On Populations in Antarctic Meltwater Pools

CHARLES W. THOMAS[1]

ABSTRACT: In meltwater pools of the Clark Peninsula area of Antarctica fresh water biota spend most of the year frozen into the ice or in underlying sediments.

In the absence of dynamic pressure (as is the case in pools), ice exerts no pressure on organisms.

Survival of organisms appears to be a function of their ability to dehydrate or encyst.

Brachionus and cosmopolitan forms have been introduced into Antarctica. The most likely agency of transport is skua gulls.

WATER SAMPLES taken from 12 meltwater pools on the Knox Coast, Wilkes Land, Antarctica show that the majority of them support myriads of animalcules. This is remarkable because these organisms spend most of the year frozen into solid ice or bottom sediments and in the absence of light. We will discuss here reasons for survival, freedom from ice-crushing, and means by which biota may have been introduced into Antarctica.

The collection of specimens and data for this study was made on Clark Peninsula and on an unnamed islet one mile northeast thereof, (66°18′S). This area on the Knox Coast of Wilkes Land has been described in some detail by Hollin and Cameron (1961). Collecting was done during the construction of a permanent scientific base on Clark Peninsula, January 27 to February 11, 1957.

Clark Peninsula, which is generally ice-free, is a headland about 5 km long and with a maximum width of 4 km. A snow field covers approximately 30% of the land area. The south end of the peninsula is overridden by inland ice which terminates in a moraine. At the time of pool sampling, ablation of the snow field had begun.

Twelve pools were sampled at the height of the antarctic summer. These had probably been ice-free less than two weeks.[2] Since freezing began in late February the pools, in 1957, were ice-free less than two months. Hollin and Cameron (supra cit.) indicate that the summer of 1957 was milder than average and that hardly any melting was apparent in February, 1959.

Descriptive information concerning the pools is shown in Table 1.

METHOD OF STUDY

Samples were collected from the pools by immersing quart jars near the bottom and allowing them to fill. Specimens for microscopic examination were meted into a watch glass or onto slides. After about 1 cc of sampled water from each pool was examined, the water was filtered through a plankton well and the concentrate preserved in 70% alcohol for further study and more positive identification of organisms. The water was then tested for salinity with a Digby and Bigg Ionic meter.

Organisms which could be identified are listed in Table 2. It is difficult to establish a criterion by which abundance of organisms may be indicated in such a heterogeneous population. A common numerical abundance of large forms might mean a paucity of small ones. Hence, the terms "abundant," "common," "few," and "rare" are relative rather than absolute.

[1] Museum of Comparative Zoology, Harvard College, Cambridge, Massachusetts. Present address: Hawaii Institute of Geophysics, University of Hawaii, Honolulu. Manuscript received April 13, 1964.

[2] Temperatures may be generally above freezing in January, but the insulating effect of snow-cover and sublimation delays thawing until ablation occurs.

The inventory in Table 2 is not complete. Many specimens were damaged beyond identification by violent churning during the rough voyage from Antarctica to Australia. This damage was probably aggravated by inadequate preservation.

DISCUSSION

While no observations were made of ice thickness in the pools considered here, John T. Hollin (personal correspondence) says the ice must have been at least 30 cm thick in the autumn and 100 cm thick in the winter, and that vehicles were freely driven across the pools. The present author, moreover, observed a pool approximately 30 cm deep frozen solid on March 5, 1956 at Ross Island (78°S). According to List (1951), about 0.98 lys. min^{-1} of solar radiation would have reached that position at the time. The same amount of energy is available to Clark Peninsula on April 1. Hollin (op. cit.) reports the pools are wind-swept with about 3 cm of fresh snow overlying several centimeters of sublimation. While the latter is quite significant, the snow-cover alone completely insulates the ice[3] and all organisms must have been frozen either into the ice or in underlying sediments before mid-April.

Hollin (op. cit.) accounts for salinity in the pools by heavy Quaternary glaciation of Clark Peninsula. After retreat of the ice the land was uplifted 30 m and, since the pools lie at a lower elevation, they were formerly pools of sea water.

[3] The albedo being ca. 72% only about .0081 lys. min^{-1} could penetrate 3 cm of fresh snow (Thomas, 1963).

TABLE 1

LOCATION AND DESCRIPTION OF POOLS FROM WHICH SAMPLES WERE TAKEN IN THE CLARK PENINSULA AREA OF WILKES LAND, ANTARCTICA, JANUARY AND FEBRUARY, 1957

POOL NO.	LOCATION	ELEVATION (ABOVE MLW) m	APPROX. AREA m^2	APPROX. DEPTH cm	SALINITY ‰
1	Wilkes Station, near meteorology building	7	140	30	1.6
2	Wilkes Station, water supply	14	340	45	0.8
3	North central side of Clark Peninsula	3	170	40	6.6
4	Northeast central side of unnamed islet	3	900	40	3.5
5	Northeast central shore of Clark Peninsula, in a creek	2.5	10	25	10.2
6	Northeast central shore of Clark Peninsula, mouth of a creek	1.5	1,000	100	24.3
7	Wilkes Station, rocky ledge above meteorology building	9	19	35	5.0
8	Clark Peninsula, 2 km southeast of station, in a creek	4	280	30	4.8
9	Pot-hole on northeast side of Clark Peninsula, near penguin rookery	12	12	30	0.6
10	Northeast side of Clark Peninsula, in a penguin rookery	3	9	20	11.2
11	Pot-hole on northeast side of Clark Peninsula, in a penguin rookery	10	4	35	0.9
12	East corner of Clark Peninsula, near lagoon	3	12	25	14.8

He believes there is a marked stratification of salinity due to meltwater in the upper layers. The present author observed that nearly all pools are subject to contamination in some degree by spray when sea ice is absent. Pool 6 (S ‰ 24.3) is periodically invaded by sea water. Pools 2, 9, and 11 are continually flushed during ablation of the snow field. The presence of fresh water forms in pool 6 may be accounted for by stratification, in which meltwater occupies the upper layers, and by migration of biota from a higher pool.

That lower forms of life can be frozen into ice and revived upon thawing has been observed by several authors. Kapterev (1936) found that *Cyclops* and *Planorbis* survive after being thawed out of shallow pools near the Amur River. He observed 20 genera of extant algae and a crustacean revived after being thawed from permafrost, in which he estimates they might have been frozen a thousand years. Luyet and Gehenio (1940) include tardigrades, rotifers, paramecia, euglenids, amoebae, and diatoms with organisms which survive extreme cold.

The present author obtained, simultaneously, three samples from a pool in Massachusetts, the surface of which was frozen. One sample was not frozen. A second was frozen solid under natural conditions for a week. The third was frozen into solid ice in less than two hours and maintained at –15° C in total darkness for a month. When the two frozen samples were thawed no mortality was apparent. The following organisms were found in the three samples: *Rhizoclonium cladophora, Melosira variens, Fragilaria* sp., *Tabellaria* sp., *Navicula* sp. A and B, *Rophaloidia* sp., *Amphora* sp., *Epithemia* sp., *Chilamonas paramecium, Urostyla* sp., *Tintinnopsis* sp., *Paramecium* sp., *Chaetogaster* sp., Bdelloid rotifers (four genera).

According to Scholander et al. (1955) a great many aquatic plants and animals (including *Daphnia*) spend the winter frozen into the ice of lakes and pools in the Arctic. Similar observations have been made by others.

Luyet and Gehenio (supra cit.) examined causes of death of organisms due to freezing as postulated by several authors. They conclude, "How enormous hydrostatic pressures have no action on protoplasm while pricking on a glass needle may, in some instances, start coagulation is entirely unknown." In the nineteenth century, bursting of cells by ice formation was widely believed to cause death.

According to Plateau (1872), ". . . it is a known physical principle that the cavities in a solid body expand like the body itself. Therefore, the cell contents cannot be crushed by freezing." He illustrated this observation with an apparatus consisting of a glass tube on the end of which was a rubber bulb filled with a liquid, and immersed vertically, the open end up, in a flask containing water. When the latter froze in the flask, the leevl of the fluid in the tube remained unchanged. This indicated that no pressure was exerted on the rubber bulb. Luyet and Gehenio take issue with Plateau on the grounds that (according to them) the results of his experiment disagreed with the principle he sought to invoke. "He should have observed a lowering of the level of the fluid in the manometric tube if the cavity around the tube were expanding."

But Plateau was right. Ice seamen are familiar with this principle. A thin-skinned ship may be frozen into static ice without damage (Dieck, 1885). For several years, the gasoline tankers (YOGs) were frozen annually into the ice in Arrival Bay, Antarctica. While the cavity created by the ship expands, new ice forms at the same rate between the ice-body and the vessel's hull. Hence, an animal frozen into ice becomes an integral part of the system without being subject to pressure.

The experiments of Scholander et al. (supra cit.) and of Kanwisher (1955) show that resistance to cellular freezing runs parallel with the ability of an organism to withstand dehydration. From the observations of Becquerel (1936) it appears that, in general, the lower forms enjoy this ability to a greater extent than do the higher ones.

The rotifers and some other animals in Table 2 were identified by Dr. C. R. Russell of Canterbury University, Christchurch, New Zealand. He says (personal correspondence) the rotifers *Brachionus quadridentatus* and *B. calcyciflorus* are generally found in temperate waters and the lowest temperature in which these species

TABLE 2

POPULATIONS OF MELTWATER POOLS ON CLARK PENINSULA AND AN UNNAMED ISLET, ANTARCTICA

ORGANISMS	POOL NUMBER											
	1	2	3	4	5	6	7	8	9	10	11	12
FLORA												
CHLOROPHYCEAE												
Pleurococcus antarcticus W. and G.S. West					C*	C	A					C
Pleurococcus sp.			A		A	A	C	C		A		C
Prasiola sp.	A			A		A				C		
Chlamydomonas intermediata Chodat.			F	F	A					A		A
Chlamydomonas sp. A					A							C
Chlamydomonas sp. B					C							A
Pandorina sp.												C
CHRYSOPHYCEAE												
Cocconeis wiekensis Petit							C					
Cocconeis sp.					A		C	A		A		A
Cyclotella operculata Kutzing				R								
Melosira sp.					C		F					
Corethron sp.						R						
Fragillaria curta Van Heurck						R						
Navicula borealis (Ehrenberg)					A	A						
Navicula murrayi W. and G.S. West			F	R	A	A	C					A
Navicula shackeltoni W. and G.S. West			F									
Navicula stauropteroides Fritsch						R						R
Navicula seminulum Grunow					A	A						F
Nacivula sp.				R			R			F		F
Denticula tenuis Kutzing					C	R				R		F
Biddulphia sp.						R						
Uroglena sp.					C	A		C		A		A

* Abbreviations: A, abundant; C, common; F, few; R, rare.

TABLE 2 (*Continued*)

POPULATIONS OF MELTWATER POOLS ON CLARK PENINSULA AND AN UNNAMED ISLET, ANTARCTICA

ORGANISMS	POOL NUMBER											
	1	2	3	4	5	6	7	8	9	10	11	12
FLORA (*Continued*)												
CYANOPHYCEAE												
Nodularia spumigena Mertens					F*					R		
Polycistus sp.	A		A		A	A	A	A	R	A		A
Lyngbya aerouginea-caerulea (Kutzing)	A		C			C	A					
Oscillatoria sp. A	A	F	A	C	A	C		C	R		R	A
Oscillatoria sp. B	A	R		A	A	A		C	R			A
Phormidium antarcticum W. and G.S. West			C	A	A	C						A
Phormidium sp.				A	C	C						A
Schizothrix antarctica Fritsch					R					A		
Stauroneis antarctica (Gran. and Angst.)				C	A	A		C				A
Stauroneis sp.				R	A							
Nostoc longstaffi Fritsch				C	A							
Anabaena antarctica Fritsch						F						
Dactyloccopsis antarctica Fritsch					A					C		
FAUNA												
Amoeba terricola Greeff.						C	C					
Stylonychia sp.					A		C	C		C		C
?*Philodina* sp.			R	C			C					
Habrotrocha sp.				R			R					
Brachionus quadridentatus Hermann			F				F					
Brachionus calyciflorus Pallas			F	F								
Macrobiotus sp.							C					
Cyclopid copepoda				R								

* Abbreviations: A, abundant; C, common; F, few; R, rare.

have been collected in New Zealand is 10° C. As far as Dr. Russell knows this is the first time members of the genus *Brachionus* have been collected in polar waters.

The presence of *Brachionus* and other cosmopolitan genera in Antarctic assemblages raises the question of how they were introduced into the south polar region. Several means of distribution have been suggested:

1. *Continental association.* According to Kuenen (1950) there are several theories to account for the dispersal of plants and animals to (and from) Antarctica. Of these the continental drift hypothesis of Wegener (1924) appears to be the most popular. It postulates the Paleozoic existence of Gondwandaland from which, in the early Mesozoic, the continents of the southern hemisphere broke off and drifted apart. Stille (1944) and others deduce from seismic evidence that much of the area between Antarctica and Australia is a slumped continent. Hedley (1911) and his school believe in an ancient isthmian link between Australia, Antarctica, and South America. Hedley's thesis is invoked by Du Rietz (1940) and others to explain the bipolar distribution of common plants.

2. *Dispersal by the wind.* Allee et al. (1950) mention "plankton of the air" consisting of dessicated animals and plants, cysts, eggs, etc., which drift with the air currents, sometimes as high as the stratosphere. Upon falling to earth, they resume normal activity where the environment is favorable.

3. *Distribution by birds.* According to Hesse et al. (1958) water birds are transportation media for aquatic microorganisms. Not only may biota be carried externally but cysts and eggs may be eaten and excreted. Eklund (1961) says skuas were often seen to drink at freshwater ponds. According to Stead (1932), *Cataracta antarctica* (*C. skua lonnbergi*) range from New Zealand to Antarctica.

Considering the application of the foregoing agencies to Clark Peninsula pools, that of continental association can be discarded for two reasons. First, there is no fossil evidence that non-marine fish, amphibians, reptiles, or mammals were ever present in Antarctica. Second, and most cogent, the pools were submerged, in Recent time, in the sea. While distribution by the wind may play a role in dispersion of fresh-water biota, the dominant one is likely that of birds. Skua gulls are capable of transporting organisms from a pool in New Zealand to one in the Antarctic.

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