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NOTES ON THE CHIRONOMID MIDGE *BELGICA ANTARCTICA* JACOBS AT ANVERS ISLAND IN THE MARITIME ANTARCTIC[1]

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Abstract: *Belgica antarctica*, the southernmost occurring free-living holometabolic insect, is studied in relation to age dominant classes occurring in larval populations, habitat preferendum, and chemical correlations with its relative abundance in various localities. Notes are included in regard to temperature and humidity tolerences, food preferences, and possible methods of dispersal.

During the pioneer voyage of the S.Y. Belgica to the Antarctic in the last decade of the 19th Century Emile G. Racovitza collected an apterous midge and its larva which is now known to be the southernmost occurring free-living holometabolic insect.

Jacobs (1900) assigned this midge to the genus *Belgica* of which *Belgica antarctica* constitutes the only known species. Wirth & Gressitt (1967) have reviewed the earlier descriptions of *Belgica* and they have incorporated earlier studies with recent field observations on the midge's ecology and biogeography. Strong (1967), who stayed the winter at Anvers Island, has provided additional information on *Belgica* relating to fecundity, copulation behavior, and adult and larval habitat preferendum.

Belgica has been observed to occur at Elephant Island in the northern sector of the South Shetland Islands, through the Gerlache Straits of the Palmer Archipelago and south to 65° 27′ S. Lat. on the western side of the Antarctic Peninsula.

The general requirements of the habitat in which *Belgica* is found are outlined by Holdgate (1964) in his discussion of the Maritime Antarctic. In the summer there is a period of over a month when the mean monthly air temperature is above freezing point at sea level, while during the winter the mean monthly air temperature rarely falls below −10°C. There is considerable rain, not only during the summer, but also sporadically in the late fall and during the early spring. Thus, it is a habitat that is quite moderate as compared to that found in the continental antarctic (Tilbrook 1967). At Arthur Harbor two flowering plants occur. One of them, the grass *Deschampsia antarctica*, forms what appears to be a community dominant with a noticeable soil profile substratum in favorable localities.

Gressitt & Leech (1961), Gressitt (1967), Wirth & Gressitt (1967), and Strong (1967) have included in their specific habitat descriptions nearly all of the possibilities where larvae and adult *Belgica antarctica* can occur. Larvae are found in association with the nitrophilous alga *Prasiola crispa*, in mosses, and in the rhizosphere of the grass *Deschampsia antarctica*. The larvae are often seen in the rich and smelly black soil associated with marine animals such as seals. The larvae are also found in association with penguin guano and feather debris, and adjacent to the nests of gulls and fulmars. Notes on the biology of *Belgica antarctica* can be found in Torres (1953), Gressitt & Leech (1961), Gressitt (1964, 1965a,b, 1967), and Strong (1967). Martin (1962) studied the chromosomes and found two inversion polymorphisms.

1. Partial results of grant GA-166 from the National Science Foundation (Office of Antarctic Programs) to Bishop Museum.
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The life cycle has been reported to be irregular. Most investigators feel that the life cycle must extend over a season, and that generations are annual. The adults appear to function only for sexual reproduction. The females generally lay eggs within a day or two after emergence from the pupa. They lay only one egg mass, with the number of eggs within one mass varying between 30 and 50. They appear to live only a week after oviposition. Adults have been seen in dense aggregations by Leech, Gressitt, and others during the summer. It is not uncommon to see two or more adult males in copulation with one female at the same time. The purpose of this paper is to provide additional information on the physical parameters which influence *Belgica antarctica* in the habitat in which it lives.

CHEMICAL ANALYSIS OF THE HABITAT

Dalenius (1965) and others have mentioned the importance of the influence of animals associated with the marine habitat in modifying the terrestrial habitat in the Antarctic.

Obvious correlations exist between many of the terrestrial microarthropods with the guano and fecal material from animals which achieve their food supply from sources within the sea. However, there are some microarthropods in the terrestrial ecosystem whose distribution and livelihood does not necessarily correlate with the biological modification of the habitat from marine sources. The trombidiform mite *Nanorchestes antarcticus* is probably more closely dependent on the Nostoc commune described by Boyd, Staley & Boyd (1966), while the cryptostigmatic mite *Halozetes belgicae* is observed to be directly associated with the thali of various encrusting and foliose lichens.

Belgica antarctica lives in association with biologically modified soil materials and debris (Gressitt 1967, Strong 1967). However, it is also found in areas which are not obviously being modified by birds and seals at the present time. Notable among these locations are where larvae have been found within the rhizosphere of the grass *Deschampsia antarctica*. This often grows in localities where there are presently no indications of birds or seals to modify the habitat. However, nest locations vary in time, and to make an observation in regard to biological modification of the environment it is necessary to know what materials are present in the soils that contain the microarthropods.

Soil samples were collected from the Arthur Harbor and Norsel Point area. Microarthropods were extracted from the soils by the controversial and somewhat approximate technique introduced by Berlese (Williams 1913), and chemical analyses were done in appropriate quantities to determine the composition of the soils which were collected within a sample series.

A few samples which relate to the relative abundance of *Belgica* larvae are presented below to provide an indication of the relation between chemical variation of the soils and the abundance of *Belgica* larvae within the habitat. Chemical comparisons with the same apparatus described below have been done in the Ross Dependency quadrant of the Antarctic by Campbell & Claridge (1966), Spain (1970), and Boyd, Staley & Boyd (1966).

The analyses were done with a Hellige-Truog Combination Soil Tester (Hellige Inc., Garden City, N.Y.) This is an approximate technique and chemical concentration values can be considered only as relative indications of the strength of the soils tested. The apparatus reads directly into pounds per acre, or as a relative value of strength. To obtain parts per million it is necessary to divide a figure which corresponds to the approximate pounds per acre of normal farm land soils for the soil types sampled. In most samples, soil materials were assumed to have a consistency similar to the dry density of a peat soil, since decaying bryophyte carpets were a predominant feature of many of the localities sampled. The conversion to parts per million was found by the formula ppm $= \frac{\text{pounds/acre}}{.5}$

The habitat where *Belgica* larvae were seen to occur in the greatest abundance was adjacent to a small pod of the southern elephant seal, *Mirounga leonina*. This location contained debris material from penguin feathers, fecal material from both *Mirounga* and *Pygoscelis* sp., urea in small crevices and between cracks in the rocks. There were some small pools of water which were turned dark with organic material. The whole area was permeated with a pungent, heavy, and disagreeable odor. At this time there were no adult *Belgica* and the microarthropod population consisted solely of *Belgica* larvae and dense aggregations of the cryptostigmatic mite, *Alaskozetes antarcticus*. The location of the collection was at Bonaparte Point, Arthur Harbor, Anvers Island, 64° 46′ 47″ S. Lat. and 64° 03′ 08″ W. Long. There were approximately 2,500 *Belgica* larvae and 5,000 adult and larval *Alaskozetes* confined within 1,000 cm^3 of the debris. A large number of both species were found in their densest quantities lining the surface of the rocks which were buried within the detritus. This habitat was approximately 1.5 to 2 meters above sea level.

Table 1. Analysis of soil sample taken at Bonaparte Pt, 4 April 1966

Test	pounds/acre	ppm	Relative Reading
pH			7.0
Phosphorous	1,600	3,200	Extremely high
Potassium	680	1,360	Very high
Calcium	8,000	16,000	Extremely high
Magnesium	2,000	4,000	High
Nitrate	50	100	High
Ammonia	200	400	Extremely high
Soil Nitrogen	2,400	4,800	Extremely high
Sulfate	6,000	12,000	Very high
Chloride	350	700	Low

A sample collected from Tern Hill on Norsel Point, 26 October 1966 appeared favorable for the support of numerous *Belgica* larvae. The sample was adjacent to the nest of a giant petrel *Macronectes giganteus*. The dominant living plant was *Prasiola crispa* a nitrophilic chlorophytic alga, which was growing over a decaying *Drepanocladus* carpet. *Alaskozetes antarcticus* was the most abundant arthropod. A 56 gm (dry weight) sample of the soil yielded in Berlese extractions 4,369 *Alaskozetes*, 188 Collembola, and 5 *Belgica* larvae.

Twenty cores were taken of the rhizosphere of the grass *Deschampsia antarctica*. *Deschampsia* was growing on a decaying moss carpet where there was a considerable peat substratum. A small layer of viable bryophyte growth consisted of *Drepanocladus* sp., with *Bryum* sp. and *Polytrichum* sp. filling in the moss mosaic.

Included in the carpet were limpet shells, fragments of bryozoans, and other remains from marine invertebrates. This material is left by birds such as the gull *Larus dominicanus*, the blue-eyed shag *Phalacrocorax atriceps*, and the giant petrel *Macronectes giganteus*. These birds often collect materials from marine areas and carry them to shore for engorgement. The blue-eyed shag was observed carrying clumps of red algae onto shore, the gull dislodges the limpet *Patinigera* sp. from the intertidal area and pecks the living portion from the shell, while the giant petrel has been seen to regurgitate sublittoral material such as octopi, annelids, and fragments of nemerteans near their nest sites when disturbed. This collection station is at 64° 05′ 00″

Table 2. Analysis of soil sample from Tern Hill, Norsel Pt, 26 Oct. 1966

Test	Pounds/acre	ppm	Relative reading
pH			5.5
Phosphorous	730	1,460	Extremely high
Potassium	680	1,360	Extremely high
Calcium	1,000	2,000	Low
Magnesium	$<3{,}000$	$>6{,}000$	Very high
Nitrate	<100	>200	Very high
Ammonia	<100	>200	Very high
Organic Soil Nitrogen	1,600	3,200	Extremely high
Sulfate	<250	<500	Very low
Chloride	<500	$<1{,}000$	Low

W. Long. and 64° 45′ 00″ S. Lat. on Astro Point, a small rocky outcropping on Norsel Point.

Samples were taken 17 March 1966. Of 20 samples, *Belgica* larvae constituted 35.4% of the numbers of all the animals extracted. However, the percent per sample varied considerably, with samples varying from 7.14% to 89% for *Belgica* in relation to the total number of microarthropods per sample. With the exception of the pH of the soil and the available organic nitrogen, the chemical analyses of the 20 samples were strikingly uniform. The pH varied from between 6.1 and 6.8 while the amount of organic nitrogen varied from between 450 ppm as a low to 1,500 ppm in the most concentrated collection. No correlation could be found in analyses which compared separately the pH and the amount of organic soil nitrogen with the percentage of *Belgica* larvae in each sample.

The fourth collection, also taken at Astro Point, was removed from between large boulders, where there was a decaying moss carpet. This moss, *Drepanocladus* sp., was covered with a fresh layer of the chlorophytic alga *Prasiola crispa*. This habitat was obviously the location of a nesting site at one time, and there were considerable numbers of limpet shells imbedded in the turf. In this sample *Alaskozetes antarcticus* (Michael), *Cryptopygus antarcticus* (Willem), *Friesea grisea* (Schaffer) and *Stereotydeus villosus* (Trouessart) were abundant. No *Belgica* larvae were observed. Location was at Astro Point, 64° 46′ 00″ S. Lat., and 64° 05′ 00″ W. Long. Collection date was 8 Nov. 1966.

Another collecting site, which consisted of a well developed soil that is superficially com-

Table 3. Analysis of soil sample from Astro Pt, Norsel Pt, 17 March 1966

Test	Pounds/acre	ppm	Relative reading
pH			6.8
Phosphorous	1,600	3,200	Extremely high
Potassium	320	640	Very high
Calcium	16,000	32,000	Extremely high
Magnesium	1,000	2,000	Medium
Nitrate	25	50	Medium
Ammonia	25	50	Medium
Organic Soil Nitrogen	600	1,200	Very high
Sulfate	250	500	Very low
Chloride	250	500	Very low

Table 4. Analysis of soil sample (by boulders), Norsel Pt, 8 Nov. 1966

Test	Pounds/acre	ppm	Relative reading
pH			6.0
Phosphorous	1,600	3,200	Extremely high
Potassium	640	1,280	Extremely high
Calcium	6,000	12,000	Extremely high
Magnesium	2,000	4,000	High
Nitrate	5	10	Very low
Ammonia	15	30	Low
Organic Soil Nitrogen	550	1,100	Very high
Sulfate	250	500	Very low
Chloride	250	500	Very low

parable to that mentioned by Rudolph (1966) as Arctic Brown Soil, and which appeared under a dominant community of *Deschampsia antarctica* was sampled from a location directly behind Palmer station site on Anvers Island. In this area, the surrounding habitat was lichen encrusted, with *Usnea* sp. being the dominant lichen on rocks and exposed areas. At the collection site, soil had developed in areas to 20 cm and more. *Deschampsia antarctica* had dominated the habitat with very few moss associates remaining. From a sample of 20 cores of the *Deschampsia* root material two *Belgica* larvae were encountered.

The chemical analyses remained uniform for the range of the accuracy of the analysis apparatus. The mean pH was 4.76 with a range from 4.4 to 5.4. The sample in which the two *Belgica* larvae were extracted had a pH value of 4.4 with an organic soil nitrogen value of 2,600 ppm. This sample was collected on 14 March 1966. Its location is 64° 04′ 40″ W. Long., 64° 46′ 02″ S. Lat.

Table 5. Analysis of soil sample, old Palmer Station, 14 March 1966

Test	Pounds/acre	ppm	Relative reading
pH			4.7
Phosphorous	950	1,900	Very high
Potassium	280	560	Very high
Calcium	5,000	10,000	Extremely high
Magnesium	<250	<500	Very low
Nitrate	5	10	Very low
Ammonia	100	200	Very high
Organic Soil Nitrogen	1,350	2,600	Extremely high
Sulfate	<250	<500	no ppt
Chloride	<250	<500	no ppt

The foregoing data provide a few indications of soil types in the Arthur Harbor area. In all of the localities studied there were high concentrations of potassium, phosphorous, and organic soil nitrogen. In only one instance was larval *Belgica* found in a habitat which had a pH below 6.0, and they were sparse in that habitat. In this same sample it was seen that larvae could occur where there was a low concentration of nitrates; however there were high concentrations of organic soil nitrogen and ammonia within the same sample. This may indicate that there are few available soil microorganisms to perform the nitrifying process, or that the limited buffering capacity of the soils has reduced this process.

The rich organically modified environment in itself does not seem the single factor which allows for optimum growth for *Belgica*. Sterilized field-collected media produce no feeding response by larvae. It seems that the abundance of possible yeasts, fungi, algae, and bacteria which may thrive on such rich media are far more important in determining the success of *Belgica* larvae within a given locality.

The larvae appear more sensitive to pH extremes than their habitat associates *Alaskozetes antarcticus*, *Stereotydeus villosus*, or *Cryptopygus antarcticus* and this may be related to their lack of tolerence to humidity variations.

LARVAL SIZE CLASSES

Investigators who have observed samples of *Belgica* larval populations have noted that most age classes of larvae are found in the habitat throughout the year. However, it is difficult to readily identify a larval instar class, and to date, the number of instars have not been adequately determined.

Two studies were instituted to determine larval population size structure. The first attempt to determine the number of larval instar sizes was to make direct measurements of the body length, a technique attempted on collembola by Janetschek (1967). The second method used measurements of the hard, and less flexible, larval head capsule.

After measuring a sample of 100 larval body lengths, it was found that the measurement error was of a significant magnitude to mask any differences between class sizes. Measurements were then concentrated on the length of the larval head capsule. Measurements were made from the labrum to the most caudal aspect of the epicranium (See Fig. 1.) The average headcap length was 288.71 microns with a range in size from 85 microns to 450 microns.

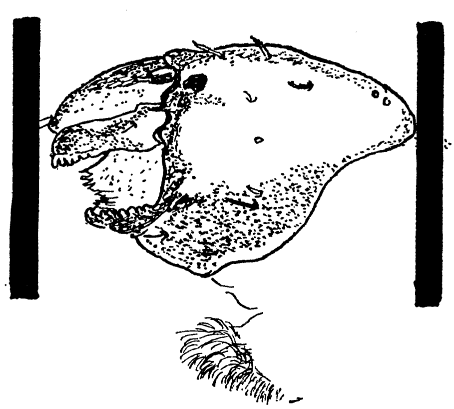

Fig. 1. Lateral diagram of larval head capsule, showing position of measurement.

From a cumulative distribution of larval head sizes it appears that there are six growth pushes or instars. However, error is certain in measurements of this type, and one of the classes (stage 4) is in doubt. Besides the well known problems of error encountered in the measurement

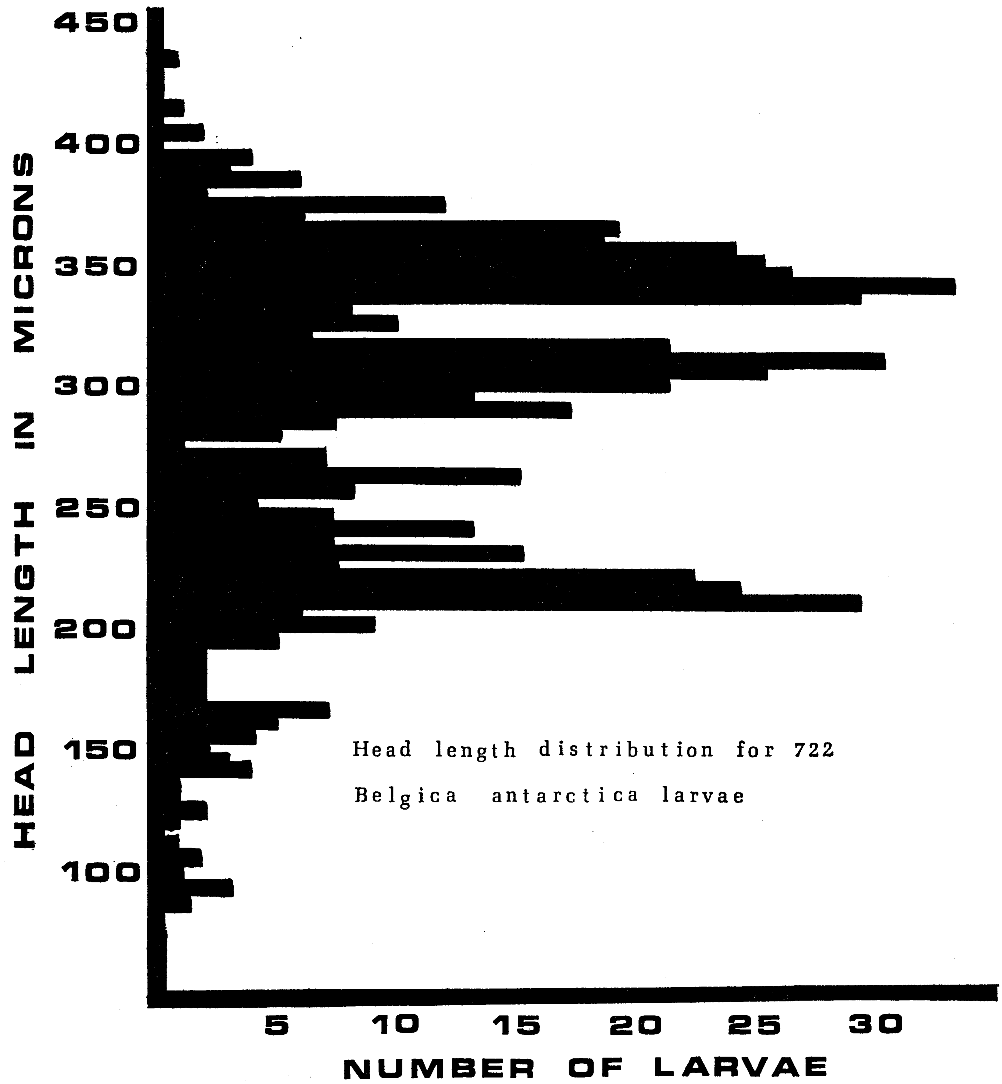

Fig. 2. Head lengths of 722 larvae.

of specimens of this type, there is also the possibility of the masking effect of the nutritive differences and consequently growth differences between populations which are in marginal habitats, and populations which are in optimum nutritive and growth potential habitats.

A technique proposed by Dr H. Janetschek (1967) to determine growth pushes by dividing the differences between actual class measurement counts and a gliding mean of those measurements gave results which did not correlate with obvious known differences in size classes. This technique would indicate approximately 13 instar stages or growth pushes, which is improbable for chironomid larvae. Fig. 2 is the cumulative graph that indicates that there are six growth pushes or instar classes. However, when a five class length gliding mean is

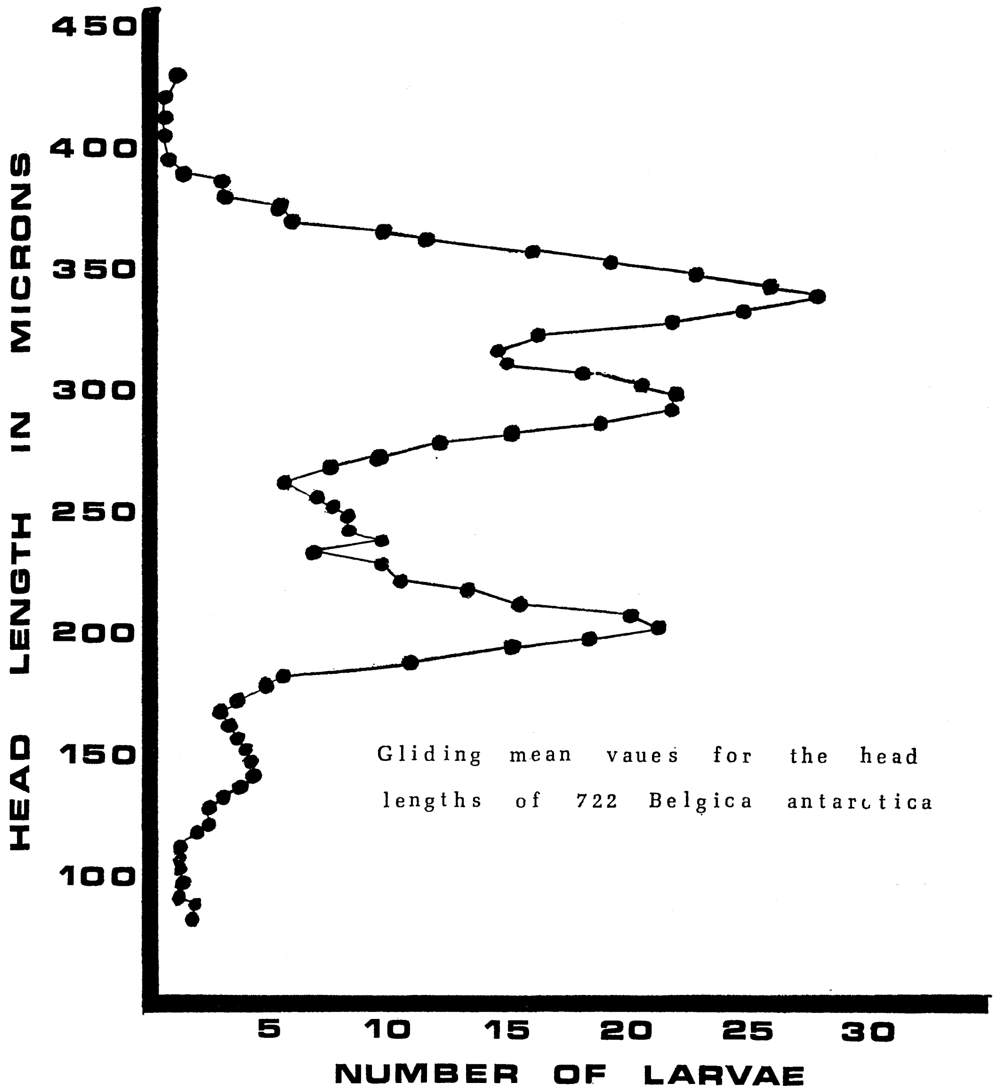

Fig. 3. Gliding mean values for head lengths.

applied to these data (Fig. 3) class number four appears as an abberation. This may decrease the number of growth pushes to five instead of six.

With the above mentioned reservations it appears that there are six instar stages to the development of *Belgica* larvae. These stages are represented by the following head capsule lengths.

Stage 1: 80 to 115 microns
Stage 2: 120 to 180 microns
Stage 3: 185 to 250 microns
Stage 4: 250 to 275 microns
Stage 5: 280 to 330 microns
Stage 6: 330 to 450 microns

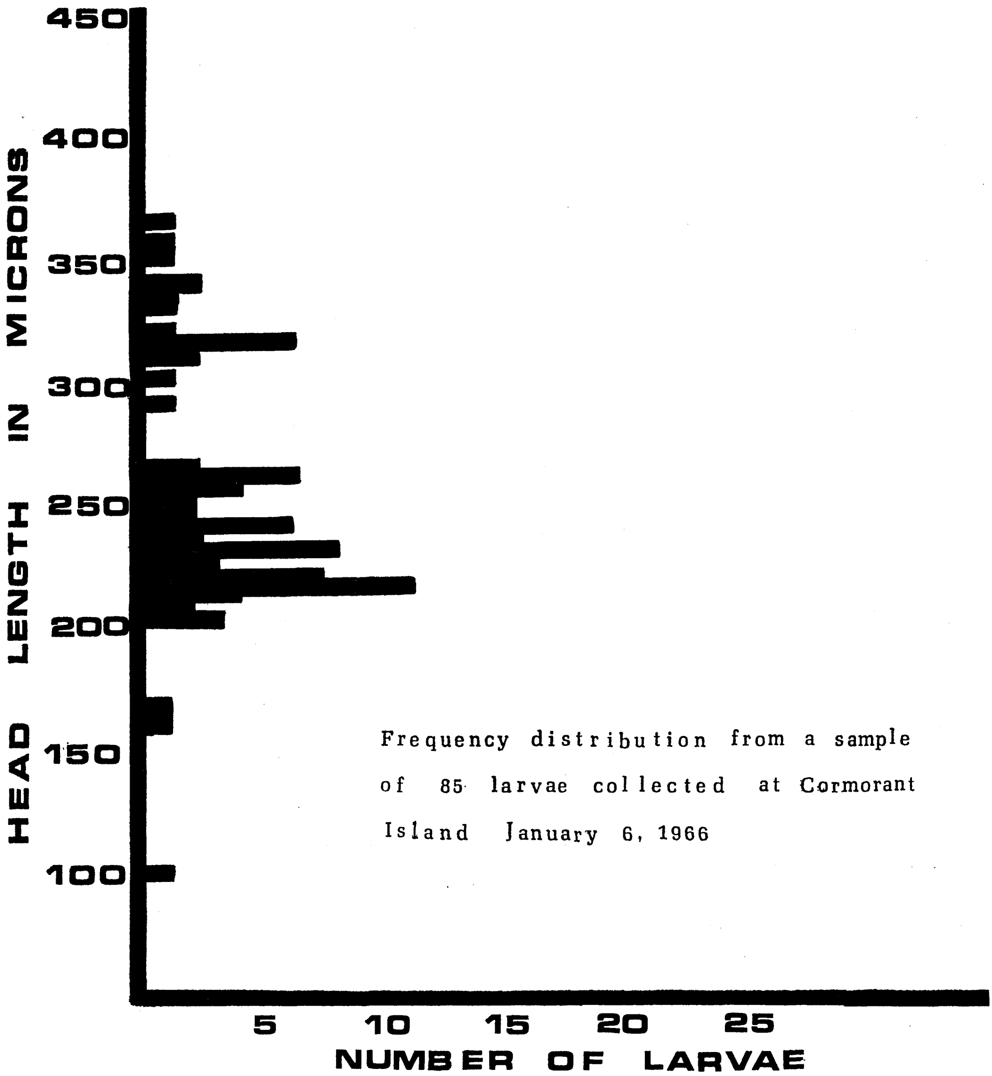

Fig. 4. Head lengths, Cormorant Island.

Fig. 4–10 are frequency distributions for various samples collected around Arthur Harbor. They tend to verify these distributional classes.

MATURATION RATE AND THE OCCURRENCE OF SIZE DOMINANT CLASSES

The greatest portion of the life cycle of *Belgica antarctica* is occupied by the developing larva. The larva matures during the periods of temperature maxima in the habitat, and while mean temperatures for a general area give a general pattern for an area's climatic picture, it ap-

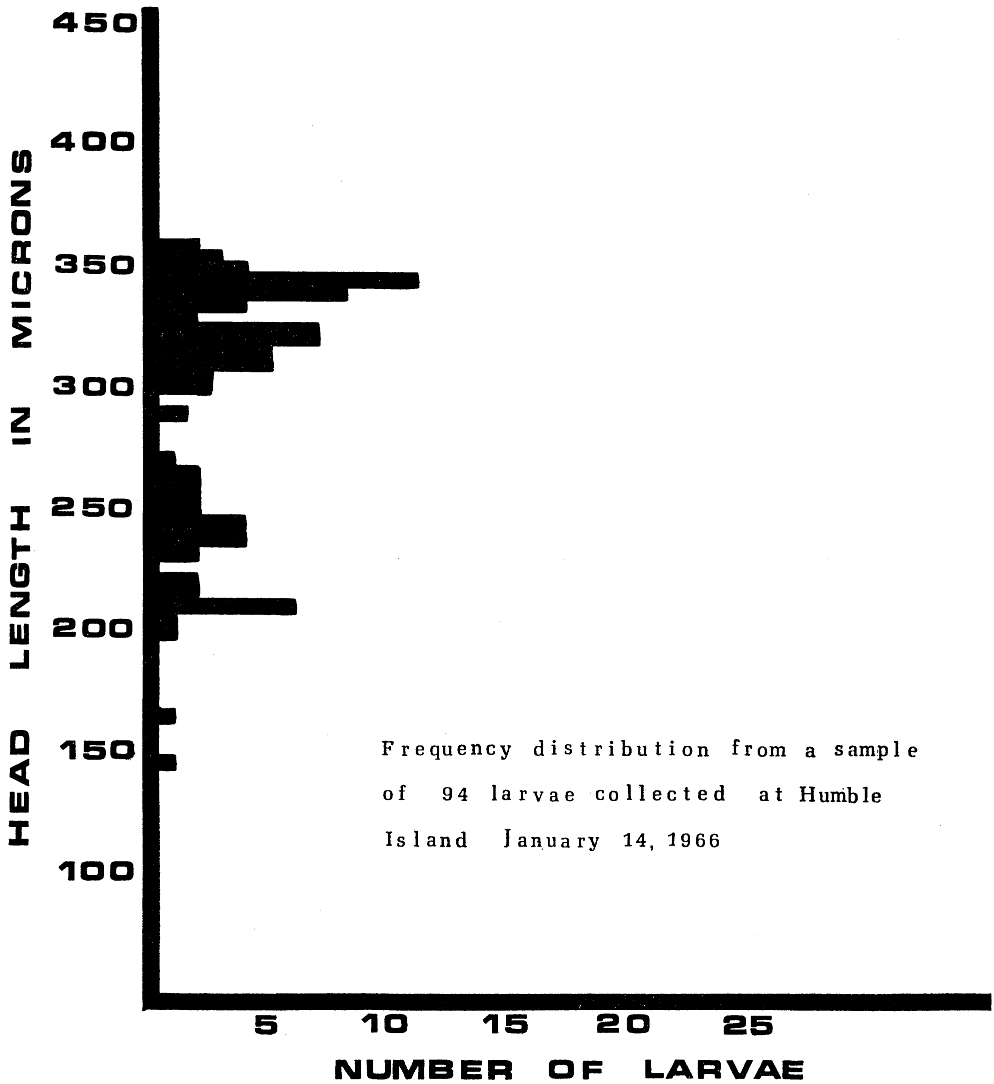

Fig. 5. Head lengths, Humble Island.

pears that it is the maximum microhabitat temperatures which have the greatest effect on the maturation of microarthropods (Llano 1962; Dalenius 1965).

Larval development rate appears as a function of time at the optimum temperature for development in a given habitat. Dormancy for *Belgica* larva begins to occur at 4°C, and the larvae appear curled and frozen at -2°C. Larvae which were collected from a sample at Bonaparte Point on 4 April 1966 were placed in a constant temperature incubator at 7°C in the field laboratory at Anvers Island. They were found to be pupating and emerging as adults on 10 May 1966. Though laboratory conditions prevented further culturing of eggs, these results do allow for the possibility that there can be more than one generation per year if

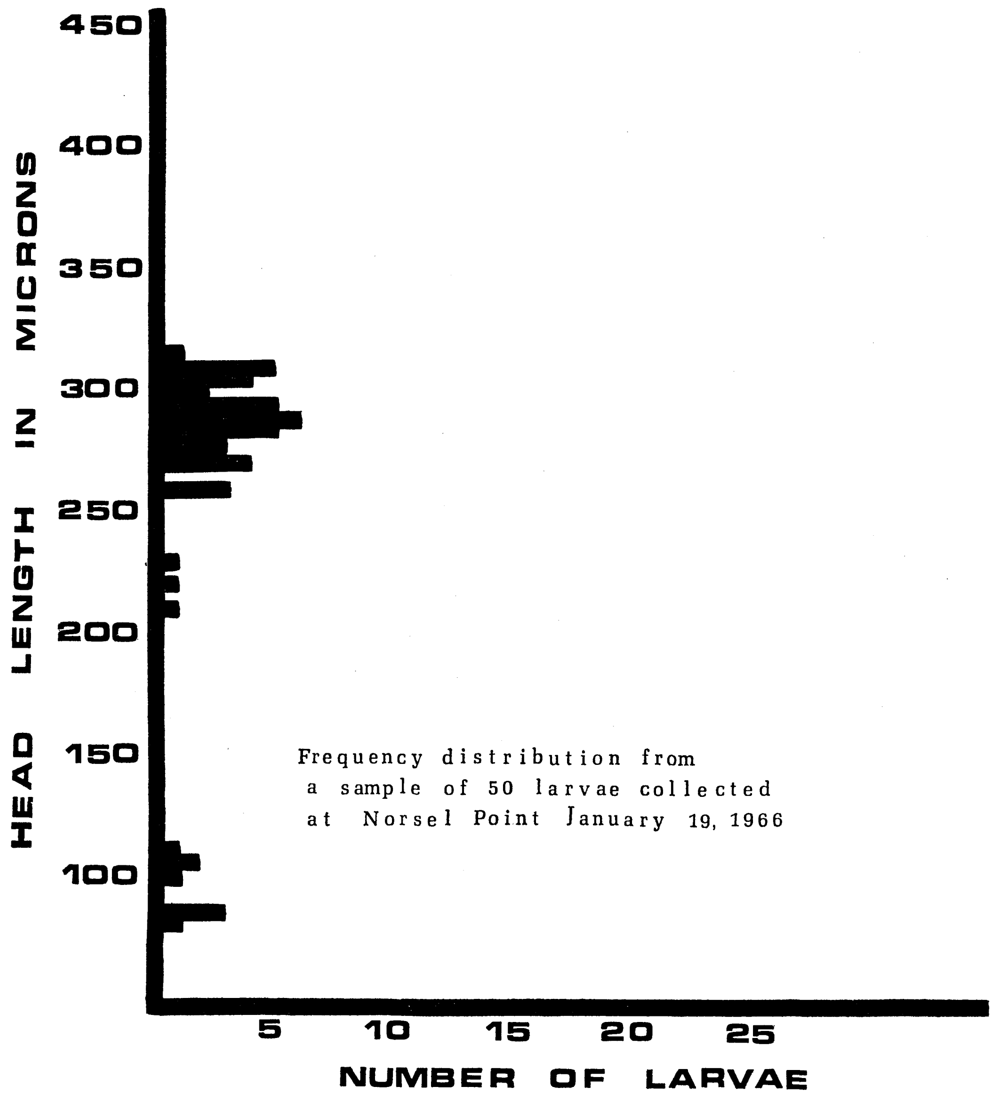

Fig. 6. Head lengths, Norsel Point.

optimum conditions exist for larval growth and development.

Irregularities in the length of larval development can often be correlated with the location of the habitat in which the larvae are found. Areas which are exposed to longer maximal microhabitat temperatures because of greater solar insolation were observed to have adults appear much earlier in the season than in other areas with less solar insolation.

Fig. 4–11 show the frequency of age dominant classes which occurred within separate samples. They indicate that there is one period where maximum reproduction occurs, but it also seems apparent that there are supplementary periods where reproduction also occurs at

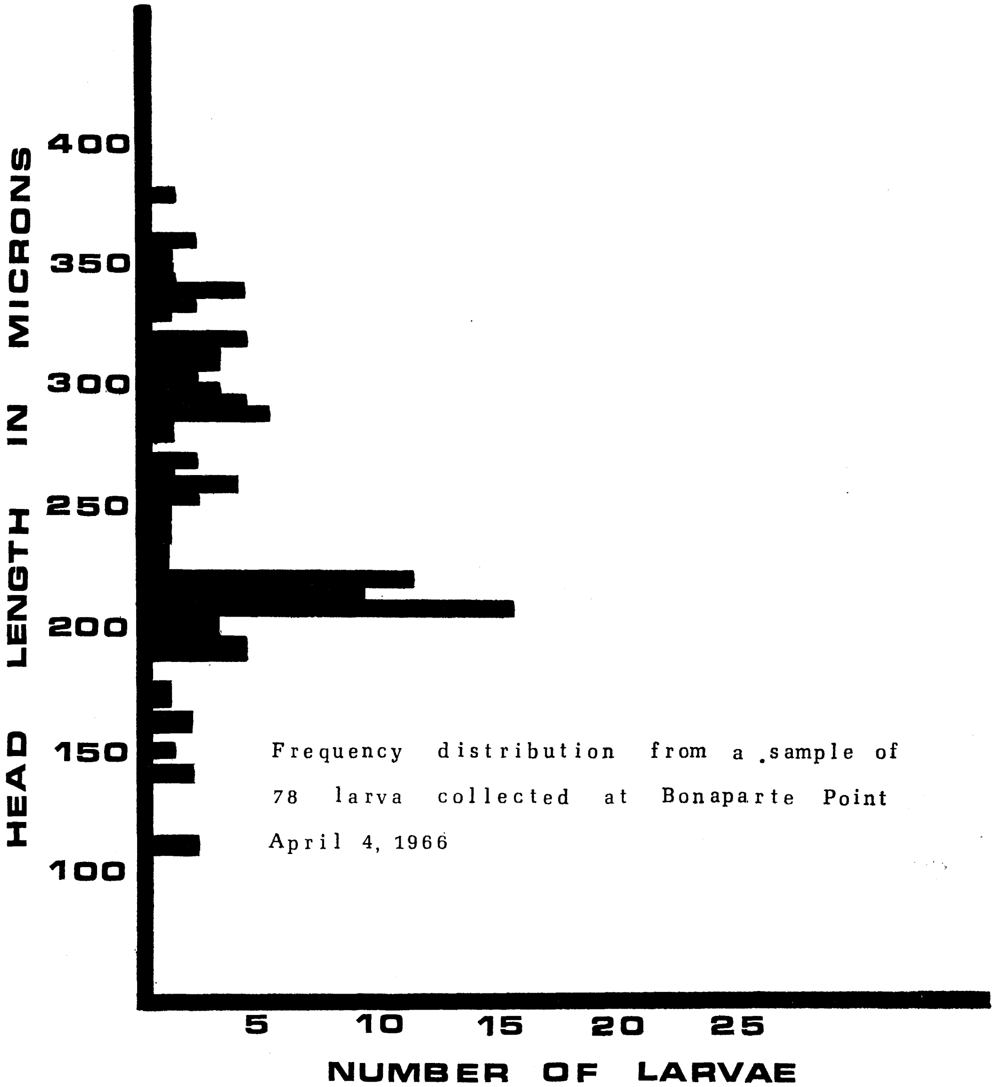

Fig. 7. Head lengths, Bonaparte Point.

lesser magnitudes. In some habitats anywhere from three to six age classes can be maturing concurrently.

The occurrence of a maximum age dominant class may provide a marker for the period of optimum conditions for maximum reproduction. In the location for the collection shown in Fig. 9, *Belgica* adults were observed as early as the middle of November, while the age dominant class at 2 December 1966 is on the verge of pupating. In contrast, Fig. 10, which was material collected from a more protected area with consequently less exposure to solar insolation shows a lag in the maturation of the age dominant classes over that ex-

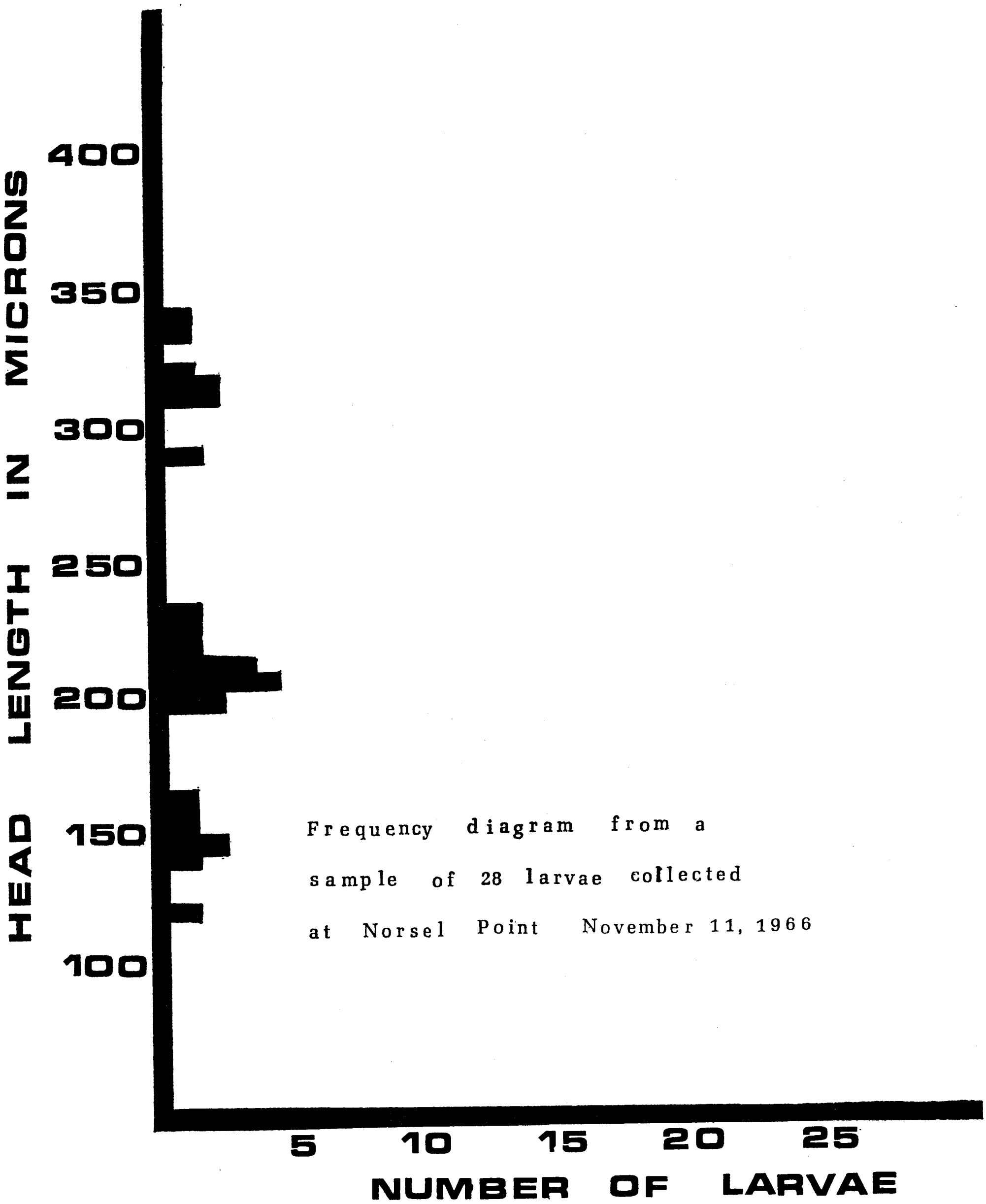

Fig. 8. Head lengths, Norsel Point.

perienced by the collection for Fig. 9.

In September the high exposed rock masses on Litchfield Island, which is located to the south of Anvers Island, had microhabitat temperature maxima during midday which were much higher than those encountered on Norsel Point because of the differences in degree of ex-

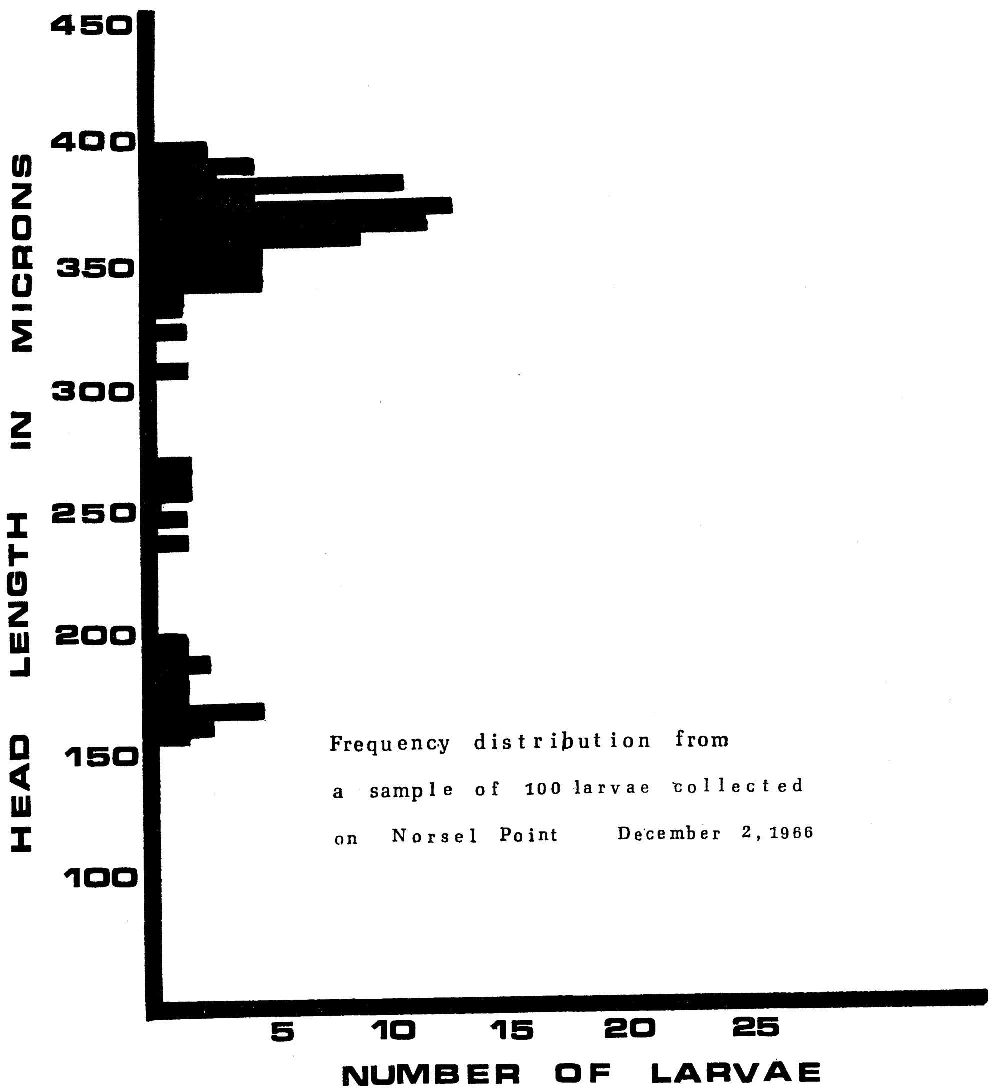

Fig. 9. Head lengths, Norsel Point.

posure to the sun's insolation. Because of the shading effect of Anvers Island on Norsel Point it was not until nearly a month later that there was the warming of the microhabitat by the sun on Norsel Point which compared in intensity and time to that which occurred in the high altitudes in September on Litchfield Island.

Every habitat varies in its optimum insolation qualities to provide support for *Belgica* larvae. It is not surprising therefore if it was found that there were more age classes per summer season occurring in the northern latitudes of *Belgica's* range.

On Norsel Point, the occurrence of *Belgica* adults varied considerably with the habitat at the onset of the summer season. Adult *Belgica* were observed on Tern Hill, a northern facing slope on

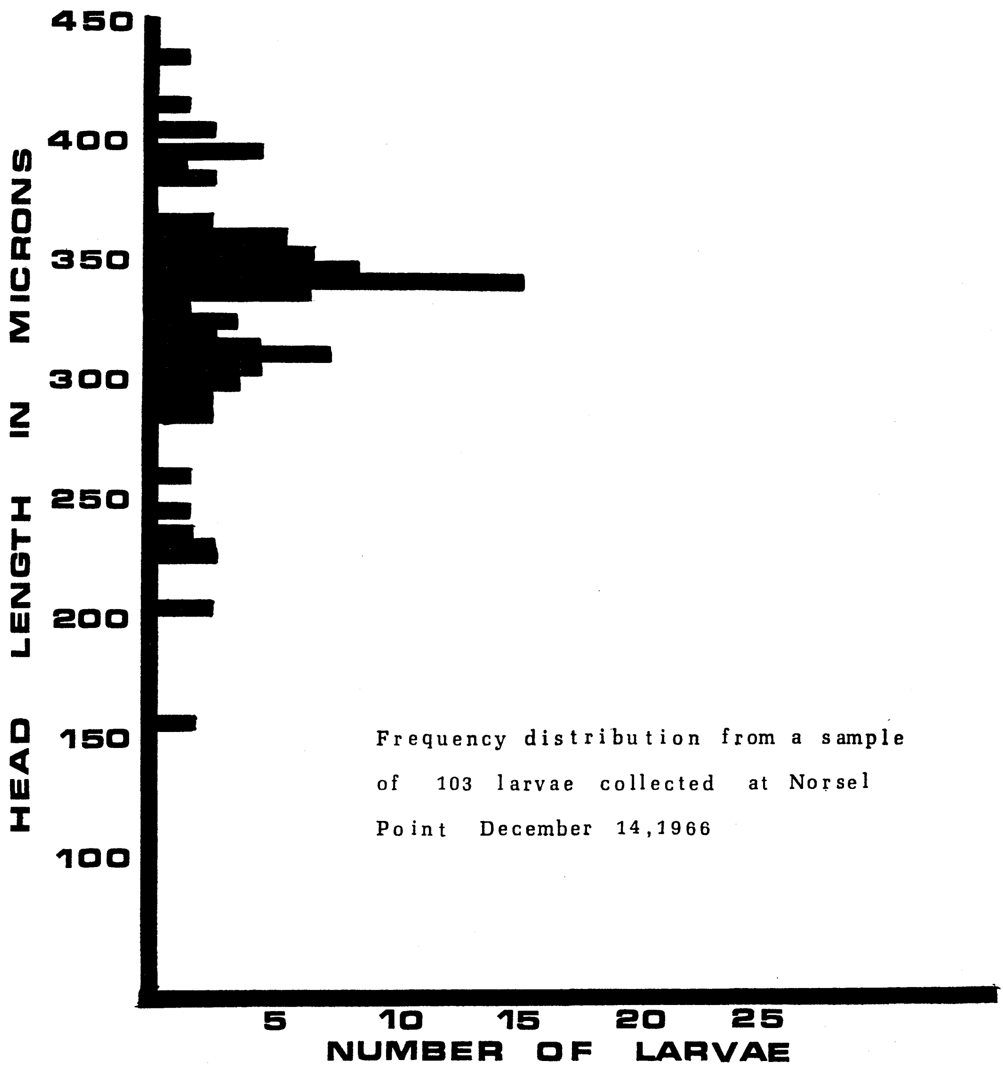

Fig. 10. Head lengths, Norsel Point.

Norsel Point in mid November. Adults occurred by 10 December in the high areas on a slope which was facing slightly to the South, and in the hollow near the Biology Laboratory, which was nearly the most protected area where the larvae could occur, adults were not observed until early January.

MOISTURE REQUIREMENTS

The weight losses of *Belgica* larvae were calculated in relation to humidity variations in order to provide an indication of the extremes in habitat humidity that *Belgica* larvae could tolerate.

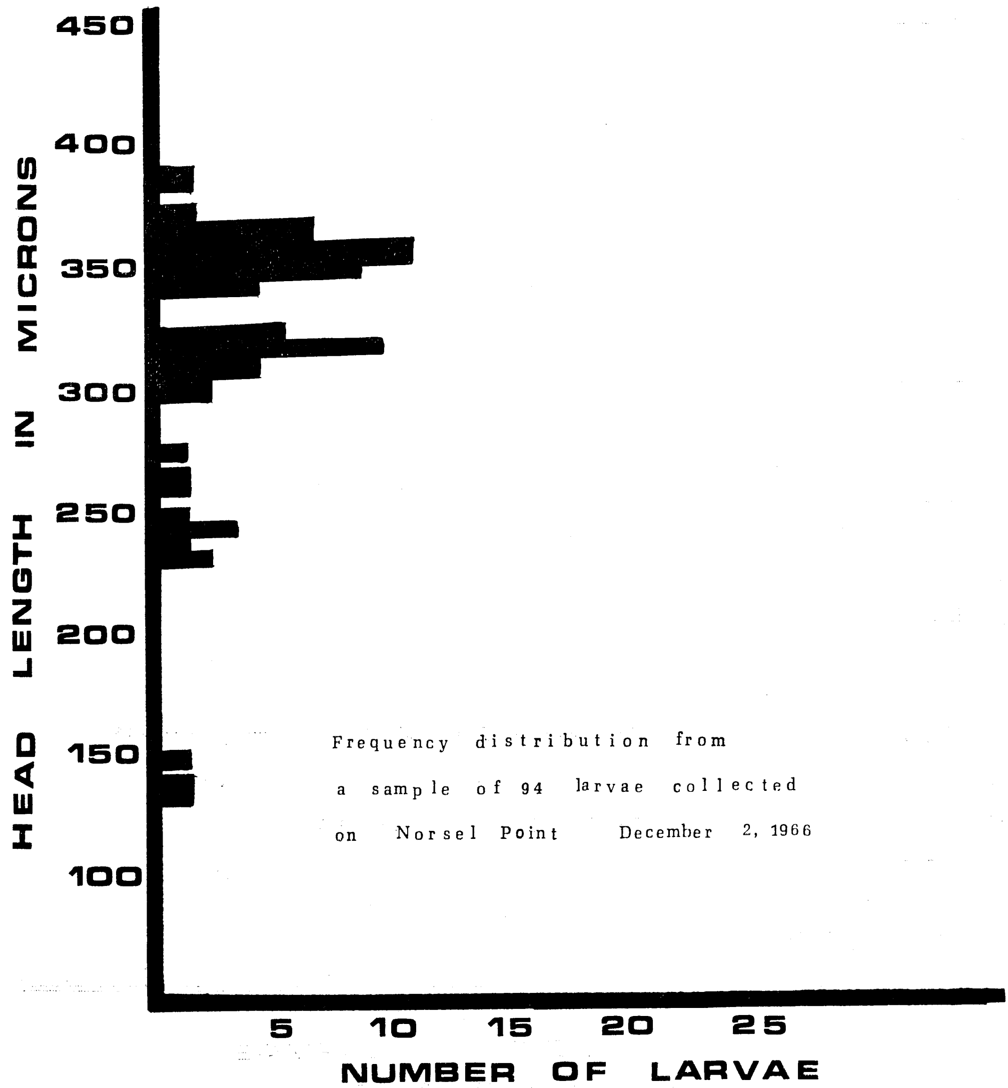

Fig. 11. Head lengths, Norsel Point.

Sealed containers containing various sulphuric acid solutions were used to control the level of humidity. Techniques described by Buxton & Mellanby (1934) and by Solomon (1945) were used to calculate standards. Small vials with the larvae were suspended over the sulphuric acid solutions. Each vial contained 20 larvae, and the vials were designed so that there could be diffusion of air to stabilize the humidity inside and outside of the vials while still preventing the larvae from escaping. At regular intervals the vials were weighed on an analytical balance, and the results were adjusted to a control.

After 37 hrs at 5°C and at approximately 90% RH there was a 12% loss of weight, while at 80% RH there was a 72% loss. At 60% RH there was a 75% weight loss and over calcium chloride crystals there was a 79% weight loss. These figures indicate the inability of *Belgica* larvae to withstand any desiccating action from environmental conditions.

It was suprising to find that the animal's behavior shows that total immersion in water is prohibitive. Larvae which are caught in small water pockets in culture dishes and which are unable to escape are often dead within a few days. In closed dishes this may be due to an increase in pH of the fluid as a result of metabolic activity. When there is a piece of filter paper both in and out of the water the larvae will crawl from the wet area to the moist area and avoid the water.

The adults are incapable of withstanding a situation such as encountered on wet filter paper. They become entangled in the paper-water interfaces and become immobile and readily succumb. In contrast to this, they are able to support themselves on the surface film of standing water, and in this situation they have been observed by Gressitt & Leech (1961), Strong (1967) and by myself. The dense aggregations of adults are possibly accidental, and surface film aggregations are common with other microarthropods such as the collembolans.

FOOD PREFERENDUM

In the laboratory larvae have been observed to feed on the alga *Prasiola crispa* with which they are commonly found associated, but not on the other common associate, the moss *Drepanocladus* sp. However, observations of the gut contents of preserved larvae have shown only the remains of moss fragments and debris. The discrepancy between these two findings may be due to the difficulty encountered in identifying the softer plant materials of *Prasiola* in the gut, or it may be that the larvae can and do eat both materials and there is a preferendum for *Prasiola* when it is available.

Both *Drepanocladus* sp. and *Prasiola* sp. were placed in a glass stacking dish. Two 1-gr. pieces of each plant were placed at equal distances from each other in the dish. The arrangement of plant material was in quadrants with the *Prasiola* located opposite the *Drepanocladus* on a piece of moist filter paper to prevent movement of larvae and adults from being directed along a humidity gradient. At the center of the dish there was the staging area where all of the animals were placed at the beginning of the experiment. The test dish was retained within a constant temperature incubator in the dark at 5°C.

After 48 hrs the following distributions were seen.

	Location	*Number of animals in position*	*Percentage*
1.	Adults on *Drepanocladus*	2	4.0%
2.	Larvae on *Drepanocladus*	2	13.3%
3.	Adults on *Prasiola*	4	8.0%
4.	Larvae on *Prasiola*	8	53.33%
5.	Dead adults found on media such as filter paper and the sides of the dish.	41	82.00%
6.	Live adults	2	4.0%
7.	Larvae under filter paper	5	33.33%
8.	Adults unaccounted	3	6.0%

In all tests where there was an attempt to limit the environment of the adult animals experimentally there has been a consistently high mortality. This may partially be due to their exceptionally short longevity. However, in open stacking dishes with more extensive and diverse culture media there was not the high mortality described above. Thus while the results in regard to the behavior of the adults in this experiment were inconclusive, the tests with the larvae indicate that over half of the sample (53.33%) settled ultimately onto the *Prasiola*. This is in marked contrast to the 13.33% found on *Drepanocladus* sp. and with the 33.33% of the larvae which were found under the filter paper.

Larvae were also placed in association with pure cultures of fungi which were raised on plates of potato dextrose agar. In all of the studies with Anvers Island fungi, *Belgica* were not observed to feed on the fungi, and on the contrary, the larvae showed a distress behavior reaction when they came in contact with the fungal cultures.

LIGHT REACTION

Belgica larvae are strongly photonegative. In a petri dish which contained moist filter paper, the larvae will actively crawl under the paper when the dish is brought into a lighted room. However, they will often be found on top of the paper in a dark incubator. Behavior experiments also show that the larvae will crawl directly away from a light source which is cooled with a water bath. Pupae also show a strong photonegative response. However, their avoidance response is not as efficient as that of the larvae.

The adult animals are generally photopositive. In an extraction chamber adults were attracted to a 75 watt electric bulb. They were attracted to the light source until the area reached a temperature approaching 30°C. Up to this point there would be no negative reaction to the increase in temperature from the bulb. Photopositive reactions were also observed from colder light sources such as neon bulbs, window light, and from sources with a water cooling filter.

The differences between behavior of adults in response to a light source can be attributed to sexual differences. The greatest percentage of the adults which were attracted to the light bulb source were the active males. However, there were females which were also attracted to the light source, but they were much fewer than their known abundance in the sample involved. It may be that after copulation the females seek a more protected habitat deep within the moss and rock interstices while egg maturation begins. Males on the other hand were observed to seek and achieve copulation immediately after performing the same act a few moments earlier.

Often more than one male will be attached to a female at the same time, and occasionally two males will be attached by the genital claspers. The greatest male-female ratio seen in copulation was five males to one female. The males thus do not appear to change behavior in relation to light during the periods when they can be active on the surface of the substratum. The female *Belgica* does appear to change behavior in relation to light reaction, and this is most probably related to her sexual experience.

SEX RATIO

Gressitt (1965) mentions Leech's findings that 82% of 2,000 *Belgica* adults were males. Strong (1967) obtained similar results and expressed it as a ratio of four males to one female. A sample which I examined from Humble Island that was collected 4 January 1966 was found to consist of 55% males.

Inequalities in sexual ratios can be either a reflection of what is occurring in the natural habitat, or a result of a sampling technique which would not select randomly from the adult *Belgica* population. Since behavior differences can be correlated with sexual differences, a sampling technique which does not account for this behavior variation would then produce erroneous results.

The number of females in any one habitat would be a function of time after the class that they were in had pupated. At any given time the percent of females impregnated would be different, and thus the available number of females in exposed positions would change independently of the number of males found in exposed positions.

Collecting adults in the field, including extraction of adults from soil samples, is an unsatisfactory technique for determining sex ratios. It is felt that the most acceptable method for determining sexual ratios in *Belgica* is to obtain adults from collected larvae which are incubated in a laboratory.

LOCAL DISPERSION

Dispersion in *Belgica* appears passive and is reduced by the behavior of the adult animals. The apterous condition of *Belgica* adults and the occurrence of two inversion polymorphisms indicate selection toward reduced dispersion and population stability (Martin 1962, Downes 1965). *Belgica* adults will perform a holding behavior when blown upon or otherwise confronted with a sudden rush of wind while the desiccating effect of continuous wind forces them to seek out lower and moister strata of the moss habitat.

Many of the dense aggregations of *Belgica* were found in areas where the wind had blown debris into a hollow, and these areas were rich in guano, penguin feathers, and fragments of moss or other plant materials. Often during strong wind storms in the vicinity of Anvers Island moss fragments, grass fragments, feather material and even the denser fragments of limpet shells are blown considerable distances. *Belgica* adults and larvae which are associated with these materials would thus be carried and distributed in a random manner across barriers of ice and water.

At Arthur Harbor some of the birds also may effect local dispersion by the transport of living and dead plant materials to nest sites. This was first observed when the Dominican gull *Larus dominicanus* was observed to drop a clump of the grass *Deschampsia antarctica* onto an ice field when it accidently came in contact with an aggressive South polar skua.

I was able to examine this clump of grass, and noticed that though it did not contain any *Belgica*, it did contain other microarthropods. Since *Belgica* larvae had been extracted in clumps of grass of this sort, there is a high probability that local birds could carry quantities of larvae large enough to establish populations into areas that are biologically modified by the nesting birds. Other birds which were observed at Arthur Harbor to be carrying debris were the South polar skua, *Catharacta skua;* the Blue-eyed shag, *Phalacrocorax atriceps;* the Sheathbill, *Chionis alba;* and the Antarctic tern, *Sterna vittata*.

Dispersion of this sort would then allow the more passive larvae protection from atmospheric desiccation, since they are enclosed within the moisture buffering plant debris.

TEMPERATURE TOLERANCE

The generalized response of *Belgica* to temperature is similar to that mentioned for chironomids which have been studied in the Arctic (Downes 1965).

Belgica larvae are able to seek out temperature preferenda to temperatures of 1.0°C. At 0°C to −2.0°C the larvae curl and become dormant. They are able, however, to rapidly recover into an active state when the temperature rises above 1.0 °C. The larvae are able to continue feeding activities to approximately 25–27 °C, and at higher temperatures they are able to actively seek out cooler temperatures. Their activity increases steadily with a rise in temperature until at 40 °C they are unable to detect temperature gradients. They will vigorously twist and turn in one spot, and will be increasingly less capable of any horizontal movement until temperatures of 50–55 °C. Immobility occurs at approximately 58 °C.

The adult animals are less tolerant of temperature variation. They remain more or less dormant to 5 °C, from whence they move about in a normal attitude to temperatures approaching 18 °C. At 21 °C the adults become extremely active and perform in a frenzied manner similar to that observed in mating behavior. These activities will continue to approximately 31 °C. Temperatures to 40 °C will show the adults entering into muscle spasms, with controlled and coordinated movement decreasing with a rise in temperature. Often spasmodic movement of the legs may result in an animal turning ventral surface up, and being incapable of righting itself. Between 40 °C and 50 °C the adults become immobile.

Adults have been observed in copulation from temperatures ranging from approximately 8° to 25 °C in the field.

DISCUSSION

Belgica antarctica possesses many behavioral and physiological characteristics which enable it to function successfully in the coastal areas of the Maritime Antarctic. Like chironomids found in the high Arctic (Downes 1965), *Belgica* does not have the ability to supercool like the more evolved insects found in the Arctic. There appears to be little control through diapause or glycerol buildup to dampen the effect of environmental temperature depressions.

Both the larvae and the adult react to temperature fluctuations in an opportunistic manner. Activity occurs when the temperature rises above freezing, and activity ceases just below freezing. A slight warming will quickly thaw larvae which will immediately begin feeding activities. This occurs even after a long period of freezing.

The adult animals are melanic and they can be found "basking" on the surface of rocks and moss when the general temperature is low but when there is direct exposure to the sun. The amount of direct solar insolation to a given location appears more important to the success of *Belgica* in a given habitat than the mean air temperature. Areas where there is physical shading from the sun, or with other degrees of lessened exposure to the direct rays of the sun will show fewer *Belgica* and often later emergence as adult animals.

The growing season may last for over five months at Anvers Island, though it is marked by a high degree of unpredictability between day to day and hour to hour temperature fluctuations. Tempeıature during this period is buffered by the nearby open water, while direct solar insolation raises microhabitat temperatures over that produced by general climatic forces. Clouds have the general effect of reducing day time microhabitat temperature by blocking direct insolation.

Local topography such as high mountain ridges and catabatic wind channels cause dramatic weather changes within a short geographical range. The cloud cover at Palmer Station during 1966 occurred for nearly one third of a year longer than at the Argentine Islands which are located some 60 km to the south. At Cape Monaco on Anvers Island, there was cloud cover for nearly twice as much of the time as at Palmer Station. The percentage of cloud cover for the season affects the life cycle of *Belgica* by limiting high microhabitat temperatures and thus reducing the growing season in relation to areas which are less dominated by locally formed clouds.

The high degree of adaptability to climatic change enables *Belgica* to react to its environment in such a way that it is able to utilize every opportunity available to grow and reproduce. Possibilities of dispersal, on the contrary, appear to be accidental, and the adults have behavior reactions which reduce the chance of accidentally shifting localities.

Intraspecific pressures appear at a minimum. Predation may occur on the larvae and eggs by the mites *Rhagidia* and *Cyrtolaelaps*, while the opportunistic feeding bird *Chionis alba* may feed upon aggregations of the maggots if by chance they are encountered. There is apparently little competition for food although there is a cryptostigmatic mite, *Alaskozetes antarcticus*, which is frequently found in association with *Belgica*. The relative importance of these pressures is not clearly understood, for *Belgica* is frequently found in association with these animals but also frequently not so.

It is not surprising that *Belgica* reacts in a specialized way to environmental conditions, while it shows only generalized reactions to other animals and to food sources. The selection pressures seem similar to those of the subarctic flies which occur on the off-shore islets of Finland (Downes 1965) where there is an increased tendency toward polyploidy, heterozygosity, and ultimately parthenogenesis.

In *Belgica* the risks of mating are reduced by the elimination of the flying swarm, and sexual reproduction occurs on the surface of the ground. Large aggregations occur at one time in space and this increases the potential for varied contact between males and females. It is interesting therefore, that frenzied sexual activity can be correlated with temperature maxima, and that age dominant classes occur in the larval population structure.

Populations in the cooler microhabitats may have a life cycle that lasts for more than one year, while populations that are in more favorable microhabitats may have two or three generations occurring during a year. This situation may provide the opportunity for both increased mutation and recombination and for genetic change in a species that is in an area that is both capricious and cold in environmental favors.

REFERENCES

Boyd, W. L., J. T. Staley & J. W. Boyd. 1966. Ecology of soil microorganisms of Antarctica. *In* J. C. F. Tedrow, Ed. Antarctic soils and soil forming processes. Antarctic Res. Ser. **6:** 129–59.

Buxton, P. A. & K. Mellanby. 1934. The measurement and control of humidity. *Bull. Ent. Res.* **25:** 171–75.

Campbell, I. B. & G. G. C. Claridge. 1966. A sequence of soils from a penguin rookery, Inexpressible Island, Antarctica. *New Zealand J. Sci.* **9**(2): 361–72.

Dalenius, P. 1965. The acarology of the Antarctic regions, *In* Van Oye & Van Mieghem (Eds) Biogeography and Ecology in Antarctica. The Hague. 414–30.

Downes, J. A. 1965. Adaptations of insects in the Arctic. *Ann. Rev. Ent.* **10:** 257–74.

Gressitt, J. L. 1964. Ecology and biogeography of land arthropods in Antarctica. *In* Carrick et al. (Eds) Biologie Antarctique, SCAR Symposium, Paris, 211–22.

1965a. Biogeography and ecology of land arthropods of Antarctica. *In* Van Oye & Van Mieghem (Eds) Biogeography and Ecology in Antarctica. The Hague, 431–90.

1965b. Terrestrial animals. *In* Hatherton (Ed.) Antarctica. Methuen London, 351–71.

1967. Notes on arthropod populations in the Antarctic Peninsula-South Shetland Islands-South Orkney Islands area. Antarctic Res. Ser. **10:** 373–91.

Gressitt, J. L. & R. E. Leech. 1961. Insect habitats in Antarctica. *Polar Record* **10**(68) May: 501–4.

Holdgate, M. W. 1964. Terrestrial ecology in the Maritime Antarctic. *In* Carrick, et al. (Eds) Biologie Antarctique, SCAR Symposium, Paris, 181–94.

Jacobs, J. Ch. 1900. Diagnoses d'insectes recueillis par l'expedition antarctique Belge (parte chironomidae). *Ann. Soc. Ent. Belg.* **44:** 107–8.

Janetschek, H. 1968. Growth and maturity of the springtail, *Gomphiocephalus hodgsoni* Carp. from South Victoria Land and Ross Island. Antarctic Res. Ser. **10:** 295–305.

Llano, G. A. 1962. The terrestrial life of the Antarctic. *Sci. Amer.* **207**(3): 212–30.

Martin, J. 1962. Inversion polymorphism in an Antarctic species living in a simple environment. *Amer. Nat.* **96:** 317–18.

Salt, R. W. 1961. Principles of insect cold-hardiness. *Ann. Rev. Ent.* **6:** 55–71.

Solomon, M. E. 1945. The use of cobalt salts as indicators of humidity and moisture. *Ann. Appl. Biol.* **32:** 75–85.

Spain, A. V. 1970. Aspects of soil conditions and arthropod distribution in Antarctica. *Pacif. Ins. Monogr.* **25:** 21–26.

Strong, J. 1967. Ecology of terrestrial arthropods at Palmer Station, Antarctic Peninsula. Antarctic Res. Ser. **10:** 357–71.

Tilbrook, P. J. 1967. Arthropod ecology in the maritime Antarctic. Antarctic Res. Ser. **10:** 331–56.

Torres, B. A. 1953. Sobre la existencia del Tendipedido, *Belgica antarctica* Jacobs en Archipielago Melchior. *Mus. Ciudad Eva Peron, Ann.* (n.s.) Buenos Aires, Zool. **1:** 1–22.

Williams, C. B. 1913. The Berlese funnel. *Entomologist* **46:** 273–74.

Wirth, W. W. & J. L. Gressitt. 1967. Diptera: Chironomidae. Antarctic Res. Ser. **10:** 197–203.