

DOES HIGH TEMPERATURE IN A FRIGID COUNTRY LIMIT DIVERSIFICATION OF THE SPECIES?

H. P. K. AGERSBORG

State Department of Conservation, Springfield.

In a warm starch-waste water ditch flowing from a corn products manufacturing plant, located in the northeastern part of Decatur, Illinois, two conditions are quite apparent:

(1) Particularly on cold days, the water in this ditch seems to be steaming. That is, the water vaporizes rapidly and on days when the temperature difference between the air and the water in the ditch is the greatest, the steaming of the warmer water of the ditch is the most extensive. This stream runs under ground for about 2,700 feet in a 60-inch concrete pipe. This empties into a concrete channel (Fig.1) about 160 feet long and 15 feet wide, having 10 baffles along the sides, 15 feet apart. The waste leaves the channel through an 18-inch slot in the center of the last baffle, having a fall of about 15 inches onto a concrete apron about 18 feet long, and then into an open ditch varying in width from 10 to 15 feet. Throughout the entire length are 24 loose concrete block-barriers over which the water falls for the purpose of cooling and aerating it before flowing into the lake. Since the ditch was constructed, erosion has taken place to a considerable extent, until it is now so wide and deep that one cannot cross it by a single jump or remain dry-shod if attempting to wade it. At its confluence with the city's reservoirs (into which it flows), a delta has been built up by the eroded elements. At this place the stream divides into two forks and flows around the delta and then joins the water of the reservoir.

(2) Upon looking closely at the water in the ditch, one notices a super-abundance of fission fungi (*Sphaerotilus natans* and related species), slime algae (*Oscillaria prolifica* and *O. limosa*) and the pond snail, *Physa gyrina* Say (Fig. 2).

Ten stations were established between the beginning of the open ditch and its confluence with the lake or reservoir. Samples of the less putrescent sludge at the top surface of the sludge were collected at different times from these places during December

(1928), January and February (1929) and microscopic study made to determine the quality and approximate quantity of organisms living in this ditch.

It was soon found that only the upper stratum of the sludge, about 2 inches deep, contained organic life (save, of course, bacteria). Neither the flora or fauna is very extensively, qualitatively differentiated. Three species, however, one animal and two plants, live in such an abundance in this ditch that all others are quite trifling, comparatively.

The fission fungus (*Sphaerotilus natans*) is present as floating, flocculent sludge, as a growth covering the entire bottom, sides of the banks, the stones or concrete blocks of the dams and on every twig or blade of grass protruding from the banks out on the water's surface, and as a decaying, black mass forming a sludge bottom, more and more septic the deeper down. The other plant is two species of slime algae, *Oscillatoria* (*Oscillaria*) *prolifca* and *O. limosa*. *O. prolifca* seems to be more primitive than *O. limosa* because it is smaller and less green. *O. limosa* gives a green tinge to the condenser water on sunny days, so numerously does it grow on the top of the sludge in the bottom of the ditch. On the sides, nearly pure cultures of this species occur in definite green patches. Mixed with *O. limosa* is *O. prolifca* which is much less green, appearing as gray masses along the water's edge of the entire ditch. But its green color and oscillating movements can be quite easily seen under the microscope.

The animal species, referred to above, is the pond snail, *Physa gyrina* Say, which occurs in countless numbers of all sizes and ages, literally covering every stone and submerged object and the bottom of the ditch, from its beginning to the lake.

It will be noticed that the flora mentioned, particularly *S. natans*, is a sewage organism; these plants live on organic wastes in solution in the condenser water; there is just enough sugar present to promote this, and, in fact, the growth of *S. natans* begins in the warm water near the plant. This is seen by the masses coming out of the concrete pipe at the beginning of the open ditch. The pond snail lives on the luxuriant growth of the slime algae and the fission fungi, noticeably on *S. natans*.

These organisms, then, present a biological feature very striking in contrast with the seemingly unfavorable physical conditions of the ditch, *e. g.*, as shown by the turbidity, musty or earthy odor, and "steaming" high temperature of the water.

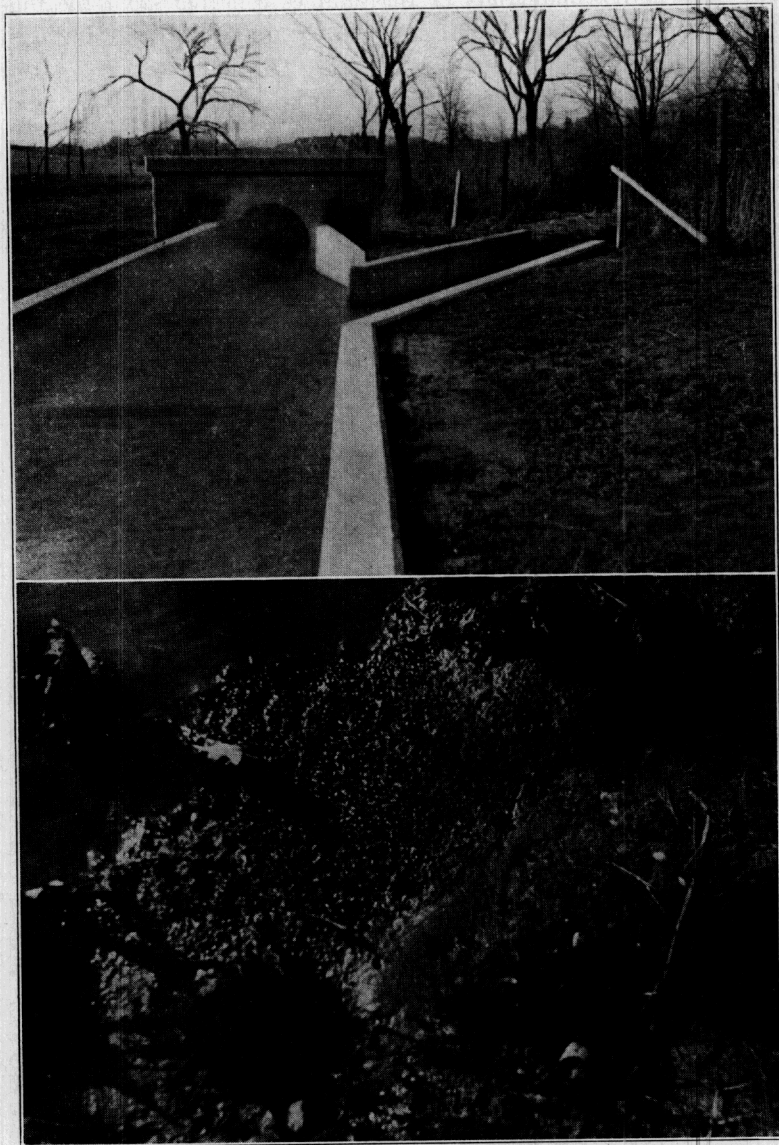


FIG. 1. (Above). Photo of the opening of the 60-inch wide concrete pipe, opening into a concrete channel. Note a baffle in the middle-foreground with a slot on the right side. Also note the side-ditch in the foreground and to the right. Station 1 is at the upper left-hand part of the stream, just below the vapor.

FIG. 2. (Below). Photo of a typical *Physa gyrina* bed. This snail lives on *Sphaerotilus natans* and *Oscillatoria prolifica*, both of which species abound in the warm condenser water.

The microscopic study of the samples collected from the top of the sludge in the bottom of the ditch at the different stations revealed the following facts:

Station A. From a side-ditch with surface water from half a mile semi-cultivated country (Figs. 3 and 4). The samples were taken beyond the fence, on both sides of the ditch. The season's temperature ranged as far as the fence. The peculiarity of this Station is the total absence of protozoa or lower metazoa. This station, however, may be characterized as belonging to the *Oligosaprobic Zone*. The bottom was composed of fine sand.

There are ten different species of algae as listed below, and the higher of these occurred in clusters along the bottom and around the border of the ditch.

Navicula viridis, Synedra ulna, N. rhynchocephalia, Pleurosigma attenuatum, Meridion constrictum, Gomphonema acumenatum, Vanheurckia rhomboides, Vaucheria repens, Ulothrix zonata, Spirogyra crassa.

Station 1. From the beginning of concrete channel (Fig. 1). The bottom covered with loose flocculent *Sphaerotilus* sludge. The temperature during the winter ranges around 35° C.

Algae	Fungi
<i>Oscillatoria prolifica</i> + + + + *	<i>Sphaerotilus natans</i> + + + +
<i>O. limosa</i> +	
Protozoa	Metazoa
None	<i>Tubifex</i> + +
	<i>Physa</i> ** +

Temp. of the air, -5° C., of the ditch, 35° C. Dissolved oxygen, 3.2 p. p. m.; 52 per cent saturation.

Station 2. This station is just below the concrete channel, at the beginning of the open ditch proper, that is, 160 feet below Station 1. The temperature at this place was usually only about two degrees lower than at Station 1.

Algae	Fungi
<i>O. prolifica</i> + + +	<i>S. natans</i> + + + +
<i>O. limosa</i> +	<i>Beggiatoa alba</i>
<i>Cymbella cuspidata</i>	
<i>Synedra ulna</i>	
<i>Brebissonia</i>	
Protozoa	Metazoa
<i>Vahlkampfia guttula</i>	<i>Physa gyrina</i> + + +
<i>V. minuta</i>	
<i>Anisonema acinus</i> +	

Temperature of the ditch 33° C. Dissolved oxygen 5.5 p. p. m.; 76.6 per cent saturation.

* The plus-sign has the following meaning: + = quite a few; + + = many; + + + = very many; and + + + + = solid masses, or a super abundance of this species. — = one or very few. ** On the opposite side of the channel, a little below the mouth of the concrete pipe, the water is 1 to 2 degrees lower in temperature and *Physa* may be seen here in quite a number. Likewise, at Station 1, proper at the mouth of the concrete pipe, this snail may be found along the upper edge of the water on the side of the concrete wall.

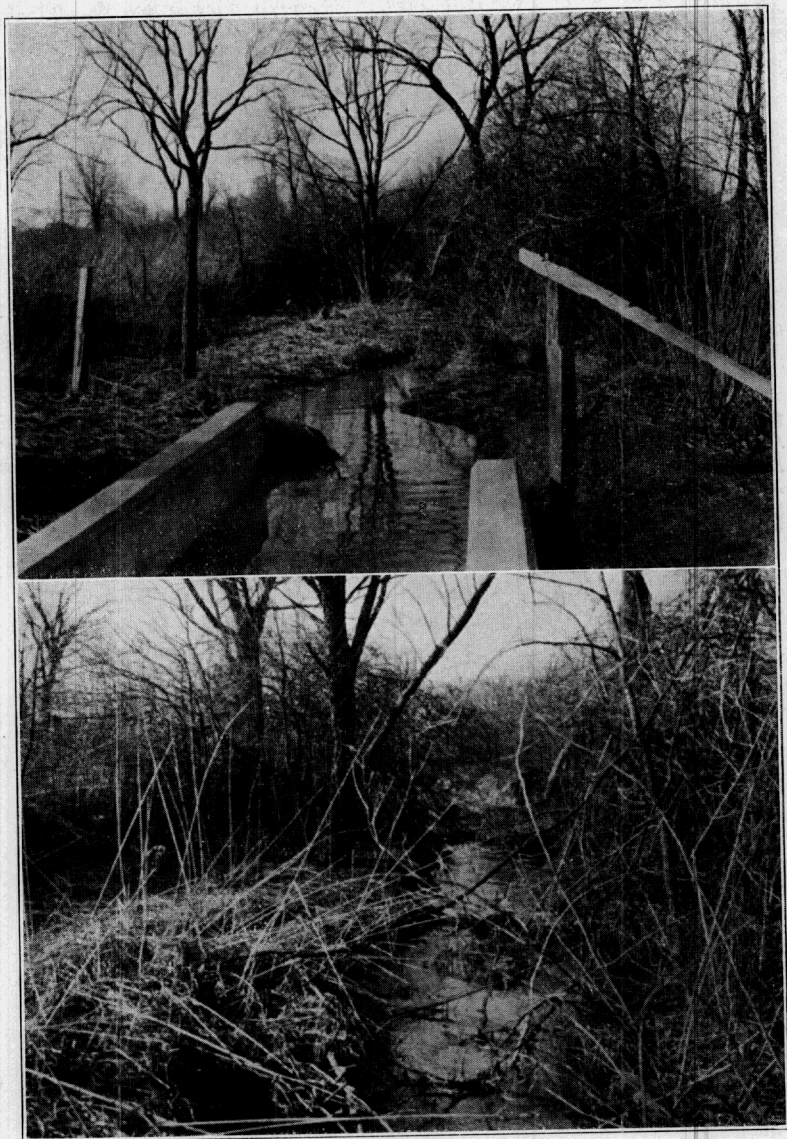


FIG. 3. (*Above*). Photo of the entrance of the side ditch seen in Fig. 1. Station A is just back of the fence.

FIG. 4. (*Below*). Photo of the wet-weather ditch from back of the fence, Station A.

Station 3. This station is just below, and opposite to, a conduit leading from the grain elevators of the manufacturing plant. It is 450 feet below Station 2. In general, the conditions are the same as at Station 1 or 2. An herd of cattle came and drank of the water from the ditch and seemed to enjoy it very much (Feb. 5, 1929). The temperature of the air was -5° C.; of the ditch, 33° C. Dissolved oxygen, 5.3 p. p. m.; 73.9 per cent saturation. There were very many snails present, and the bottom was green and gray from the growth of *Oscillatoria limosa* and *O. prolifica*, respectively.

Algae

Stauroneus anceps
Navicula gracilis
Oscillatoria prolifica + + + +
O. limosa + + +
Genicularia spirotaenia
Microcystis

Fungi

S. natans + + + +

Protozoa

Euglenoids +
Euglena acus
E. viridis
Astasia trichophora
Peranema trichophorum
Physomonas elongata
Amoeboids +
Colpoda campyla
Paramoecium caudatum
Lionotopsis anser
Colpidium striatum
Spirostimum ambiguum
Loxodes rostrum
Metopus sigmoides

Metazoa

Rotifer citrinus
Pedalion mirum
Dero limosa
Tubifex multisetosus
Physa gyrina + + + +

Station 3A. From grain elevator ditch with white bottom. The sample was taken from the white bottom (top) of the ditch. Temperature of ditch, 8° C., of the condenser water at this point, 30.5° C. The water level was lower than on January 19 and bubbles of foul air came up from the sludge.

Algae

Genicularia spirotaenia
O. prolifica
O. limosa
Mougeotia

Fungi

S. natans + + + +

Protozoa

Hartmanella + + + +
Euglena acus +
E. viridis +
Paramoecium bursaria
P. caudatum
Spirostimum ambiguum +
Colpoda campyla
Colpidium striatum
Trichoda pura
Loxophyllum ornatum
Oxytricha trichogaster

Metazoa

Planaria
Nematode
Rotifer citrinus
Tubifex
Physa gyrina + + + +

Station 4. 650 feet below Station 2. Water more turbid than earlier in the morning. Temperature 32.5° C. *Physa* and *Sphaerotilus* in super-abundance. Both species of *Oscillatoria* are also thick. D. O. 5.4 p. p. m.; 74.6 per cent Sat.

Algae	Fungi
<i>O. limosa</i> ++	<i>S. natans</i> + + + +
<i>O. prolifica</i>	
Protozoa	Metazoa
<i>Hartmanella</i> + + +	<i>Physa gyrina</i> + + + +
<i>Diffugia</i> +	
<i>Euglena</i>	

Station 5. *S. natans* and *Physa gyrina* abound. Temp. 32° C. D. O. 5.7 p. p. m.; 77.8 per cent Sat.

Algae	Fungi
<i>O. prolifica</i> + + + +	<i>Physa gyrina</i> + + + +
<i>O. limosa</i> ++	
Protozoa	Metazoa
<i>Physomonas elongata</i> +	<i>Physa gyrina</i> + + + +
<i>P. caudatum</i> +	
<i>Colpidium striatum</i> +	
<i>Spirostimum ambiguum</i> +	
<i>Frontonia</i>	

Station 6. 2,000 feet below station 2. Water very turbid and gray. Temp. 31° C. D. O. 5.7 p. p. m.; 76.2 per cent Sat.

Algae	Fungi
<i>O. prolifica</i> + + + +	<i>Physa gyrina</i> + + +
<i>O. limosa</i> +	
Protozoa	Metazoa
<i>E. viridis</i> +	<i>Physa gyrina</i> + + + +
<i>P. caudatum</i> +	
<i>S. ambiguum</i> +	

Station 7. 2,700 feet below Station 2. Opposite the delta in the field near the reservoir. Temp. 30° C. D. O. 6.0 p. p. m.; 78.7 per cent Sat.

Algae	Fungi
<i>O. prolifica</i> + + +	<i>S. natans</i> + + + +
<i>Stauroneis anceps</i>	
<i>Navicula gracilis</i>	Metazoa
Protozoa	<i>Physa gyrina</i> + + +
<i>E. minuta</i> +	Gizzard-shad + + +
<i>E. viridis</i> +	Carp + +
<i>Monas</i> + +	Bullhead
<i>P. caudatum</i> +	Chub
<i>Colpodium striatum</i>	Minnnows
<i>Colpoda campyla</i>	Sunfish
<i>S. ambiguum</i>	Bluegill
<i>Nasula ornata</i>	Kingfisher
<i>Metopus sigmoides</i> + +	Craw + + + +
	Larus + + +
	Mallard

Station 7A. About twenty paces to the east of Station 7 where the warm water of the starch-waste water ditch mingles with the seasonal cold water of a cold water ditch. Temp. 1° C. D. O. 12.8 p. p. m.; 90 per cent Sat. Gizzard-shad and other fish passing into this cold water from the warm water die in it, owing to lack of gill function. The water is clear. The rest of the biota of this cold water gives an entirely different picture from that shown by the warm water and indicated for the various stations, given above.

Algae

O. prolifica
O. limosa
Synedra ulna
S. pulchella
Navicula gracilis
Cocconema
Pleurosigma attenuatum
Nitzschia linearis
Melosira varians
Asterionella gracillima
Spirogyra crassa

Protozoa

Chlamydomonas
Trentonia flagellata
Cryptomonas ovata
Dexiotricha plagia
Oxytricha

Fungi

S. natans + +
Clonothrix
Cladothrix
Zoogloea ramingera

Metazoa

Pedestes saltator
Physa gyrina +
 Gizzard-shad + + + +
 Carp + +
 Bullhead catfish
 Chub
 Minnows
 Sunfish
 Crappie
 Bluegill
 Turtle (snapping)
 Kingfisher
 Crow + + + +
 Larus + +
 Mallard duck

Station 8. In the field below the delta by the junction of the bay reservoir. Many dead carp on the shore after receding water, and dying gizzard-shad. Temp. 29° C. D. O. 6.6 p. p. m.; 85 per cent Sat.

Algae

Navicula gracilis + +
Stauronsis anceps + +

Protozoa

Small amoebae
Euglena minuta +
E. viridis
Holophrya
Spirostimum ambiguum
Paramoecium caudatum
Holosticha vernalis
Chaenia teres

Fungi

S. natans

Metazoa

Rotifer critimus
Physa gyrina

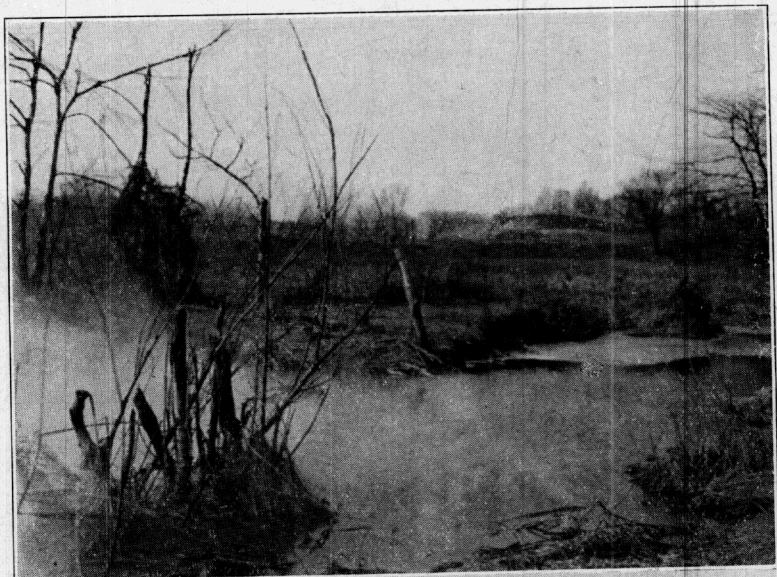


FIG. 5. (*Above*). Photo showing the confluence of the warm condenser water ditch (left) with a cold water ditch (right). Note also the ice sheet. The mixed water flows south, in the foreground of the picture. This represents Stations 7 (to the left in the "steaming" portion) and 7A to the right (in front of the ice).

FIG. 6. (*Below*). Photo of the marsh-land bay south of the mouth of the condenser water ditch, facing south and showing the main part of the bay. Lake Decatur is beyond the point.

TABLE I. NUMBER OF KINDS OF ORGANISMS AT EACH STATION

Station	Algae	Fungi	Protozoa	Metazoa	Zone		
A	10	0	0	0	Oligosaprobic water and bottom.		
1	2	1	3	2	Polysaprobic bottom, water mesosaprobic.		
2	4	2	3	1	Polysaprobic bottom, water mesosaprobic.		
3	6	1	14	5	Mesosaprobic water, polysaprobic bottom.		
3A	4	1	11	5	Polysaprobic bottom, water alpha-Mesosaprobic, judged by the metazoa there.		
4	2	1	3	1	Polysaprobic bottom, top, alpha-Mesosaprobic, judged by presence of Physa.		
5	2	1	5	1	Polysaprobic bottom, top, alpha-Mesosaprobic, judged by presence of Physa.		
6	2	1	3	1	Polysaprobic bottom, top, alpha-Mesosaprobic, judged by presence of Physa.		
7	3	1	9	12	Polysaprobic bottom, alpha and beta. Mesosaprobic; fish struggle in medium.		
7A	11	4	5	7	Oligosaprobic; temperature difference kills fish.		
8	2	1	8	13	Alpha-and beta mesosaprobic merging with Oligosaprobic Zone.		
		Algae	Fungi	Protozoa	Metazoa	Total average Algae and fungi	Total average animals
Average of all stations except A and 7A, which are Oligosaprobic.....		3	1.1	6.44	3.44	2.05	4.88

The grand total average of biota of the *Polysaprobic* and *Mesosaprobic* Stations is 3.467, and of the *Oligosaprobic* Stations = 18.5. Since Station 3 is influenced by Station 3A, the latter should be eliminated from this count. Moreover, the higher metazoa of Stations 7 and 8 must also be excluded. Then the averages for the regular eight stations will read: Algae, 2.8; Fungi, 1.1; Protozoa, 6; and Metazoa, 1.5.

The conditions described by the terms *poly-* and *mesosaprobic* bring in another factor, so that temperature alone cannot be designed as the cause for the trophobiotic condition in this frigid clime. It must, however, be borne in mind that the ecological zones are only resembling such typical conditions; they are real only in a certain measure. The water on the top layer of the sludge presents a condition which is better than that for the *beta-Mesosaprobic* zone. Because in all the situations described for each station a typical pond metazoan is present in very large numbers; here it lives, mates, multiplies, abundantly. That means, it seems, the conditions are even advanced above that typical for the *beta-Mesosaprobic* zone. And, yet, although a great amount of food is present, which could support an enormous animal population, very few species, living on this food, are present. This accounts mostly for the formation of such an extensive sludge bed. That is to say, a large number of individuals of a few species which serve as food

ditions: one represented by the pollution environment which excludes all forms save the typical pollution (*polysaprobic*) organisms; the other, by the high temperature, semi-pure water, and freshening super substratum of oxidation activity in which two chlorophyllaceous organisms (*Oscillatoria prolifica* and *O. limosa*) participate.

By Table II it is seen very graphically that Station 3 is influenced by Substation 3A (Compare biotae of these stations.) This may mean that the samples collected at Station 3 are not typical for the entire ditch, hence Station 3 is not typical for the ditch as a whole. The conditions, otherwise, are quite uniform. *P. gyrina* is well adapted to the conditions of the ditch, but apparently no other typical fresh-water forms. Probably high temperature is the factor controlling this.

At Stations 7 and 8 a number of fish enter the water of the ditch where it joins with the lake. But they have a hard time of it, especially when the temperature of the water changes suddenly, as shown by instances when fish accidentally enter cold water with the season's temperature and with nearly three times the amount of dissolved oxygen. The gills fail to function; in consequence the fish die in a short time. Likewise in the outer bay, when the water is by-passed cold at the plant, the fish die also there; while in the warm water (29 to 26° C.), the fish have a hard time of it. They die from the high temperature, the gills having ruptured. Hence the fish fauna cannot be taken as a normal population of the starch-waste water ditch. It may therefore be said with quite certainty that the high temperature in a frigid country limits the number of species which can live continuously and maintain themselves by reproduction in a given situation.

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