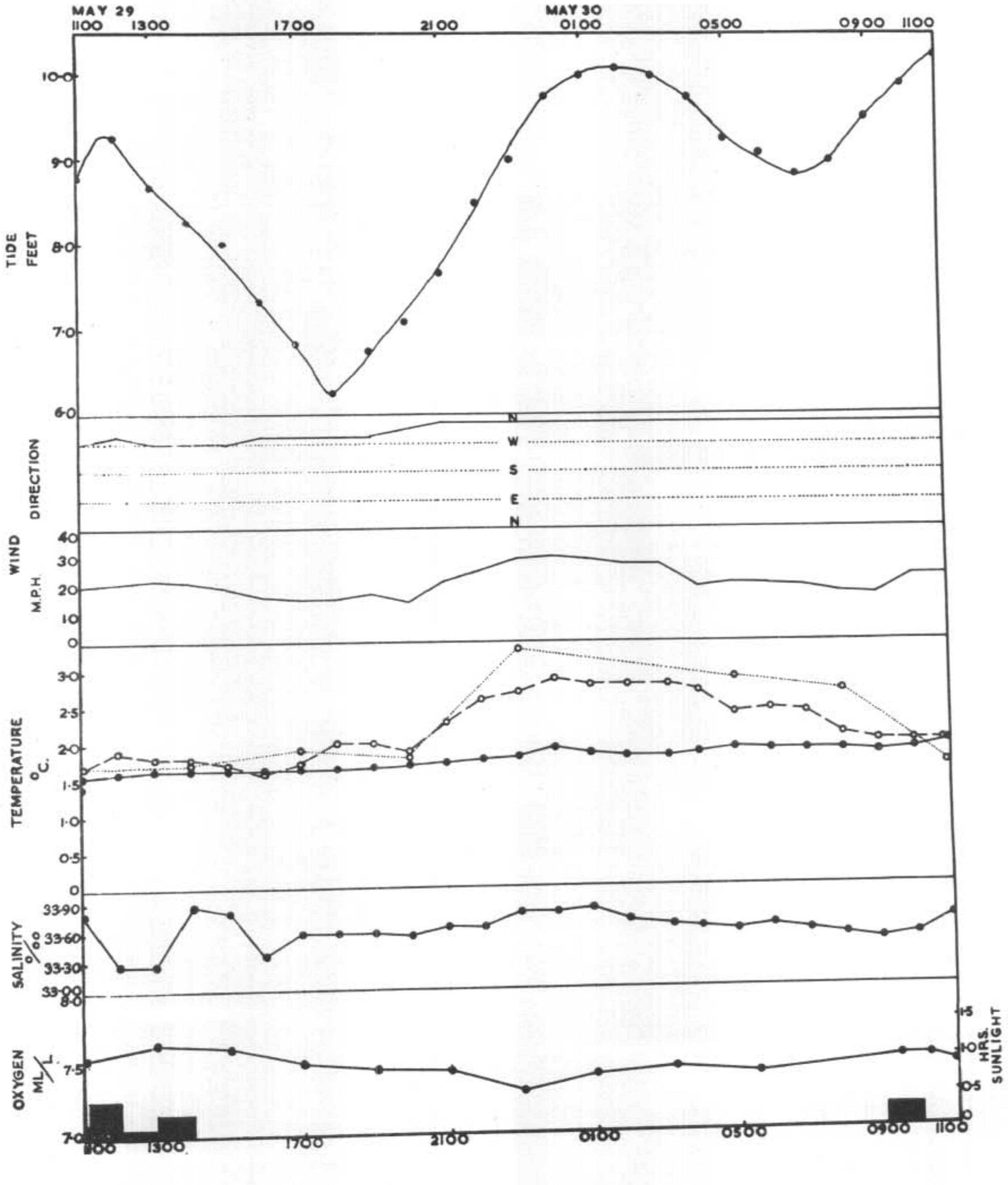

FIG. 17. TWENTY–FOUR HOUR SURVEY, MAY 29–30, 1949.

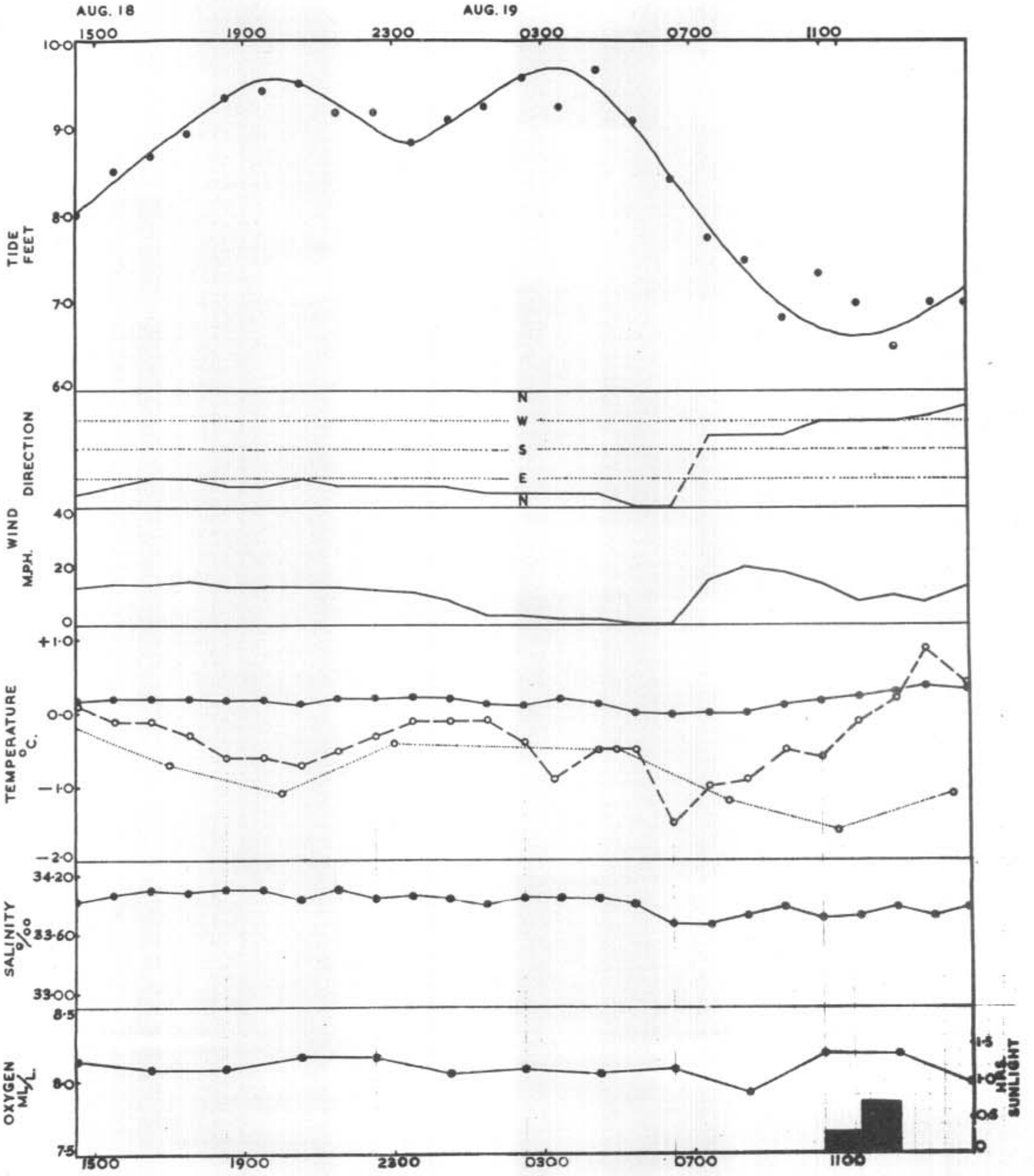

FIG. 18. TWENTY–FOUR HOUR SURVEY, AUGUST 18–19, 1949.

The tide readings on the twenty-four hour surveys were taken from the cutter with a line weighted by a flat disc of brass which rested on the bottom. The bottom was flat and sandy, and there was too little wave action to move the sand appreciably during the time of the surveys.

On 6-7 May, when the moon was at first quarter, tide range was 2.3' and on 18-19 August a day after last quarter of the moon, the range was 3.2'. Both occasions should have been close to a neap tide, yet both show a range greater than the mean spring range given by the Hydrographic Branch. On 29-30 May a day after the new moon, the tide range was 4.0', which is above the range of 3.86' given for Indian spring water.

These relatively high ranges may be partly due to wind raising the high water above normal. A north or a strong north-west wind may bank up water in Atlas Cove and upset the normal tide curve.

On 29-30 May, after a normal tide initial curve, the wind swung to the NNW. half way through the survey when the tide was rising. At the time of this second high tide, a 30 m.p.h. NNW wind was blowing, with gusts over 50 m.p.h., and this obscured the normal tide curve, raising the water.

On 6-7 May and 18-19 August two high tides were less than six hours apart with only a slight low tide between, probably due to the diurnal declinational tide of the moon superimposed on the semidiurnal tides.

Temperature. Reference has been made to the greater fluctuations of air temperature in comparison with water temperature. As might be expected, air temperature at the buoy was intermediate between the surface water temperature there and the air temperature over land at the meteorological station.

The daily water temperature range was less than 0.5°C. (0.25°C. on 6-7 May, 0.42°C. on 29-30 May, and 0.37°C. on 18-19 August). It followed fluctuations in air temperature rather than variations of tide.

Salinity. This tended to follow the tide, rising as water of higher salinity from further out was brought in by the rising tide and falling as the fresh-water from thawing on land became more noticeable at low tide. Variation was much smaller in winter (and the mean higher) when low temperatures reduced the entry of fresh water to a minimum. The low salinity at 1200 and 1300 hours on 29 May is aberrant, as it should have been high with high water.

Oxygen. For the twenty-four hour surveys, the cutter was moored in the most protected part of Atlas Cove, far enough offshore for the oxygen concentration to be unaffected by surf.

Oxygen concentration showed little variation with tide but slowly fell at night, increasing during the day with sunlight. The range of 0.34 ml./litre (29-30 May, Figure 17) between night and sunlight samples is of similar magnitude to fluctuations in surface samples between March and July (Figure 11) indicating these variations were related to the amount of sun during the few hours prior to sampling.

DISCUSSION

Weather conditions and difficulties with the cutter made it impossible to maintain throughout the year a hydrological station far enough offshore to study the changes in antarctic surface water. Conditions at Station I were close to those of normal antarctic surface water, but this station was only maintained for four months. At Station II and at the buoy local influences predominated, but these inner stations were useful in the study of the environment of organisms settling on exposed plates at the buoy and in the study of the inshore plankton at Station II (See the first part of this Report).

Factors affecting the hydrological conditions off Heard Island may be divided into general influences and local influences.

General influences. The Antarctic Convergence may be regarded as the region in the Southern Ocean where the antarctic surface water, because of its lower temperature, sinks below the less dense subantarctic water, and it is marked by a more or less sharp change in temperature of surface water. The importance of the Convergence in relation to the plankton, fishes, bottom deposits, etc., is referred to by Mackintosh (1946).

In the region of Heard Island the Antarctic

Convergence passes close to Iles de Kerguelen so that Heard Island is approximately 180 miles south of the Convergence. The position of the Convergence does not vary to any great extent. Deacon states that the variation in position might be 60 miles in extreme cases, while Mackintosh says that "probably a displacement of 50 miles or so either way is not uncommon, but it may be that the extreme displacement does not exceed about 100 miles". The slight movement of the Antarctic Convergence may be a seasonal one (being a little further north in winter) but slight variations may be found during any one month (Mackintosh) although none of much significance. Even with these slight variations in position, the Antarctic Convergence is always north of Heard Island.

Station I, the farthest offshore, showed least local effects and, during the limited time it was maintained, showed the characters of antarctic surface water.

From the records available, the mean monthly surface temperatures at Station I from March to July of 1949 are set out below, together with the approximate monthly mean temperatures for antarctic surface water off Heard Island (as read from the surface isotherms for these months in plates VII to XI of Mackintosh (1946)).

MONTHLY SURFACE WATER TEMPERATURES OFF HEARD ISLAND

Month	From Station I records	From Mackintosh (1946) isotherms in pl. VII-XI
March	2.55°C	3.1°C
April	2.40	2.3
May	1.90	1.6
June	1.41	0.8
July	1.08 +	0.5

+ 1st week of July only.

For the greater part, the surface isotherms of Mackintosh's plates VII to XI were, in the region of

Heard Island, only hypothetical, as no records were available in that locality at the time. It is of interest to note that the two months in which the values of the two sets of figures were nearest were April and May, when according to Macintosh's plates VIII and IX, the "Discovery" took records in this quadrant. But in June and July the surface temperatures as read from Mackintosh's isothermal lines are considerably lower than those taken by the author at Station I, which would indicate that Mackintosh's isothermal lines in this region are slightly too far north during these months.

It might be argued that local influences caused Station I surface temperatures to be higher, but during June and July the inshore waters were much cooler (Figure 8). Indeed, sea ice began forming in Atlas Cove during July.

The surface temperature maximum of 2.70°C. at Station I was well below the temperature of the antarctic surface water at the Convergence, which lies between the 4°C. and 5°C. isotherms during summer in this area according to Mackintosh.

In spite of local influences reducing the surface salinity of the water closer to the shore, the surface salinities at Station I were higher (range 33.89% to 34.04%) than the surface salinities recorded by Deacon (range 33.64% to 33.89%) in antarctic surface water 50 miles north of Prince Olaf Harbour, South Georgia. The range recorded by Deacon is wider than that at Station I because records from the latter were only for part of the year and so do not show the full annual range.

The higher surface salinities at Station I in comparison with South Georgia might indicate some up-welling of more saline water at the former. This could be possible; Ealey (See first part of this Report) has identified in the surface plankton specimens which normally live at greater depths.

The surface salinity at Station I increased in winter (Figure 10) as recorded by Deacon for antarctic surface water.

During March and early April at Station I the salinity was always greater at 50 metres than at the surface (maximum difference 0.10‰) while from late April there was generally little difference between surface and 50-metre samples. This is in agreement with

Deacon who recorded that 50 miles north of Prince Olaf Harbour, South Georgia, the surface salinity was 0.04°/oo lower than the salinity at 50 metres at the end of summer, but that surface and 50-metre samples were the same in winter.

Local influences. As the temperature range for air at the meteorological station on the island (4.6°C. to -3.9°C.) was much greater than that of the antarctic surface water in this region, the temperature of the inshore water was much more affected by local fluctuations. The ranges of surface temperatures increased nearer the shore (1.62°C. at Station I, 3.42°C. at Station II and 5.21°C. at the buoy) and the mean surface temperature was lower at the buoy and Station II than further offshore at Station I (Figure 8).

On two occasions the air temperature on the island fell sufficiently to cause the formation of sea ice on shallow water in a protected part of Atlas Cove, but the ice did not persist for more than a few hours.

The salinity of the inshore water was dependent upon local fluctuations of air temperature, becoming lower as rising air temperatures increased the flow of glacial streams on the island. In winter when glacial streams were very seldom flowing, the fluctuations of salinity at the buoy and Station II were smaller, but there was still a gradient of increasing salinity away from the shore from the buoy through Station II to the more stable Station I (Figure 10).

The maximum normal tide range of 3.8 feet at Heard Island (See section on "Twenty-four hour surveys") is not very large, as would be expected for an oceanic island. But there is some evidence from twenty-four hour surveys that within Atlas Cove a north or strong north-northwest wind may bank up water, upsetting the normal tide curve and raising the water above Indian spring high water.

With a marked salinity gradient increasing seawards, the salinity within Atlas Cove tended to follow the tide, rising as water of higher salinity from further offshore was brought in by the rising tide and falling as fresh water from thawing on land became more noticeable at low tide (Figures 16-18). This was less obvious in winter when the amount of thawing was at a minimum and the salinity gradient less pronounced.

The percentage saturation of oxygen was higher at inshore stations that at Station I, mainly because of the coastal algal belt (dominated by masses of Durvillea antarctica Hariot) and possibly because of the surf zone.

At the inner stations an annual oxygen cycle was found (Figure 12) which could be correlated with diatom and algal variations (See the third part of this Report). When the plant growth on experimental plates at the buoy was at a minimum in winter, dissolved oxygen (expressed as percentage saturation) was at a minimum, rising in the spring to supersaturation in December and January at the time of and just after the maximum settling of diatoms and algae on the plates. In February, as the plant decrease became more pronounced, oxygen fell below saturation point.

Phosphate phosphorus and nitrate nitrogen concentrations showed an inverse relationship with photosynthesis, falling in summer when plant activity was greatest. They were higher nearer the shore (Figures 14 and 15) due to the breakdown of the more plentiful plant material there and possibly to the excretory products of the large populations of birds and seals on the shore.

TABLES OF HYDROLOGICAL RECORDS FROM HEARD ISLAND

MARCH 1949 - FEBRUARY 1950

STATION I RECORDS

Date	Depth (metres)	Temp (°C)	Chlor. (°/oo)	Sal. (°/oo)	Oxygen		PO_4.P µgr/l	NO_3.N µgr/l
					(ml/l)	(%)		
18 March	0	2.60	18.77	33.91	7.5	97.5	40	554
	20	2.50	18.80	33.96	7.55	98.5	-	-
19 March	0	2.70	18.78	33.93	7.6	99	42	460
	25	2.50	18.77	33.91	7.4	97	50	487
	50	2.45	18.81	33.98	7.45	97.5	46	444
31 March	0	2.35	18.79	33.95	7.16	94	50	464
	25	2.37	18.86	34.07	7.19	94	45	408
	50	2.39	18.82	34.00	7.30	95	40	454
9 April	0	2.51	18.77	33.91	7.28	95	34	457
	25	2.43	18.85	34.05	7.26	95	38	484
	50	2.41	18.88	34.11	7.26	95	40	488
30 April	0	2.30	18.75	33.89	7.35	95	38	440
	25	2.30	18.76	33.89	7.22	94	51	439
	50	2.31	18.75	33.87	7.33	95	32	313
27 May	0	1.90	18.80	33.96	7.38	94.5	42	441
	25	1.95	18.81	33.98	7.31	94	29	464
	50	1.95	18.80	33.96	7.27	93.5	39	424
11 June	0	1.43	18.77	33.91	7.00	89.5	41	424
	25	1.43	18.85	34.05	7.06	90.3	33	358
	50	1.49	18.84	34.04	7.10	91	30	386
14 June	0	1.40	18.77	33.91	7.06	90.3	38	384
27 July	0	1.08	18.84	34.04	7.47	94.5	42	373
	25	1.11	18.82	34.00	7.51	95	42	346

STATION II SURFACE RECORDS

Date	Temp. (^{o}C)	Chlor. (^{o}/oo)	Sal. (^{o}/oo)	Oxygen		$PO_4.P$ µgr/l	$NO_3.N$ µgr/l
				(ml/l)	(%)		
19 March 1949	3.37	18.52	33.46	7.69	102	40	634
31 March	–	18.80	33.95	7.27	94 .5	42	620
9 April	3.08	18.43	33.30	7.50	99.0	52	570
30 April	2.09	18.74	33.86	7.36	95.0	–	–
27 May	1.50	18.71	33.80	7.60	96.5	–	–
11 June	1.09	18.77	33.91	7.20	91.0	–	–
14 June	0.80	18.73	33.84	7.29	91.5	–	–
29 June	0.60	18.79	33.95	7.76	97.5	53	636
2 July	0.35	–	–	7.79	–		
28 July	0.00	18.71	33.80	7.70	95	44	666
18 August	0.20	18.84	34.04	8.14	100	47	651
13 September	0.47	18.75	33.88	8.06	100	–	–
29 September	-0.05	18.64	33.68	8.10	100.5	56	601
8 October	0.35	18.72	33.82	7.97	99	43	652
21 October	0.97	18.53	33.48	7.96	99.5	48	631
11 November	1.01	18.79	33.95	7.82	98.5	43	618
21 November	1.20	18.82	34.00	7.83	98	34	569
1 December	1.05	18.79	33.95	7.96	99.5	38	557
8 December	1.80	–	–	–	–	–	–
9 December	2.65	–	–	–	–	–	–
15 December	1.60	–	–	–	–	–	–
18 December	2.65	18.22	32.92	7.76	100.5	38	583
25 December	1.81	–	–	–	–	–	–
3 Jan. 1950	2.14	18.67	33.73	7.80	100	31	477
15 January	2.68	18.46	33.34	7.64	99	37	463
27 January	3.00	18.71	33.79	7.58	99.5	29	–
4 February	2.19	18.79	33.95	7.61	98	39	501
14 February	2.31	18.77	33.90	7.44	96.5	40	526

SURFACE RECORDS AT BUOY

Date	Temp. (°C)	Chlor. (°/oo)	Sal. (°/oo)	Oxygen	
				(ml/l)	(%)
14 March 1949	2.90	18.42	33.28	7.7	100
19 March	3.37	18.27	33.01	7.65	102
31 March	2.15	18.78	33.93	7.29	94.5
9 April	3.08	18.14	32.76	7.63	100.5
29 April	2.10	18.58	33.57	7.17	95
30 April	2.34	18.35	33.15	7.43	96
6 May +	1.85	18.57	33.56	7.56	96.4
21 May	1.66	18.61	33.62	7.65	95
27 May	1.55	18.71	33.80	7.64	97
30 May +	1.87	18.60	33.61	7.46	95.2
11 June	0.90	18.77	33.91	7.24	91
29 June	-0.15	18.61	33.62	7.70	94
28 July	-0.26	18.64	33.68	7.75	95.6
19 August +	0.16	18.77	33.91	8.09	99.9
29 August	0.25	18.63	33.66	-	-
13 September	0.41	18.72	33.82	8.01	99.5
26 September	-0.02	18.39	33.22	7.95	97
28 September	0.30	18.50	33.42	8.16	100
8 October	0.10	18.70	33.78	8.04	99
21 October	1.07	18.48	33.39	7.93	99.5
23 October	1.10	-	-	-	-
11 November	1.79	18.18	32.84	7.87	100
21 November	1.56	18.77	33.90	7.87	99.5
1 December	1.13	18.77	33.91	8.03	100
8 December	1.90	-	-	-	-
9 December	2.80	-	-	-	-
15 December	1.77	-	-	-	-
18 December	2.38)	18.39	33.22	7.84	100.5
18 December	3.09)	-	-	-	-
25 December	2.20	-	-	-	-
3 January 1950	2.06	18.74	33.85	7.91	101
15 January	2.83	17.98	32.48	7.74	100
27 January	3.41	18.62	33.63	7.63	101
4 February	2.12	17.79	33.95	7.49	96.5
14 February	3.10	17.99	32.49	7.54	98.5

\+ Means from twenty-four hour surveys.

SUMMARY

The results of a year's investigation of the hydrological conditions at Heard Island, in the northern zone of the antarctic surface water, are recorded and discussed.

Temperature, salinity, dissolved oxygen, phosphate phosphorus and nitrate nitrogen were investigated at stations close to the island; hence some of the effects were local. The formation of sea ice in the more sheltered water of Atlas Cove is recorded.

Variations in tide, air and water temperature, salinity and dissolved oxygen over three twenty-four hour periods are listed and discussed. Tidal constants for Atlas Cove are given.

The position of the Antarctic Convergence in relation to Heard Island is discussed with its general and local influences upon the hydrology of the area.

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3. THE SETTLEMENT OF MARINE ORGANISMS ON SUBMERGED SURFACES AT HEARD ISLAND, 1949.

by R.G. Chittleborough.

INTRODUCTION

At Heard Island (53°S. 73½°E.) most of the organisms which foul shipping, wharf-piles and buoys in lower latitudes are absent. The following study was undertaken in 1949 in order to discover what organisms do settle upon surfaces exposed in these regions, to follow their seasonal variations and to compare them with warmer regions.

APPARATUS AND METHODS

Frosted glass plates measuring 100 mm. x 82 mm. and of 7 mm. thickness were held in a frame which was hung three feet below the water surface by means of a buoy.

Frames for holding the plates were made on the island. The slots for the plates were of 18-gauge sheet copper, and the general framework was of 10-gauge copper wire soldered together. A frame held six plates 9 cm. apart. When in the frame each plate had a total area of 150 sq. cm. exposed. Nylon rope was used for hanging the frames and, though this tended to chafe, it proved satisfactory if replaced at regular intervals.

At first the frame was hung from the large mooring buoy in Atlas Cove (See Figure 1) where the mean depth was approximately eight feet, but rough weather caused the frame to be battered against the mooring chain, resulting in the loss of plates or even the whole frame. Later a six gallon drum with an encircling band holding a ring was used as a buoy and from this the frame was hung by three nylon ropes as shown in Figure 19. Below the frame another nine feet of nylon rope was attached to a chain shackled to a small anchor. This apparatus was placed 25 yards from the mooring buoy and proved quite satisfactory for the remainder of the work.

After exposure the growth on the plate was examined microscopically, while still fresh, under low (90X) and high (400X) powers and the organisms present were listed. For microscopic organisms, the numbers in 15 low-power fields along the upper part of the plate and a further 15 fields along the lower part of the plate were totalled and converted to density per sq. cm. Colonial diatoms were recorded as the number of colonies per sq. cm.

Macroscopic organisms were measured and counted, the numbers of each species being converted to numbers per 100 sq. cm.

After examination, each plate was dried to constant weight above a room heater at temperatures of up to 100°C. and weighed when cool. The fouling film was then scrubbed off with a nail brush in water and the plate was dried and weighed. The difference between the two weights represented the dry weight of organisms on the whole exposed surface (150 sq. cm.). This weight was reduced to weight per 100 sq. cm.

Nineteen plates were examined after being exposed for one month, six after three months, and one after six months. With eight of the eleven consecutive monthly plates the work was done on two similarly exposed plates and the numbers of organisms and the total dry weights compared.

No anti-fouling preparations were tested as the investigation was confined to discovering what organisms caused the fouling and their seasonal variations in numbers and growth rate.

ORGANISMS FOUND ON PLATES AND BUOYS

The only organisms attached to buoys and experimental plates at Heard Island were diatoms and algae. Although the plate holders were entirely of copper (more suitable material not being available on the island) this appeared to have little effect on the growth on the plates, the film extending practically to the edge of the holders. Metallic copper is electro-negative to hydrogen and so copper is less toxic than copper salts which ionise more or less readily to give Cu^+. Therefore sheet copper fouls to some extent, though a certain amount of Cu^+ would no doubt be present even at the temperatures of -1.8°C. to 3.41°C. found at Atlas Cove, Heard Island.

Parker (1924), Clarke (1947) and Ketchum et al. (1945) have worked upon the poisoning of fouling

FIG. 19. FOULING FRAME AND MOORING SYSTEM, ATLAS COVE, HEARD ISLAND

animals by copper ions, but though Ketchum found some algae sensitive, less is known of the tolerance of other algae to copper.

On the other hand, Hendey (1951) states that diatoms are often highly resistant to copper and he grades fouling species at Chichester Harbor according to resistance. Some species in his list were also identified from Heard Island (*Amphipleura rutilans*, *Navicula Grevillei*, *Cocconeis scutellum* and *Biddulphia aurita*) so these at least might be expected to be found on the copper holders. Unfortunately, although some diatom film appeared on the copper holders, it was not noted which species were present in this film.

The following diatoms have been identified by Dr. N.I. Hendey from scrapings from the plates:-

Amphipleura rutilans (Trentepohl) Cleve
Amphora Charcotii Peragallo
Biddulphia aurita var. *obtusa* (Kützing) Hustedt
Cocconeis imperatrix Schmidt
Cocconeis pinnata Gregory ex Greville
Cocconeis scutellum Ehrenberg
Conscinodiscus denarius Schmidt
Coscinodiscus Charcotii Peragallo
Coscinodiscus lentigenosis Castracane
Coscinodiscus Oestrupii Van Heurck
Coscinodiscus radiatus Ehrenberg
Entopyla kerguelensis Karsten
Eucampia balustium Castracane
Fragilaria striatula var. Van Heurck
Fragilaria new sp.
Fragilariopsis antarctica (Castracane) Hustedt
Gomphonema Charcotii Peragallo
Hyalodiscus stelliger Bailey
Licmophora Charcotti Peragallo
Licmophora Lyngbyei (Kützing) Grunow ex Van Heurck
Melosira sol Kützing
Navicula directa (Smith) Ralfs ex Pritchard
Navicula Gainii Peragallo
Navicula glaciei Van Heurck
Navicula Grevillei (Agardh) Cleve
Pleurosigma acus Mann
Rhoicosphenia sp.
Thalassionema nitzshioides Hustedt
Trachyneis aspera (Ehrenberg) Cleve
Trachyneis aspera var. *antarctica*

Coscinodiscids are really planktonic but occasional examples were found entangled amongst the growth on the plate.

Only two species of algae were identified from the plates, Chaetomorpha sp. and Monostroma sp., although red algae spores and very young plants too small for identification were occasionally recorded.

On the mooring buoy which had been in the water approximately 18 months at the time of examination, algae represented the final stage of fouling.

H.B.S. Womersley of the Botany Department, University of Adelaide, is examining the algae from Heard Island and preliminary identification of those from the buoy include the following:-

Chaetomorpha sp.
Cladophora pacifica
Desmarestia sp. near ligulata
Durvillea antarctica (Chamisso) Hariot
Ilea fascia (Müll.) Kützing
Monostroma sp.
Porphyra sp. (at least two species)
Prasiola sp. near crispa (Lightf.) Menegh.
? Punctaria sp.

No animals were found attached to the plates, though a few ciliate protozoa were occasionally seen swimming amongst the algae and diatoms. Although the limpet Nacella kerguelepsis (Smith) abounded on the rocks nearby, none was found attached to the buoys or plates except on one occasion when a frame had broken away and spent some time resting on the bottom. Several of these limpets were wandering across the plates clearing paths in the diatom film, so could be listed as anti-foulers.

Sheltering amongst the plant growth on the buoys and longer term plates were numerous amphipods, mainly Pontogeneia chosroides (Nicholls), as well as Hyale hirtipalma (Dana), an isopod Exosphaeroma gigas (Leech) and a few young fish, Notothenia sp. Adult Notothenia coriiceps often had large quantities of red algae in their stomachs.

SETTLEMENT ON ONE MONTH PLATES

The bulk of the growth on one-month plates consisted of diatoms which grew in a fairly even film, a very faint yellow-brown when thin in April to August and a dark brown when diatom growth was dense from October to January.

The dry weights of the films, expressed in centigrams per 100 sq.cm. are listed in the table below and plotted as a histogram in Figure 20 which also shows temperature and oxygen saturation at the buoy and phosphate phosphorus from Station II (See Figure 1). It can be seen that oxygen saturation tends to be lower during the winter while diatom growth is at a minimum and rises to saturation in the spring as diatoms increase. In early December, at the time of the diatom maximum, oxygen reached super-saturation and maintained this during January when the diatom growth was still high but definitely falling off. In February, when growth was very much less, oxygen fell again below saturation.

DRY WEIGHTS OF ONE MONTH FOULING FILMS

FOUR WEEKS ENDING	DRY WEIGHT (CGM. PER 100 SQ.CM.)		
	Plate 1	Plate 2	Mean
1 April, 1949	7.2	---	7.2
29 April, 1949	3.5	---	3.5
27 May, 1949	3.5	---	3.5
31 July, 1949	3.4	4.4	3.9
29 August, 1949	4.3	4.5	4.4
26 September, 1949	8.2	11.1	9.6
23 October, 1949	20.6	21.9	21.2
21 November, 1949	36.2	36.3	36.3
18 December, 1949	39.5	41.4	40.4
15 January, 1950	31.1	32.6	31.8
14 February, 1950	11.7	15.0	13.4

The diatom maximum at the end of November and early December agreed with the work of Hart (1941) who found with the phytoplankton in the South Georgia area

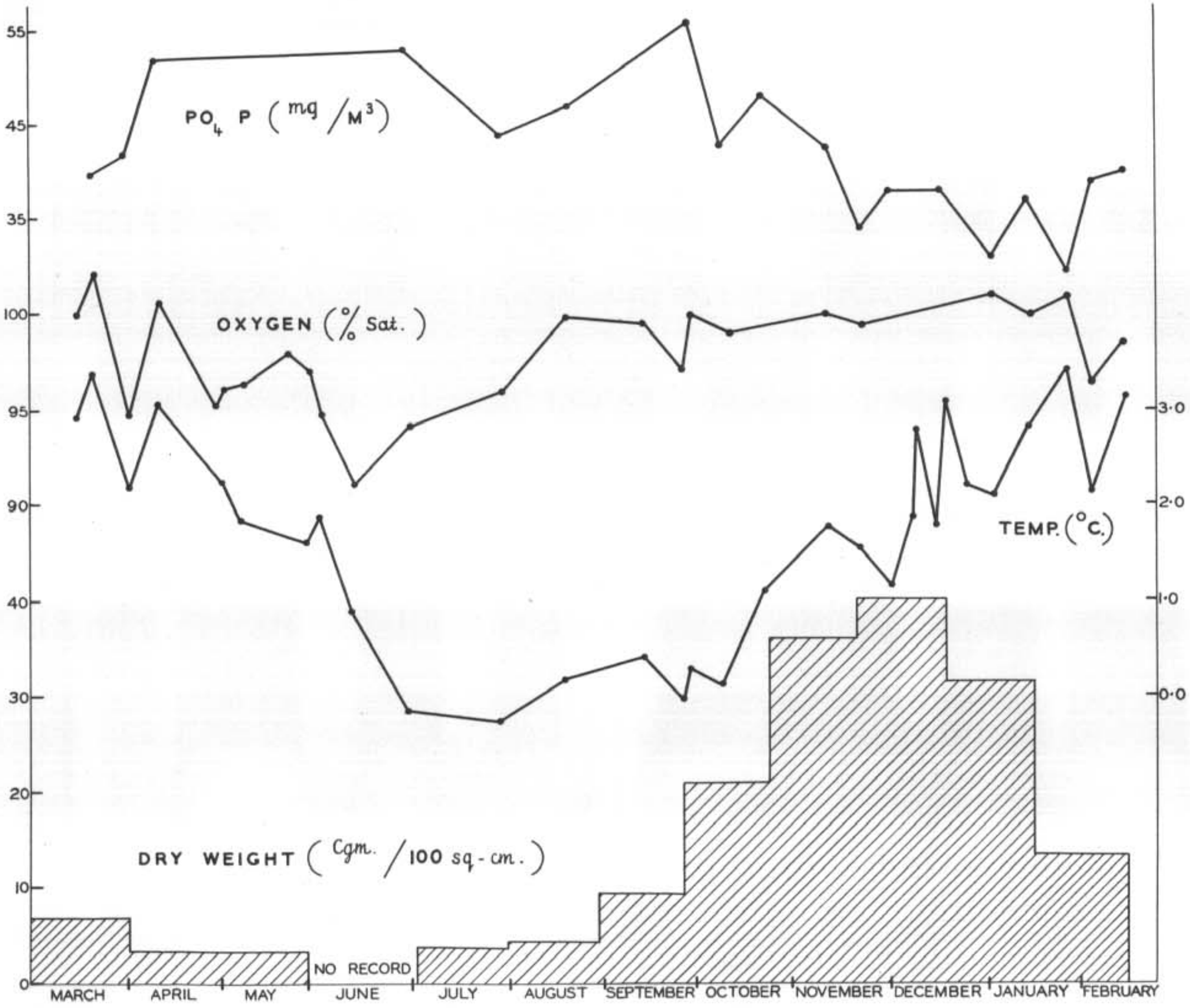

FIG. 20. DRY WEIGHTS OF ONE-MONTH PLATES, HEARD ISLAND, MARCH 1949 – FEBRUARY 1950.

that the "Main increase begins suddenly late in October and rises to a high peak about the end of November. There is then a marked post-maximal decrease to a late summer minimum in February and a secondary autumnal maximum in March before the final descent towards minimal winter values".

The dry weights of monthly growths at Heard Island (Figure 20) show no secondary autumnal maximum for total growth in March, but counts of individual species on the plates do show that several species including *Gomphonema charcotii*, *Cocconeis* species, *Fragilaria striatula*, and *Chaetomorpha* sp., did have secondary increases in March.

Ealey (See the first part of this Report) has also shown that the spring phytoplankton rise at Heard Island reached a maximum in mid-November, falling again in December, followed by a rise in zooplankton in January.

Though erratic, the sea water phosphate phosphorus figures show an inverse relationship to the monthly dry weights (Figure 20). In April, when diatom growth is very slight, phosphate phosphorus shows a recovery and is thought to be then relatively high all the winter, reaching a maximum of 56 μgr. per litre at the end of September. From this point, as diatom growth increases, phosphate phosphorus in the water falls reaching a minimum of 29 μgr. per litre in January when diatom growth is still high but has already begun to decrease. With a further decrease in diatom growth in February the phosphate shows signs of a recovery. Recovery is very slow in March due to slight secondary increase in some species of plants as seen in counts of individual species (See table showing numbers of organisms on one-month plates) but not sufficiently marked to increase the weight of the whole film.

It is doubtful if the minimum of 29 μgr. of phosphate phosphorus per litre of water was the limiting factor of the summer burst of attached diatoms. Hart (1934, 1941) and Clowes (1938) maintain that lack of phosphate cannot be the limiting factor of the summer burst of phytoplankton, Hart pointing out that "While decrease in phosphate content of the surface waters may augment the post maximal decrease in phytoplankton, it is extremely unlikely that shortage of this nutrient salt is ever sufficient to account by itself for that decrease". Similar evidence is shown for nitrate.

Hart suggests that grazing on the phytoplankton may be a major factor in its post-maximal decrease, but there was little evidence of grazing upon the diatom film upon the plates at Heard island.

Though light may be important, the reduction of silicate is probably a major cause of the decrease of the diatom film on the monthly plates in January and February. Unfortunately it was not possible to do silicate estimations at the time. Hart suggests silicate decrease may be a major factor in the post-maximal decrease.

The deterioration of the diatom film on the two one-month plates to 14 February, 1950, was quite marked. Lighter patches with ragged edges showed signs of disintegration of the film.

From July to February (inclusive) the one-month plates were done in duplicate to see if settling was uniform and to get increased accuracy in seasonal variation. The values plotted on the histogram of Figure 20 are the means of the two dry weights for each month, but the two plates showed close similarity in their growth as can be seen in the table showing dry weights of the one-month fouling films.

Diatom counts from one-month plates. Diatom counts of the dominant species on the monthly plates generally agreed with the variation in dry weights.

Gomphonema Charcotii was by far the most abundant species, always dominating the growth on one-month plates, except in April when Cocconeis exceeded it. The minimum densities of Gomphonema Charcotii were of 700 cells per sq. cm. in April and 1500 per sq. cm. in May. In July the density was 3,000 per sq.cm. and increased rapidly in the spring so that by October it was impossible to make more than a rough estimation of at least 100,000 per sq. cm. For the rest of the summer the film was so dense that insufficient light was transmitted to allow accurate counts to be made, except on the edges, but the numbers must have approached 500,000 per sq. cm.

The three species of Cocconeis were counted together and in the aggregate were the second in abundance on one-month plates, though the numbers were generally well below those of Gomphonema Charcotii. A density of 1,000 *Cocconeis* per sq. cm. in May had fallen to 200 per sq. cm. in July, rising to 550 per sq. cm. in August. Though the numbers increased in September, the increasing *Gomphonema Charcotii* made counting difficult, so that from October to February it was not possible to count *Cocconeis* for the masses of the former species.

The densities of *Gomphonema* and *Cocconeis* and species of colonial diatoms common on the one-month plates are shown in the following table. There the densities of colonial species are expressed as the number of colonies per square centimetre. As the colonies stood out from the more sessile *Gomphonema Charcotii* and *Cocconeis* species it was not quite so difficult to count them.

Fragilaria striatula, *Fragilariopsis antarctica* and *Licmophora Lyngbyei* again showed a tendency toward a summer maximum, but *Biddulphia aurita* var. *obtusa* showed a winter maximum in contrast to the other diatoms, though numbers were not high. Ealey also noticed *Biddulphia* sp. in the winter phytoplankton at Heard Island.

Colonies of *Amphipleura rutilans* and *Navicula glaciei* (taken together in this Report because of their similarity in appearance) which grew to over 60 mm. on the buoy and became much more important on longer term plates, were only occasionally seen on one-month plates, a few more in summer than winter. Growth rate was faster in summer than winter as the largest colony on a one-month plate in May was 327µ high, in July the largest was 290µ, and in February 1600µ high.

Algae on one-month plates. *Chaetomorpha* sp. was the only alga commonly occuring on one-month plates and it only appeared in very fine filaments. The numbers per sq. cm. are listed in the following table. July specimens grew only to 25µ while January ones reached 28 mm. but still did not have the large bulbous cells characteristic of the more mature specimens on longer-term plates. *Gomphonema Charcotii*, *Licmophora Lyngbyei*, *Licmophora Charcotii*, etc., were abundant epiphytes on these filaments.

Monstroma sp. only occurred on the plates occasionally in late summer, the largest on a one-month plate being 162µ long in March.

NUMBERS (per sq.cm.) OF MORE IMPORTANT ORGANISMS ON ONE MONTH PLATES

	1 April 1949	29 April 1949	27 May 1949	31 July 1949	29 Aug. 1949	26 Sept. 1949	23 Oct. 1949	21 Nov. 1949	18 Dec. 1949	15 Jan. 1950	14 Feb. 1950
Gomphonema Charcotii	200,000	700	1,500	3,000	20,000	10,000	100,000	TOO DENSE TO COUNT			
Cocconeis Species	100,000	50,000	1,000	200	550	HIGH BUT OBSCURED BY GOMPHONEMA					
Fragilaria striatula	200	0	0	4	38	21	72	210	120	190	105
Fragilariopsis antarctica	5	0	0	0	0	0	28	33	42	18	6
Licmophora lyngbyei	18	2	0	38	20	22	32	27	6	27	15
Biddulphia aurita var. obtusa	2	20	22	22	6	2	0	0	0	0	0
Chaetomorpha Species	205	23	2	2	5	18	38	130	58	158	34

Spores of red algae settled irregularly throughout the year in small numbers but were never sufficiently advanced for identification.

SETTLEMENT ON THREE-MONTH PLATES

Although the dark brown diatom film, mainly of Gomphonema Charcotii, was present on the three-month plates, the growth was usually dominated by the larger colonial diatoms, especially Amphipleura rutilans and Navicula glaciei, and the green algae Chaetomorpha sp. and Monostroma sp.

The dry weights of three-month growths, expressed as cgm. per 100 sq. cm., are shown in the following table.

GROWTH ON THREE-MONTH PLATES

	Three months ending:-					
	21 May 1949	24 Sept. 1949	23 Oct. 1949	18 Dec. 1949	15 Jan. 1950	14 Feb. 1950
Dry wt. cgm./100 sq. cm.	52	66.2	103	27.8	38.6	31.5

At first sight these weights do not bear out those of one-month plates, having a maximum in late winter instead of summer. The explanation is that from May to September Chaetomorpha sp. settled in quite large numbers but at the lower temperature the growth rate was slower, so that relatively large plants were still present at the end of three months. From October to February Chaetomorpha sp. were still settling on the plates but the growth rate was much more rapid, plants reaching maturity and beginning to die off and disintegrate after seven or eight weeks. A plate two months immersed taken out in February had many Chaetomorpha sp. with large bulbous cells, a few of which were already dead.

The summer three-month plates had lost most of the larger Chaetomorpha plants (withepiphytic Gomphonema Charcotii and Licmorphora species attached), leaving Amphipleura rutilans and Navicula glaciei colonies dominating the growth, but lowering the total dry weight of fouling material on these plates.

The dominant plants are given in the table below in order of importance for each three-month plate. It can be seen that *Amphipleura rutilans* and *Navicula glaciei* not only settle in larger numbers in summer, but have a faster growth rate.

In summer the filaments of the larger *Amphipleura rutilans* and *Gomphorema glaciei* colonies brushed off the surrounding sessile diatoms such as *Gomphonema Charcotii*.

DOMINANT SPECIES ON THREE-MONTH PLATES

Species	Order of Dominance	Density	Maximum Length	Remarks
Three-month plate to 21 May 1949				
Chaetomorpha sp.	1	75/100 sq.cm.	27 mm.	
Gomphonema Charcotii	2	>300,000/ sq.cm.	-	Dark film
Fragilaria striatula	3	∼100/sq.cm.	4 mm.	
Monostroma sp.	4	7/100 sq.cm.	2.27 mm.	
Three-month plate to 24 Sept. 1949				
Chaetomorpha sp.	1	90/100 sq.cm.	46 mm.	Plants of 30 filaments
Fragilaria striatula	2	>500/sq.cm.	6 mm.	
Gomphonema Charcotii	3	+		+ Very dark film
Amphipleura rutilans) *Navicula glaciei*)	4	11/100 sq.cm.	9 mm.	Largest Colony had over 70 filaments
Three-month plate to 23 Oct. 1949				
Chaetomorpha sp.	1	100/100 sq.cm.	40 mm.	Past prime - some cells dead.
Gomphonema Charcotii	2	Dark film too dense to count		
Fragilaria striatula	3	>500/sq.cm.	6 mm.	
Amphipleura rutilans) *Navicula glaciei*)	4	36/100 sq.cm.	5 mm.	
Monostroma sp.	5	4/100 sq.cm.	200	

Species	Order of Domi-nance	Density	Maximum Length	Remarks
Three-month plate to 18 Dec. 1949				
Amphipleura rutilans)+ *Navicula glaciei*)	1	44/100 sq.cm.	11 mm.	
Chaetomorpha sp.	2	36/100 sq.cm.	17 mm.	Tops of many filaments dead.
Fragilaria striatula	3	>200/sq.cm.		
Monostroma sp.	4	2/100 sq.cm.	7.6 mm.	
+ Brushing off sessile diatoms round them.				
Three-month plate to 15 Jan. 1950				
Amphipleura rutilans) *Navicula glaciei*)	1	49/100 sq.cm.	16 mm.	Colonies of hundreds of filaments
Monostroma sp.	2	>30/100 sq.cm.	5 mm.	
Fragilaria striatula	3	200/100 sq.cm.		Small filaments
Chaetomorpha sp.	4	20/100 sq.cm.		All older plants dead.
Three-month plate to 14 Feb. 1950				
Amphipleura rutilans) *Navicula glaciei*)	1	98/100 sq.cm.	20 mm.	Plants with hundreds of filaments.
Monostroma sp.	2	6/100 sq.cm.	6 mm.	Also many young.

SETTLEMENT ON SIX-MONTH PLATE

Only one plate was successfully kept immersed for six months, from 31 August 1949 to 15 January 1950. When examined, the growth was dominated by *Monostroma*; 11 plants per 100 sq.cm. could be counted macroscopically, the largest plant having 13 plates to 102 mm. long. Several other plants were 60-70 mm. As well as these large *Monostroma* sp., there were many (over 50 per sq.cm.) very young ones to 200 μ just beginning to grow on the plate but, because of overcrowding, few of these could reach maturity.

Also important on the six month plate were *Amphipleura rutilans* and *Navicula glaciei*, there being 80 large colonies per 100 sq. cm. But many of these were breaking up, especially in the centres of some colonies. The largest were 26 mm. high which does not compare well with a colony four months old taken from the buoy in November and measuring 65 mm.

On the six-month plate were many (50 per sq. cm.) yellow-brown rounded flat colonies of cells, raised slightly in the centre. The largest was 1200 μ in diameter. Some pink colonies of similar shape were of only 120 μ in diameter. These were probably the basal discs of developing brown and red algae, the final stage of fouling to be found at this locality, but were too young to identify.

Other diatoms, *Fragilaria striatula*, *Gomphonema Charcotii*, *Cocconeis* etc., were common on the six-month plate, but of lesser importance. Many had been brushed off by the larger *Amphipleura rutilans*, *Navicula glaciei* and *Monostroma* sp. plants.

The dry weight of the six-month fouling film was 1.05 grams per 100 square centimetres.

DISCUSSION

Frosted glass plates exposed in Atlas Cove, Heard Island, were colonised only by diatoms and algae. A thick diatom growth, mainly of *Gomphonema Charcotii*, made up the primary film as shown by one-month plates.

After three months the algae, especially *Chaetomorpha* sp. and the colonial diatoms *Amphipleura rutilans* and *Navicula glaciei*, became important, *Chaetomorpha* sp. dominating the three-month growth in winter; but after two months in summer this had passed its peak and *Amphipleura rutilans* and *Navicula glaciei* became the dominant organisms.

After three months *Monostroma* sp. gradually increased in importance and by six months covered the other plants, though *Chaetomorpha* sp. continued to cover the sides of buoys at the water surface.

Following *Monostroma* sp., the final stable fouling mass consisted of red and brown algae, including *Porphyra* (two species), *Ilea fascia*, *Punctaria* sp., *Desmarestia* sp. (near *ligulata*) and others yet unidentified, with some *Durvillea antarctica* (which covers the lower littoral and sublittoral rocks) growing away from these.

Although the species were not the same, the succession of plants on submerged surfaces at Heard Island was similar to that found by Wilson (1925) at La Jolla, California, where a predominantly diatom film was followed by green algae, these being gradually replaced by small reds and browns with large kelps as the final stage of colonisation.

Seasonal changes in diatom settling, as recorded by the dry weights of the film on monthly plates, showed that settling was minimal from April to August, with lowered oxygen saturation during this period as shown in Figure 20. In the spring there was an increase in diatom settling, to a maximum early in December (with the surrounding water supersaturated with oxygen). Settlement decreased slowly in January and more rapidly in February, at which time the dissolved oxygen in the water fell below saturation point.

Sea water phosphate phosphorus showed an inverse relationship with this seasonal cycle. In April, when diatom growth was very slight, phosphate phosphorus showed a recovery, remaining high all the winter, reaching a maximum at the end of September. As the plant growth increased in spring phosphate phosphorus in the water decreased, reaching a minimum in January just after the maximal settling of diatoms. With a marked decrease in diatom settling in February, phosphate showed a recovery.

Counts of several species (*Gomphonema Charcotii*, *Cocconeis* sp., *Fragilaria striatula*, *Licmophora lyngbyei* and *Chaetomorpha* sp., (See table showing numbers of organisms on one-month plates) on one-month plates followed the changes of dry weight of the films, some species showing in addition a small secondary increase in March. The overall diatom cycle was similar to that found by Hart in the phytoplankton off South Georgia, where after a minimum of phytoplankton in winter, a sudden rise in October reached a high peak in late November, followed by a marked post maximal decrease to a late summer minimum in February and a secondary autumnal maximum in March.

SUMMARY

In Atlas Cove, Heard Island, only diatoms and algae grew on exposed experimental plates and buoys. The species found on these surfaces are listed.

Although diatoms settled on plates throughout the year, numbers (and dry weights) were low in winter, increasing in spring to a pronounced maximum in December, at which time dissolved oxygen in the water increased and phosphate phosphorus decreased. There was some evidence of a slight autumnal increase in some diatom species, so that the cycle of sedentary diatoms was similar to that of phytoplankton off South Georgia.

Faster growth rates of some species of diatoms and algae in summer than winter were observed.

An outline is given of succession in the colonization by diatoms and algae of exposed surfaces at Heard Island.

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