den Fall also, dass man eben alles Plankton gewinnen will, reicht mithin die Methode des Fischens mit dem Gazennetze nicht aus, wie dies ja bereits Hensen in seinem mehrfach citiertem Berichte ausführt. Dann könnte nur noch die Pumpe in Anwendung kommen, wie ich dies an anderer Stelle dargelegt habe [1]), und Mikromembranfilter, nach Empfehlung von Hensen (l. c.) resp. irgend ein anderes gegen geformte Materie völlig undurchlässiges Filter. Für alle übrigen Zwecke jedoch, wo obige Bedingungen nicht gestellt werden, reichen die feineren Gazenummern aus. Sehr hinderlich steht einer allgemeineren Benutzung derselben jedoch ihr hoher Preis entgegen, wozu noch kommt, dass manche Geschäfte die feinsten Gewebe (Nr. 20 u. 22) gar nicht liefern. Selbst von Nr. 18, welches 66 Fäden pro cm aufweist, kostet das qm allein Mk. 11,50 (Landwehr), und Nr. 19 mit 70 Fäden: 13 Mk. Nun bin ich zwar der Ansicht, dass diese letzteren beiden Nummern für gewöhnlich ausreichen werden, wie ja auch die mikroskopische Prüfung in der That kaum noch erhebliche Unterschiede zwischen den einzelnen Nummern erkennen lassen. Dazu kommt aber noch ein weiterer günstiger Umstand, der gleichzeitig zeigt, wie manches Unglück doch auch manchen Nutzen im Gefolge haben kann. Wie nämlich oben besprochen wurde, wirken die im Plankton verteilten Detrituspartikelchen verstopfend auf die Gaze, indem die Poren verengert werden. Ebenso wurde oben gezeigt, dass selbst heißes Wasser nicht im Stande ist, jene Partikelchen völlig zu verdrängen, so dass also immer noch eine gewisse Verengerung der Poren zurückbleibt. Diese ist nun gleichbedeutend einem feineren Gazegewebe, und man kann eben durch jene Verunreinigung eine Verbesserung des Netzes erreichen, eine Meinung, von deren Richtigkeit man sich leicht durch einen Versuch überzeugen kann. So fand ich, dass ein in oben angegebener Weise behandeltes Netz erheblich mehr Plankton zurückhielt als ein neues, und ich halte ein Netz erst dann für völlig brauchbar, wenn es so verstopft ist, dass es in heißem Wasser konstant bleibt. Für gewisse Zwecke möchte ich sogar ein stark verstopftes, nicht gereinigtes Netz vorziehen, da dieses noch undurchlässiger ist. Dann freilich würde ich aber nur noch die Planktonpumpe anwenden, um wirklich das erforderliche Wasserquantum zu filtrieren. [34]

The Vertical Distribution of the Limnetic Crustacea of lake Mendota.

E. A. Birge, University of Wisconsin.

In this journal, Vol. XV, Nr. 9, I published a brief account of the vertical distribution of the limnetic crustacea of lake Mendota during

1) Die Planktonpumpe l. c. S. 196 fg.

July 1894. I there showed that there were about 50 % of the crustacea in the upper three metres of the lake; nearly 30 % between 3 and 6 metres; 15 % between 6 and 9 metres; 5 % between 9 and 12 metres; and less than 1 % between 12 metres and the bottom at 18 metres or in deeper parts of the lake at 22 metres. A complete account of the work was published in the 10th volume of the Transactions of the Wisconsin Academy of Sciences, Arts and Letters, p. 421—484.

This study has been carried on since July 1894, with the design of determining the annual and vertical distribution of the limnetic crustacea, and the series of more than 400 observations was closed with the end of 1896. The results of the study of the annual distribution of the crustacea will be published in the forthcoming 11th volume of the Transactions of the Wis. Academy, but the full report of the vertical distribution must be further postponed in order to complete the investigation of some details. I therefore present a brief synopsis of the results thus far obtained, regarding vertical distribution.

1. The vertical distribution of the limnetic crustacea, in summer, is like that of Juli 1894, in all essential particulars.

2. Soon after the formation of the transition stratum of temperature („Sprungschicht") about July 1, the crustacea in the lower water either die or migrate into the water above the transition stratum. This forms thereafter the lower limit of the crustacea, 95 % or more of the whole number present being found above it. This condition lasts as long as the transition stratum is found — until after the middle of September — and the crustacea follow the transition stratum as it gradually moves downward through the lake. It lies at a depth of about 9 meters in July when it becomes the lower limit of the crustacea, and lies at about 15 metres in September, when the autumnal gales cause it to disappear.

3. This limitation of the downward extension of the crustacea is not due, for most species, to the change in temperature occurring at the transition stratum. The crustacea are excluded from the deeper water by the accumulation there of the products of the decomposition of the plankton. The exact nature of these substances is the chief point requiring further study.

4. In plankton-poor lakes the crustacea are found in and far below the transition stratum, though not always to the bottom of the lake. Certain species are found in the deeper water in greater abundance than near the surface. *Diaphanosoma* has not been found in numbers below the transition stratum and very probably never enters the cooler water.

5. The limitation of the crustacea is very abrupt. Ten times as many crustacea may be found in a single metre in and above the transition stratum as are contained in the whole 8 or 10 metres below

it. The larvae of *Corethra* are the only animals which pass freely up and down through the transition stratum of lake Mendota.

6. The effect of light is not traceable in lake Mendota deeper than 1—2 metres; within this limit it has a powerful influence on the distribution of the crustacea. During the day the upper metre or so is occupied by swarms of young crustacea, especially *Diaptomus* and *Daphnia hyalina* and *D. retrocurva.* In the case of *Daphnia* the adults are repelled by light while the young are attracted or are indifferent. In *Diaptomus*, the young are more strongly attracted by light than are the adults. On bright days therefore the young crustacea can feed on *Aphanizomenon* and other small plants in the upper water without competition from the older animals. At night old and young become mingled, but there is no general movement toward the surface. On cloudy days the adults rise toward the surface coming within about $^1/_2$ metre of it. This rise comes immediately after the sun is obscured and an immediate descent follows the reappearance of the sun.

7. Gravity aids in causing the older and weaker adults to move toward the bottom and accumulate there. This fact is especially noticeable in the old age of broods of *Cyclops* and *Daphnia. Diaptomus* does not show it. In winter, *Cyclops* is found in large numbers near the bottom, $50^0/_0$ or more of the total catch being often found in the lower three metres. It is also found in very large numbers near the bottom when the enormous spring broods are dying off in early summer. *Daphnia* shows the same tendency to the bottom in late spring on the part of those individuals which have lived over winter and are near the end of life. The same thing occurs in late October and early November when the summer broods are dying. Throughout the year the older animals are proportionally more numerous in the lower strata of the water.

8. In autumn the upper strata of the water are more densely populated than those below so long as reproduction is active. No species is distributed through the water with even approximate uniformity until its reproductive period is over and it has begun to decline in numbers. In late fall and winter the crustacea are more uniformly distributed than at any other time, although even then the upper three metres contain much more than their exact share. *Daphnia pulicaria* alone shows a decided tendency to aggregate near the surface at this time, and *Cyclops*, as already said, is found in swarms at the bottom during winter.

9. In spring the young of each species of crustacea first appears near the surface. They move gradually downward as numbers increase and more room and food are needed. This downward movement continues during May, until the lower water is densely populated, chiefly by *Cyclops.* In June, as the lake warms, the bottom water

becomes uninhabitable; the crustacea die or withdraw and by July 10, the water below the transition stratum is practically without crustacea.

10. *Daphnia pulex*, var. *pulicaria* is found in summer in and just above the transition stratum, with a very few stragglers extending to the surface. The distribution of the species becomes fairly uniform in October during the autumnal storms. The species has a marked reproductive period in late autumn, during and after which it moves upward so that in December 50% or even 75% are found in the upper three metres. Most of this number are in the upper metre; indeed when this species is abundant, it may be seen through the ice, crowded in dense swarms just below the ice. This position near the surface it retains during the winter, differing in a striking way from *D. hyalina*, which is distributed with a fair degree of uniformity. In spring the species descends as the lake warms, and in Juni 80% or more are below the middle of the lake (9 metres), and occasionally as many as 60% are found in the lower three metres (15—18). In late June the species begins to leave the bottom and during the first part of July it moves to the summer position at the transition stratum.

In plankton-poor lakes the species probably occupies the whole region below the transition stratum; this conclusion rests, however, on only two observations.

The summer position of this species is determined primarily by the temperature of the water.

11. *Cyclops*, *Diaptomus*, *Daphnia hyalina*, *D. retrocurva*, *Diaphanosoma brachyurum* and *Chydorus sphaericus* agree in general in their vertical distribution. There are, however, constant minor differences which appear when a series of observations is studied. These can not well be shown without taking too much space here. In general it may be said that *Diaptomus* and *Chydorus* show the greatest tendency to aggregate in the upper strata of the water and that *Cyclops* shows the least of this tendency, while the *Daphnias* are intermediate in this respect.

12. The forces affecting the vertical distribution of the limnetic crustacea are numerous and their action is complex. The quantity and kind of food in any stratum of the water constitute a prime factor in determining its crustacean population. The distribution is also modified by light, temperature, gravity, wind, and the chemical condition of the water. These forces act in different ways on different species and also act differently on the individuals of the same species at different ages; and in many cases have more effect than food on the vertical distribution of the crustacea. [40]

Madison, Wis., U. S. A., Jan. 14, 1897.