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BENTHIC ASSOCIATIONS OF SUGARLOAF LAKE

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Knowledge of the density and distribution of the animals and plants inhabiting a lake bottom is necessary before an appraisal can be made of benthic productivity. The objectives of this investigation were to learn (1) whether the littoral zone of Sugarloaf Lake, a shallow eutrophic Michigan lake, can be divided into biotic associations which should be sampled independently for productivity studies, and (2) if such assemblages are present, whether they can be associated with environmental differences.

The animal-plant associations of the littoral zone have been discussed frequently in the literature. Assemblages characteristic of specific habitats within the littoral zone have been discussed by Pennak, 1940; Moffett, 1943; Neel, 1948; and Krecker and Lancaster, 1933. Numerous other studies have dealt with the animals and plants at one or more collecting stations within the littoral zone (Eggleton, 1952; Andrews and Hasler, 1944; Brundin, 1949; Ball, 1948). The great effort expended in sorting and identifying the animals in bottom samples perhaps has discouraged intensive quantitative investigations and restricted the number of sampling sites established. The usual procedure is to select one or more transects passing through what appear to be typical portions of the lake bottom and to rely upon samples from points along these transects for estimates of conditions throughout the lake basin as a whole. Choice of transects and sampling sites is usually subjective, and depends upon the investigator's familiarity with the lake. The transect method was employed in a previous study of the benthic productivity of Sugarloaf Lake (cf. Anderson and Hooper, 1956). Samples were collected at three stations along a transect extending from a point near shore to the lake's maximum depth. Bottom vegetation and soils along the transect appeared similar to those of large areas of the lake bottom. In general, monthly samples were similar in the kinds of animals present, and showed consistent population trends for some species. However, appearance of certain discrepancies in the counts of other species led to the suspicion that the investigator failed to return to the same sampling location on successive months. Since the sampling stations were re-located each month by visual reference to shore points, deviation might be expected in the actual sampling site. The suspicion that considerable variability existed in what appeared to be uniform areas, led to the present analysis of the entire lake bottom and its bottom fauna, flora, and soils.

Clearly, an appraisal of the homogeneity of a lake bottom is needed if the events taking place over a lake basin as a whole are to be evaluated quantitatively. The discrete biological zones of the lake should be sampled as separate units. This procedure minimizes sampling variations and adds to the reliability of sampling data.

The definitions of littoral and sub-littoral zones used here are those given by Eggleton (1931). The only area considered in this paper is the zone where aquatic vegetation is present (littoral). A small sub-littoral area is present in the vicinity of station 15 where the basin is deeper than 12 feet.

Sampling Stations and Methods

Sugarloaf Lake, located in the northwestern part of Washtenaw County, has been the site of numerous studies in management of warm-water fish by the Institute for Fisheries Research. Many of the lake's limnological features have been discussed (Cooper, 1953; Hooper, 1956; Anderson and Hooper, 1956).

Samples were taken at 24 points in the lake. The location of 22 sampling stations was determined by superimposing a system of grid lines on a map of the lake. There was no conscious orientation by the investigator of the grid intersections on the map. Each grid intersection within the lake boundaries except those less than 25 feet from shore was used as a sampling station (Fig. 1). One station had to be abandoned because of its proximity to shore. Samples of bottom fauna were also taken at two points (stations A and B) which have served for several years as regular monthly collecting sites (stations 1 and 2 of Anderson and Hooper, 1956). Sampling was completed at 21 stations on November 23, 1955 and at the three remaining stations the following day. Four hauls were made at each station with a modified Ekman dredge. This modification of the Ekman dredge for sampling a firm, shallow bottom has been described by Anderson and Hooper (1956). These authors also described the procedures used in the present study for collecting, sieving, and sorting of benthos.

In addition to the four samples collected at each station for analysis of bottom fauna, one dredge sample was taken for soil analysis. An alliquot of each soil sample was oven dried, weighed, and washed through a graded series of Tyler screens. Soil fractions retained by each screen were also dried and weighed. A second alliquot of each soil sample was oven dried, weighed, and neutralized with 0.1 normal hydrochloric acid. The sample was then ashed in a muffle furnace and re-weighed. From the amount of acid used to neutralize the soil, the marl content was calculated (as percentage calcium carbonate); and from the loss in weight by ashing, the quantity of organic matter in the sample was estimated. A quantity of calcium chloride equivalent to the calcium carbonate content of the original sample was subtracted from the ash weight. The difference was a measure of all inorganic substance except marl.

The modified Ekman dredge penetrates through materials on the mud surface and collects rooted aquatic plants present. Hence the plants removed from the dredge haul provided a sample of the quantity and kind of vegetation at each station. After they were removed from the mud, plant samples were washed in 0.1 normal hydrochloric acid to remove marl, dried in an oven at 60° C. and weighed on a sensitive balance.

Dr. LaVerne L. Curry, Central Michigan College, verified our identification of midges. R. O. Anderson and W. F. Hunter of the Institute for Fisheries Research staff assisted in collecting and analyzing bottom samples.

Morphometry and Soils

The basin of Sugarloaf Lake is saucer-shaped. From the water's edge, it slopes gradually for 50 to 100 feet. Beyond this point, the water is between three and four feet deep, and the bottom is essentially flat. The five-foot contour circumscribes a small, central depression (Fig. 1). The bottom of this depression is irregular and is broken up into several small sub-depressions. The deepest of these (near station 15) has a depth of 20 feet. A second sub-depression is in the vicinity of stations 5 and 9 (Fig. 1).

The analysis of soil particle size indicated that the bottom sediments were surprisingly uniform (Table I). At fifteen stations, from 35 to 55 per cent of the soil consisted of particles less than 0.147 millimeters in diameter. Particles of this size correspond to the very fine sand and silt categories of the U. S. Department of Agriculture textural classification. Sediments from only four stations contained over 10 per cent of particles greater than 0.840 millimeters in diameter (coarse sand and gravel). Samples varied considerably in their percentage of soil particles greater than 0.42 millimeters in diameter. Much of the variation between stations in the quantity of larger sized particles was due to variable amounts of mollusc shell. The highest percentages of particles in the intermediate size ranges (0.42-0.147 millimeters) were to be found where the bottom was firm (stations 1, 6, 7, 20, and 22). The silt fraction was highest in the shallow embayments on the windward side of the lake (stations 19 and 23) and at station 5.

Chemical properties of the soils also showed considerable uniformity (Fig. 1). The marl content varied between 11 and 38 per cent. It was highest near the central depression (stations 5, 9 and 15) and lowest where the bottom was firm (stations 3, 20, and 22). Ash content tended to be highest at the shallowest depths and on the more exposed shores (stations 1, 3, 20, 22 and 23). Sediments at station 8 had a high ash content although records showed that benthos samples were taken at depths of 4.5 to 5 feet. It is believed that the soil sample for station 8 was taken a short distance from the bottom sampling site, on a projecting sand spit, where the water is between 3 and 4 feet deep. This sample therefore is probably not representative of conditions at the benthos-collecting site.

Table I

Percentage of Bottom Sediment Retained by Sieves

Station number	Sieve aperture in millimeters 0.840	0.420	0.208	0.147	Less than 0.147 *
1	7.2	8.2	27.7	12.8	44.1
2	15.5	15.7	20.2	8.2	40.3
3	4.4	13.7	19.8	9.8	52.2
4	6.5	24.6	23.5	6.8	38.6
5	0.5	4.6	8.6	3.4	82.9
6	12.2	5.7	43.3	13.4	25.4
7	4.2	17.9	31.7	12.1	34.1
8	0.5	23.3	25.1	7.6	43.5
9	51.3	9.9	10.4	5.4	23.0
10	0.4	20.5	20.0	9.2	49.8
11	0.6	22.0	23.0	8.2	46.2
12	0.9	13.9	22.3	7.8	55.2
14	0.6	16.8	22.0	9.7	50.8
15	1.5	14.1	19.2	12.1	53.2
16	11.1	14.0	18.9	10.2	45.9
17	1.5	16.3	27.4	9.0	45.8
18	0.2	24.5	19.0	9.8	46.5
19	0.5	3.6	18.1	15.9	61.8
20	0.4	11.7	30.0	20.3	37.6
21	0.4	25.5	17.9	8.5	47.7
22	6.2	9.8	52.4	22.6	9.1
23	0.2	18.0	19.2	2.1	60.5

* The percentage of sediment that passed through a sieve aperture of 0.147 millimeters.

The organic content of the sediments varied between 16 and 50 per cent. The lowest values occurred at the more exposed or shallow stations (1, 20, 22, 23). However, the organic content was not appreciably greater in the central depression than at depths of three to five feet.

Ash content appeared to be the most diagnostic of the soil measurements. It separated the compact bottom at stations on exposed shores in very shallow water from the bottom types at other stations. Particle size, marl content, and organic content were more variable measurements because they were strongly influenced by local concentrations of plant detritus and mollusc shells.

Vegetation

The stonewort Chara was the predominant submerged plant, constituting at least 95 per cent of the vegetation at 17 of the 23 sampling stations (Fig. 2). At five of the remaining stations there was an association of Najas and Potamogeton. Najas was predominant in sheltered bays (stations 12 and 18), and Potamogeton predominated in the central depression (stations 9, 15, and 16). At one station (22), there was a sparse stand of Chara and Najas, with a trace of Potamogeton.

Sampling and visual observation indicated that there were no dense stands of Chara. Samples from the Chara zones averaged only 1.83 grams dry weight per one-quarter square foot. By contrast, samples from the Najas-Potamogeton beds averaged 5.88 grams per one-quarter square foot.

Invertebrates

Thirty-two kinds of invertebrates were identified from the benthos of Sugarloaf Lake. The mean number of individuals collected at each station is listed in Tables II and III. Plotting the occurrence of

Table II

Average Number of Invertebrates Per One Quarter Square Foot in the

Chara-Tanytarsus Association in Sugarloaf Lake.

[Four samples from each station; tr. = less than 0.5]

Organisms	Stations A	B	2	4	5	6	7	8	10	11	14	17	19	21
Sphaerium spp.	...	...	...	...	...	tr.	...	...	...	tr.	tr.	...	...	...
Chaoborus punctipennis	3	7	1	tr.	1	...	tr.	6	2	3	1	1	...	...
Pentaneura flavescens	3	1	1	tr.	...	...	...	...	tr.	tr.	...	1	2	...
Pentaneura monilis	6	1	1	...	1	1	2	3	tr.	3	2	tr.	1	...
Procladius spp.	38	34	16	22	13	1	18	27	14	27	21	19	10	8
Clinotanypus sp.	4	4	1	...	1	1	1	...	1	1	...	3	1	7
Calopsectrini	19	10	1	3	3	3	10	8	2	18	12	4	8	5
Microtendipes pedellus	2	3	4	2	2	6	8	9	3	13	8	2	4	4
Polypedilum spp.	65	61	20	35	25	11	42	1	16	31	36	60	81	43
Tanytarsus jucundus	20	86	5	144	4	12	3	11	49	4	14	2	...	3
Stictochironomus sp.	3	2	...	...	1	1	1	...	1	2	...	...	1	1
Cryptochironomus digitatus	11	14	...	4	1	1	1	2	3	1	5	1	1	1
Pseudochironomus sp.	...	...	...	...	1	1	2	2	tr.	1	1	1	18	2
Glyptotendipes sp.	5	12	5	38	...	...	...	...	20	...	...	...	...	...
Tendipes (*Tendipes*) sp.	...	tr.	...	1	...	...	...	1	tr.	3	1	...	1	...
Tendipes nervosus	5	17	4	4	6	34	18	25	7	43	71	18	14	26
Tendipes tendipediformis	...	...	...	...	...	...	...	...	...	...	...	...	...	tr.
Heleidae	8	8	5	4	6	2	3	7	4	9	11	8	17	23
Psychomyiidae sp. A	13	11	8	15	25	9	17	14	14	9	30	39	27	32
Polycentropus interruptus	3	2	1	...	1	tr.	1	6	1	4	1	1	...	1
Leptoceridae	...	tr.	tr.	...	...	...	...	...	...	tr.	1	1	1	1
Coenagrionidae	...	...	tr.	...	2	...	2	...	tr.	2	3	1	1	4
Libellulidae	...	...	...	...	1	1	1	...	1	tr.	2	1	2	1
Hexagenia sp.	...	...	...	...	...	tr.	1	...	...	...	...	tr.	1	1
Ephemerella sp.	...	...	...	...	...	tr.	...	...	...	...	1	...	...	...
Caenis sp.	57	10	1	4	1	25	14	14	1	38	43	5	30	16
Hydracarina	tr.	tr.	...	tr.	...	tr.	2	...	...	2	3	...	2	tr.
Orconectes sp.	...	...	tr.	...	tr.	tr.	...	...	...	tr.	tr.	tr.	...	1
Hyalella azteca	189	147	124	118	156	142	186	201	158	121	156	184	270	163
Hirudinea	...	...	1	...	...	...	1	1	tr.	tr.	3	tr.	1	1
Oligochaeta	...	...	tr.	tr.	1	1	...	...	1	2	...	...	1	...
Turbellaria	1	1	...	...	1	...	2	1	...	1	1	1	2	2

Table III

Average Number of Invertebrates Per One Quarter Square Foot in the Chara-Hexagenia and Najas-Potamogeton-(Tendipes) Association in Sugarloaf Lake.

[Four samples from each station; tr. = less than 0.5]

Organisms	Stations									
	Chara--Hexagenia					Najas--Potamogeton -(Tendipes)				
	1	3	20	22	23	9	12	15	16	18
Sphaerium spp.	...	...	1	...	...	...	...	tr.	...	...
Chaoborus punctipennis	...	...	tr.	...	...	4	2	20	5	3
Pentaneura flavescens	tr.	tr.	1	tr.	1	2	1	5	8	2
Pentaneura monilis	1	2	1	...	1	3	2	3	6	2
Procladius spp.	9	9	14	4	20	12	15	3	3	9
Clinotanypus sp.	tr.	1	9	3	6	...	...	...	...	...
Calopsectrini	1	tr.	3	3	4	6	6	15	7	5
Microtendipes pedellus	5	3	1	tr.	tr.	4	12	12	14	8
Polypedilum spp.	25	4	36	9	84	5	115	6	...	34
Tanytarsus jucundus	14	1	3	1	2	...	...	...	2	...
Stictochironomus sp.	1	1	1	tr.	1	1	1	2	3	4
Cryptochironomus digitatus	1	1	1	...	1	tr.	...	tr.	1	...
Pseudochironomus sp.	...	...	6	13	16	1	...	1	1	1
Glyptotendipes sp.	2	...	tr.	...	...	...	...	...	...	...
Tendipes (*Tendipes*) sp.	...	...	1	...	1	8	13	45	27	1
Tendipes nervosus	1	1	3	1	4	30	11	32	24	7
Tendipes tendipediformis	...	...	...	...	...	tr.	6	2	16	...
Heleidae	2	3	16	2	16	2	2	4	5	8
Psychomyiidae sp. A	1	7	4	...	2	...	tr.	3	18	2
Polycentropus interruptus	1	tr.	...	...	1	...	4	3	2	tr.
Leptoceridae	...	...	1	1	1	tr.	13	1	1	3
Coenagrionidae	tr.	...	4	tr.	1	2	tr.	tr.	1	5
Libellulidae	tr.	...	2	1	1	2	1	3	3	1
Hexagenia sp.	1	1	3	8	15	...	...	...	...	...
Ephemerella sp.	...	...	...	...	...	...	...	...	1	...
Caenis sp.	...	1	139	3	48	7	111	21	21	42
Hydracarina	...	...	tr.	...	1	1	2	2	1	1
Orconectes sp.	...	...	...	...	...	...	tr.	...	...	...
Hyalella azteca	84	123	174	77	112	8	31	24	30	66
Hirudinea	...	...	1	...	1	...	1	3	2	7
Oligochaeta	2	...	...	2	...	3	tr.	...	...	3
Turbellaria	...	tr.	1	1	...	1	...	...	...	...

invertebrate species on a map of the lake revealed several distributional patterns. Some animals were of general distribution; others were restricted to definite areas. Some species, although found generally throughout the lake, reached their highest concentration at specific groups of stations. The most distinctive distributional patterns were of the following species:

Hyalella azteca. *Hyalella* exceeded all benthic animals in both density and frequency of occurrence; this amphipod seemed truly ubiquitous (Fig. 3). It was found in large numbers at all stations, but occurred in lesser concentrations in the central depression.

Chaoborus punctipennis and *Tendipes* (sub-genus *Tendipes*) sp. Large numbers of these two insects were found below the five-foot contour (Fig. 4). Even higher concentrations occurred in the sub-littoral zone (Anderson and Hooper, 1956). A few individuals also appeared throughout the shallower areas.

Clinotanypus sp. This species occurred in greatest numbers at stations along the windward shore (Fig. 5). Other areas had few *Clinotanypus*; none were found in the central depression.

Hexagenia sp. Nymphs of this mayfly were found only in the firm substrate of the shallower on-shore stations around the periphery of the basin (Fig. 6).

Tanytarsus jucundus and *Glyptotendipes* sp. These midges were concentrated in the central portion of the lake basin (Fig. 7). Nothing in the soil or vegetation analyses, or in the physical configuration of the basin distinguished the area of concentration from the surrounding lake bottom. In the absence of evidence that either the soil or the vegetation was distinctive, we can only suggest that wind or water currents may have concentrated eggs or early larval stages of these two species in this part of the basin.

Biotic Associations

The variety of habitats encountered at the 24 stations is small compared to that in lakes having complex basins, irregular shore lines, and extensive shoals (Eggleton, 1952). Soil and vegetation analyses indicated that the littoral zone was remarkably uniform. The regularity of the shoreline and of the lake basin tended to create such uniformity.

Principal variations encountered in the lake bottom were increases in firmness and in ash content of sediments with increasing exposure to wave action. The more compact bottom occurred at depths of two feet or less in the sheltered bays, but extended out into the lake to depths of three to four feet along the west and southwest shores where wave action was most severe.

Qualitatively, the animal assemblage of the shallow zone resembled that of the deeper water. A few forms, such as the burrowing mayfly *Hexagenia* sp., seemed almost restricted to this zone. Another mayfly, *Caenis* sp., reached its highest concentration here. However, the majority of species found here were more abundant in other parts of the lake. This assemblage has been termed the *Chara*-*Hexagenia* association.

At slightly greater depths and in more protected areas where the bottom was less compact, *Chara* remained the dominant plant but the animal assemblage differed considerably. Two species of midges (*Tanytarsus jucundus* and *Cryptochironomus digitatus*) and one caddis fly (Psychomyiidae sp. A) were most abundant here, although they occurred also in other areas (Tables 2 and 3). This zone, termed the *Chara*-*Tanytarsus* association, constituted over half of the lake basin.

In the more protected parts of the littoral zone, Chara was replaced by Najas and Potamogeton as the predominant vegetation. This replacement occurred in the central depression below the five-foot contour, and at depths of three to four feet in the protected bays at the north and south ends of the lake. Although this zone was not well differentiated from the Chara-Tanytarsus association in bottom type, it was marked by greater standing crops of rooted aquatic vegetation. (Tendipes) sp. and Chaoborus punctipennis were characteristic of this zone.

The differences between the three biotic associations described above were chiefly quantitative. To illustrate these differences, frequency-density diagrams were made of 12 more abundant invertebrates (Fig. 8). All forms diagrammed were believed to be represented in the data by a single species. The dimensions of the rectangle representing each species indicate its average abundance and its frequency of occurrence in all collections from each association. This diagram emphasizes that each association consists of a mixture of distinctive and ubiquitous species, and that differences in animal assemblages appear only when quantitative data are compared for a large number of forms.

Summary

1. Samples of bottom fauna, submerged plants, and bottom soil were collected at 22 stations within the littoral zone of a shallow eutrophic lake.

2. Soil samples were quite uniform in texture and chemical composition. The principal variation was a higher ash content and a slight decrease in organic matter of the shallow-water sediments and the sediments of exposed shores.

3. *Chara* was the predominant submerged plant except in the central depression and in the more protected bays. Here *Najas* and *Potamogeton* were more important.

4. The occurrence of certain species appeared to be associated with depth and soil conditions; other forms appeared to be distributed rather uniformly. Two midges, *Tanytarsus jucundus* and *Glyptotendipes*, were concentrated in a small area that could not be distinguished from the rest of the basin by depth, soil, or vegetation type.

5. Three biotic associations have been described for the littoral zone. These associations are distinguished on the basis of soil and vegetation characteristics and quantitative differences in animal assemblages.

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Fig. 1a. Chemical composition of soil samples collected at 23 stations in Sugarloaf Lake on November 22, 1955. Identification numbers of the sampling stations are given immediately above the circles.

CHEMICAL COMPOSITION OF SOIL

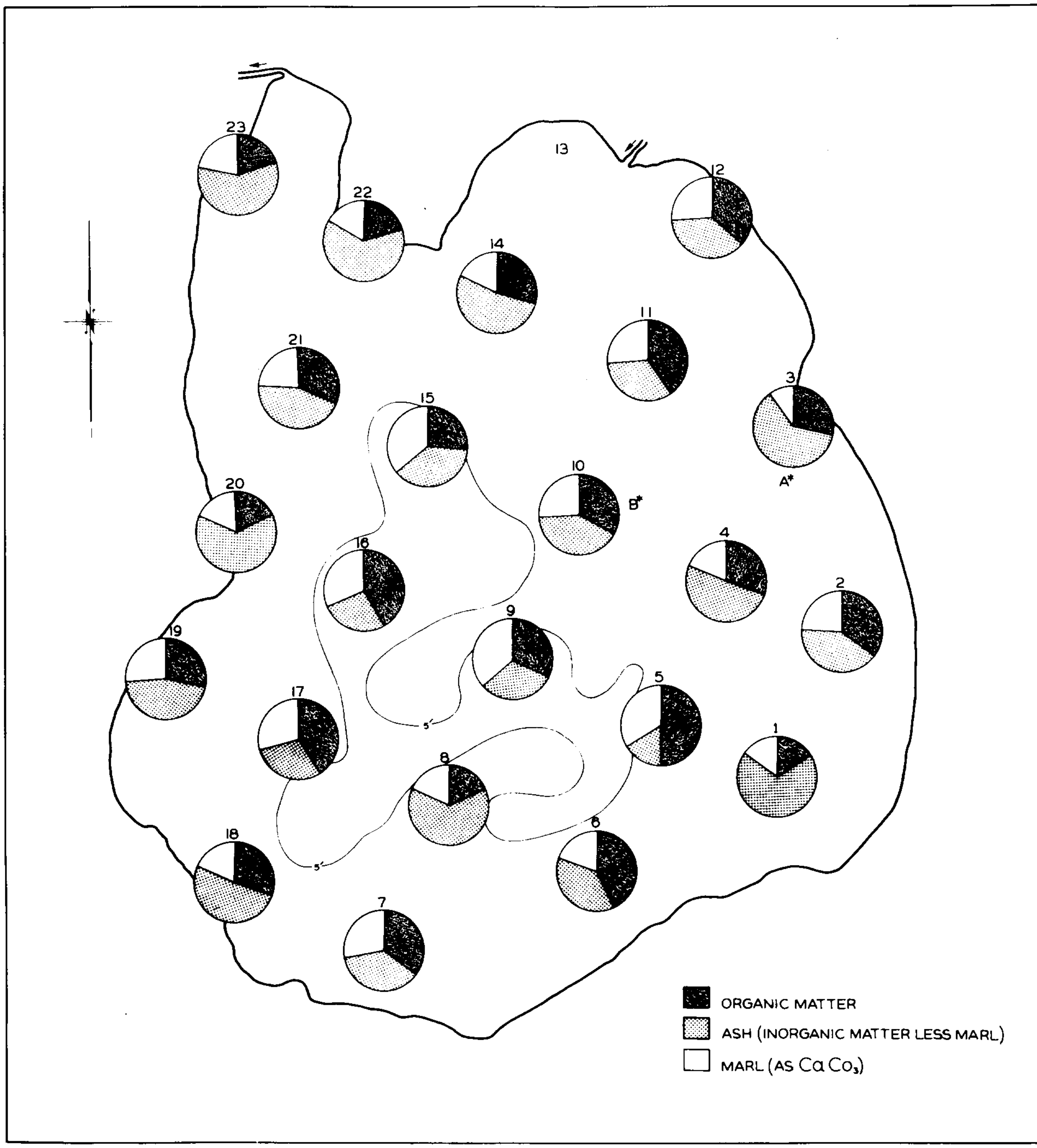

Fig. 1a

Fig. 1b. Soil particle size of samples collected at 23 stations in Sugarloaf Lake on November 22, 1955.

SOIL PARTICLE SIZE

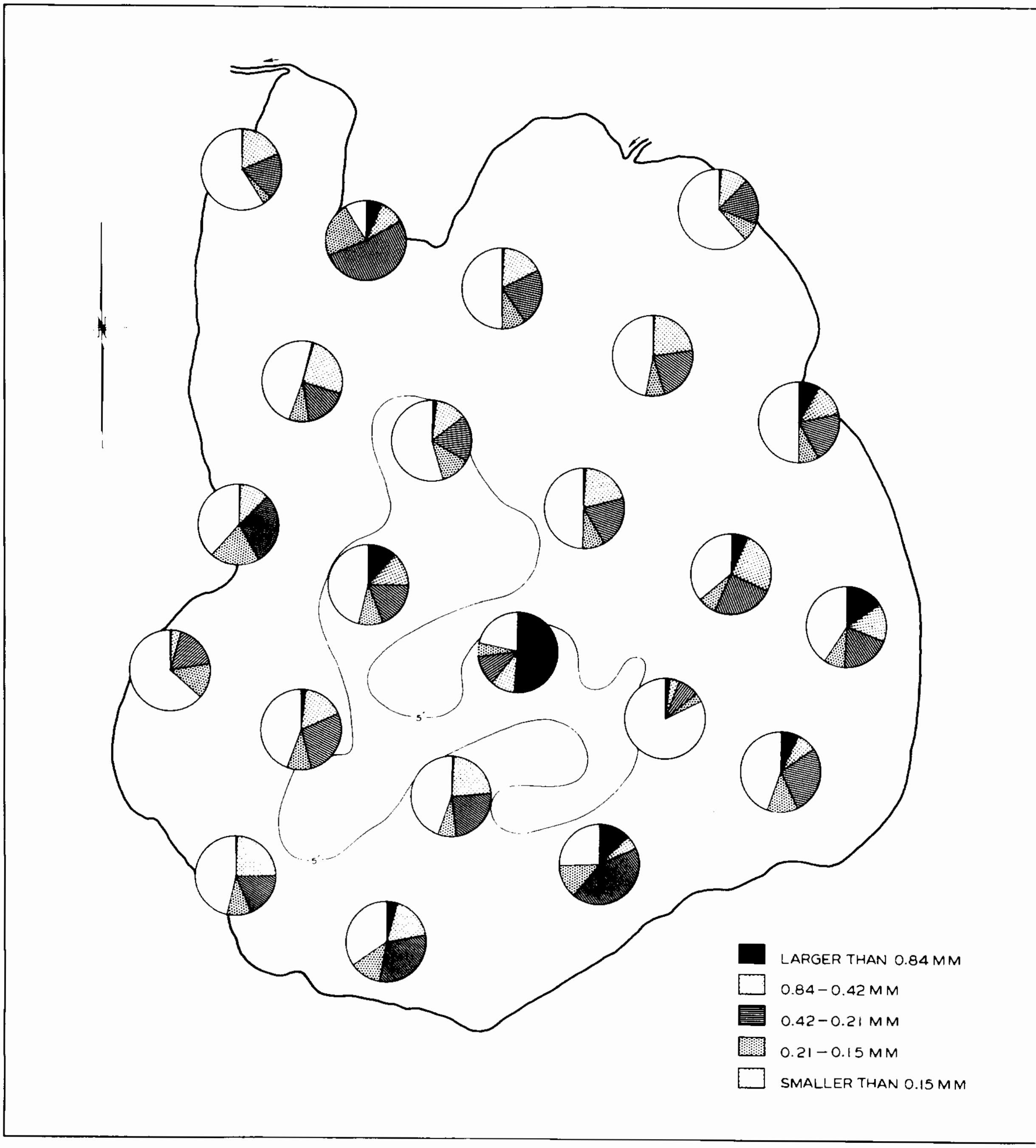

Fig. 1b

Fig. 2. Abundance and composition of submerged vegetation in samples taken at 21 stations in Sugarloaf Lake on November 22, 1955. Mean dry weight of plant samples collected at each station is proportional to radius of circle; standard error of the mean is represented by a line indicating increase or decrease in length of the radius.

SOIL PARTICLE SIZE

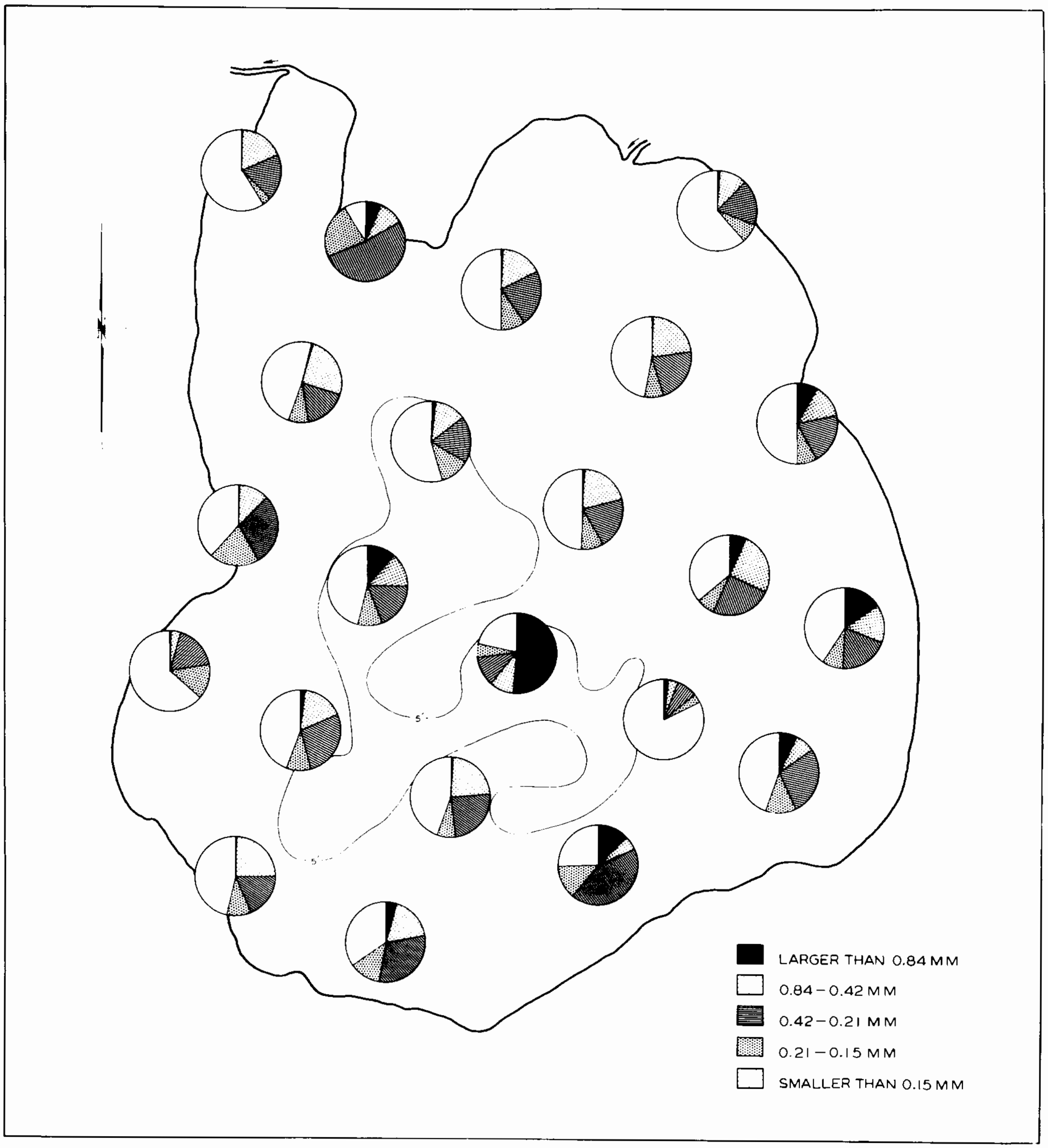

Fig. 2

Fig. 3. Distribution and abundance of *Hyalella azteca* at 25 stations in Sugarloaf Lake on November 22-25. Mean number of animals per sample is given by a number in or beside each circle and is proportional to its radius; standard error of the mean is represented by a line indicating an increase or decrease in length of the radius.

HYALELLA AZTECA

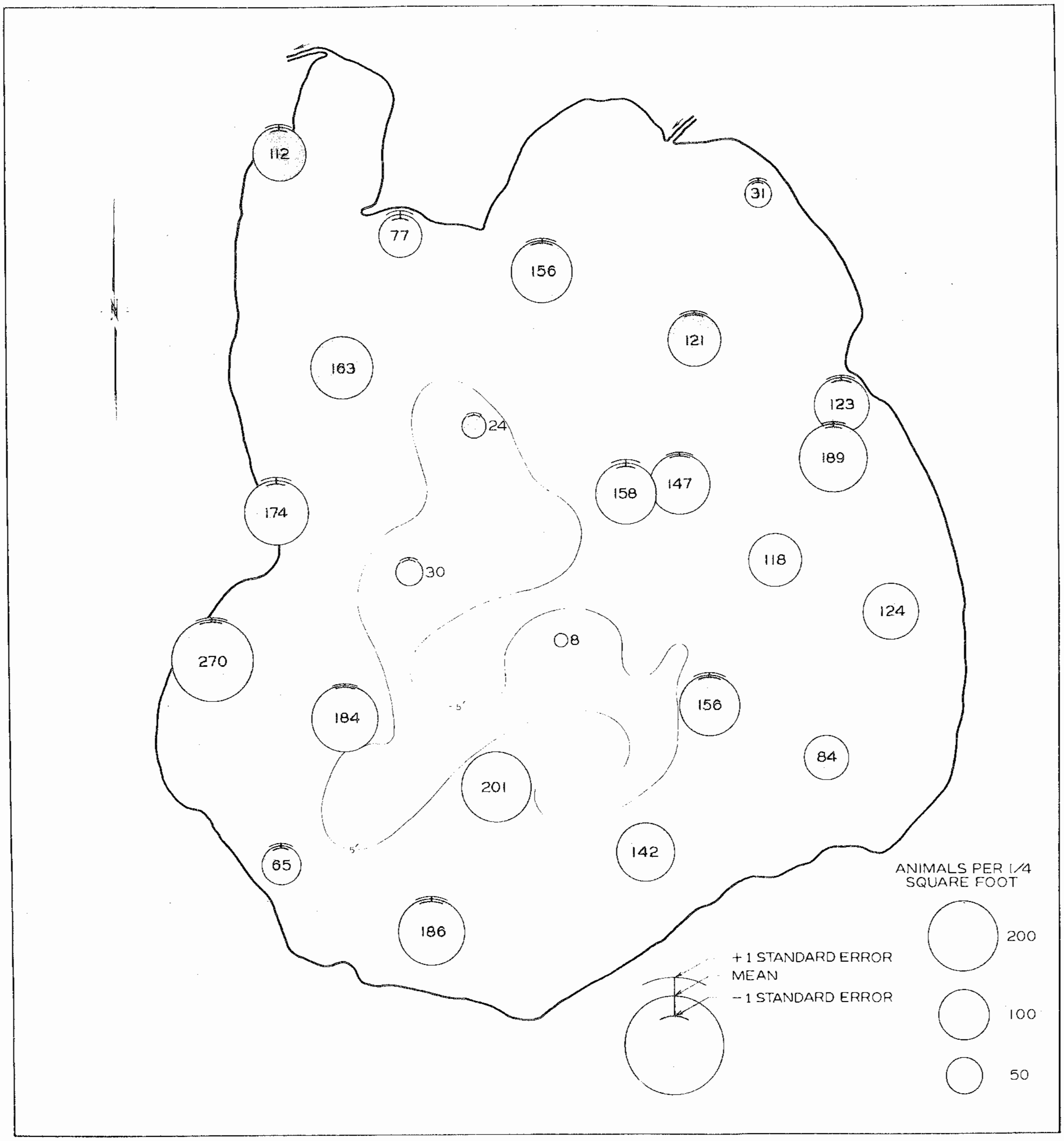

Fig. 3

Fig. 4a. Distribution and abundance of Chaoborus punctipennis at 25 stations in Sugarloaf Lake. (For explanation see Figure 3.)

CHAOBORUS PUNCTIPENNIS

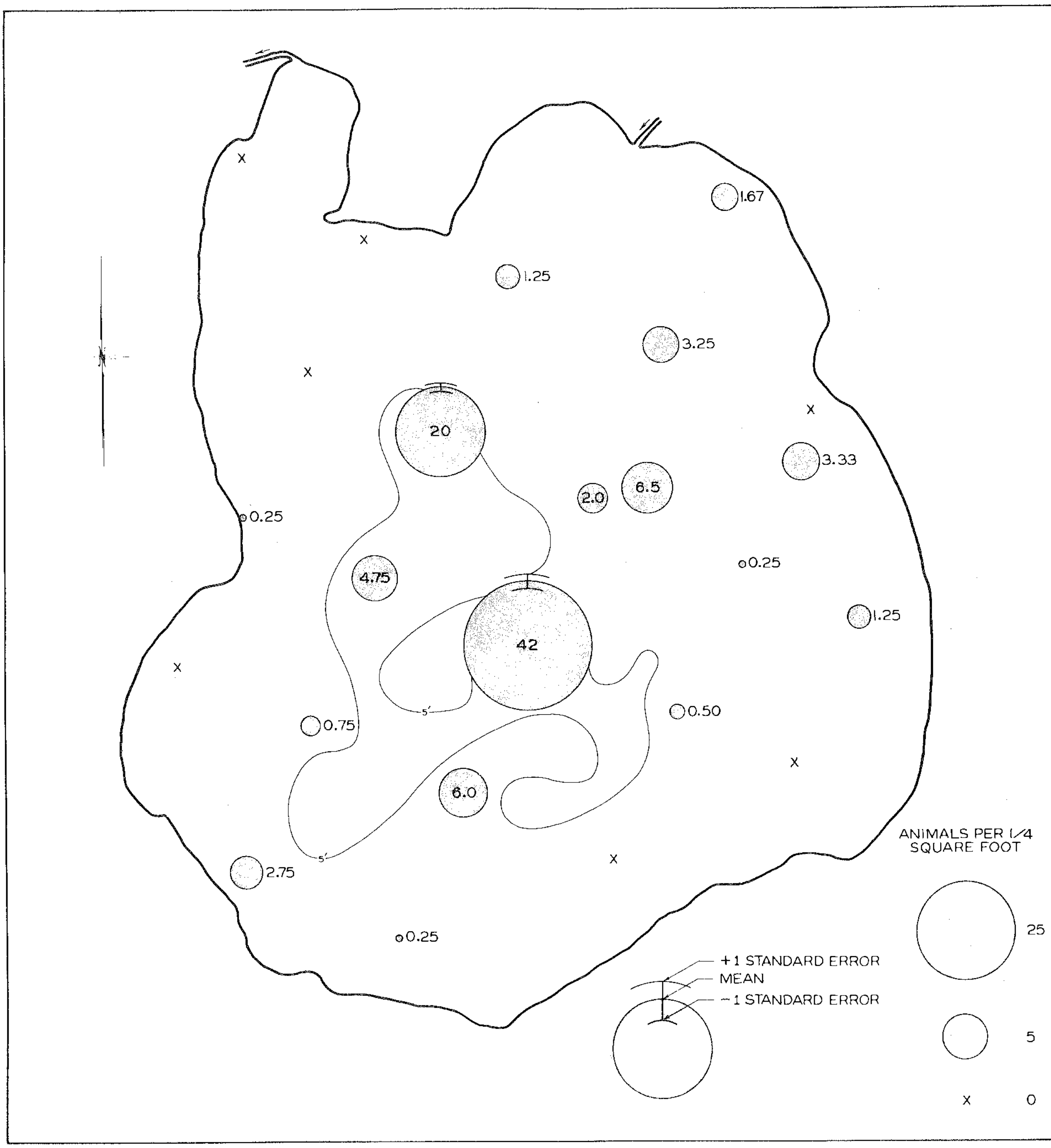

Fig. 4a

Fig. 4b. Distribution and abundance of _Tendipes_ (_Tendipes_) sp. at 25 stations in Sugarloaf Lake. (For explanation see Figure 3.)

TENDIPES (TENDIPES) SPP.

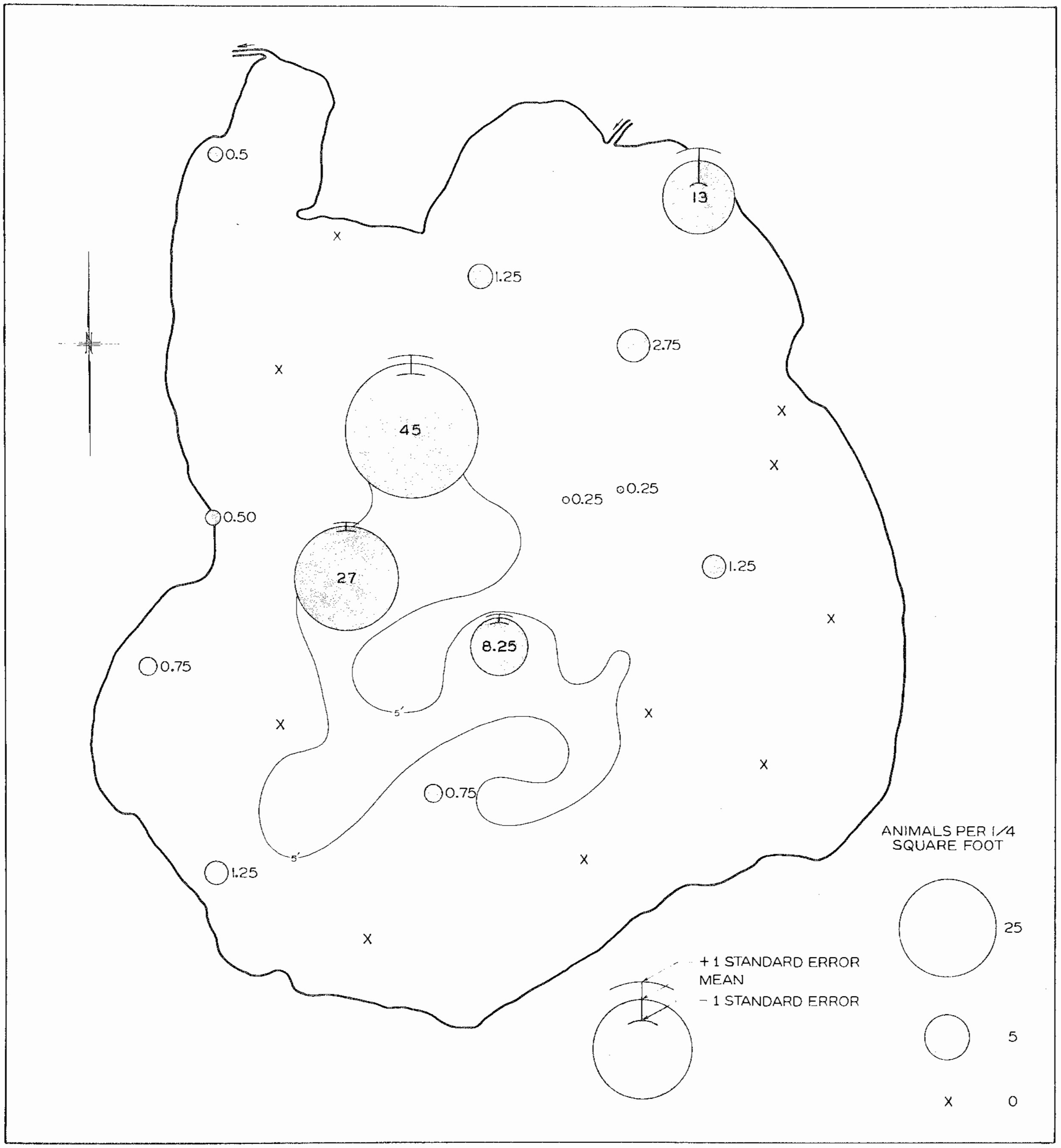

Fig. 6b

Fig. 5. Distribution and abundance of Clinotanypus sp. at 25 stations in Sugarloaf Lake. (For explanation see Figure 3.)

CLINOTANYPUS SP.

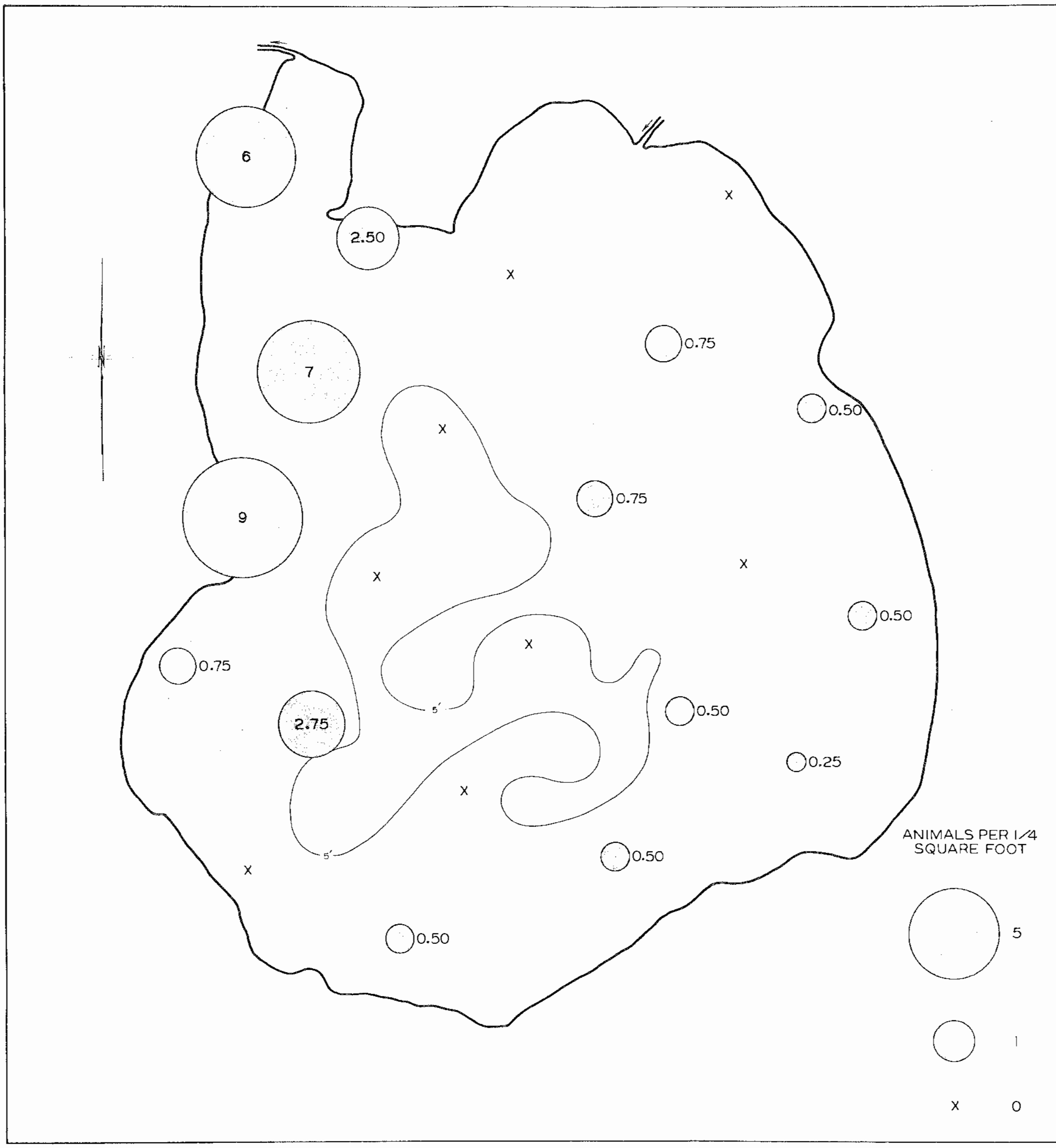

Fig. 5

Fig. 6. Distribution and abundance of Hexagenia sp. at 25 stations in Sugarloaf Lake. (For explanation see Figure 3.)

HEXAGENIA SP.

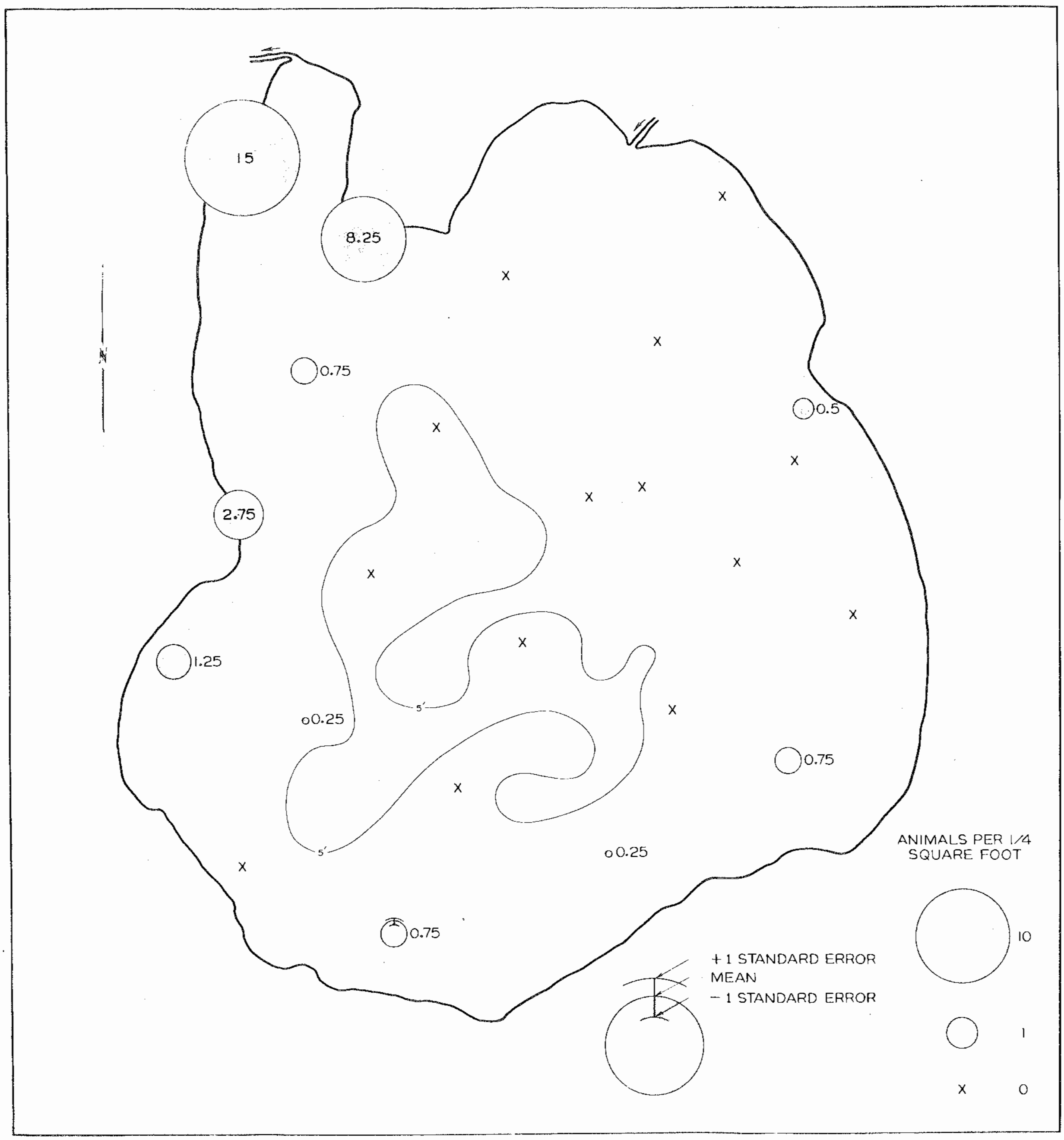

Fig. 5

Fig. 7a. Distribution and abundance of *Tanytarsus jucundus* at 25 stations in Sugarloar Lake. (For explanation see Figure 3.)

TANYTARSUS (TRIBELOS) JUCUNDUS

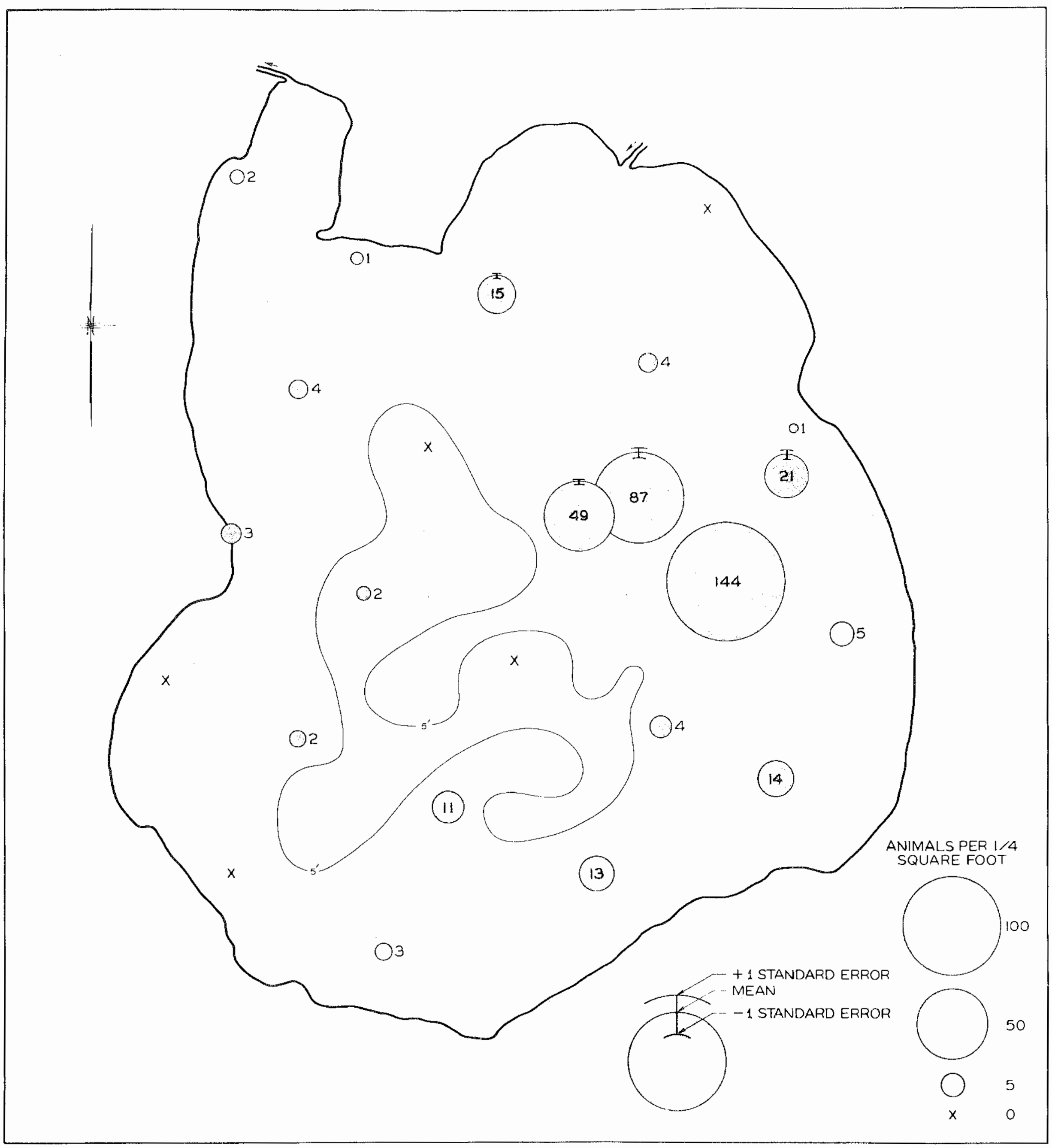

Fig. 7a

Fig. 7b. Distribution and abundance of _Glyptotendipes_ (sp.) at 25 stations in Sugarloaf Lake. (For explanation see Figure 3.)

GLYPTOTENDIPES SP.

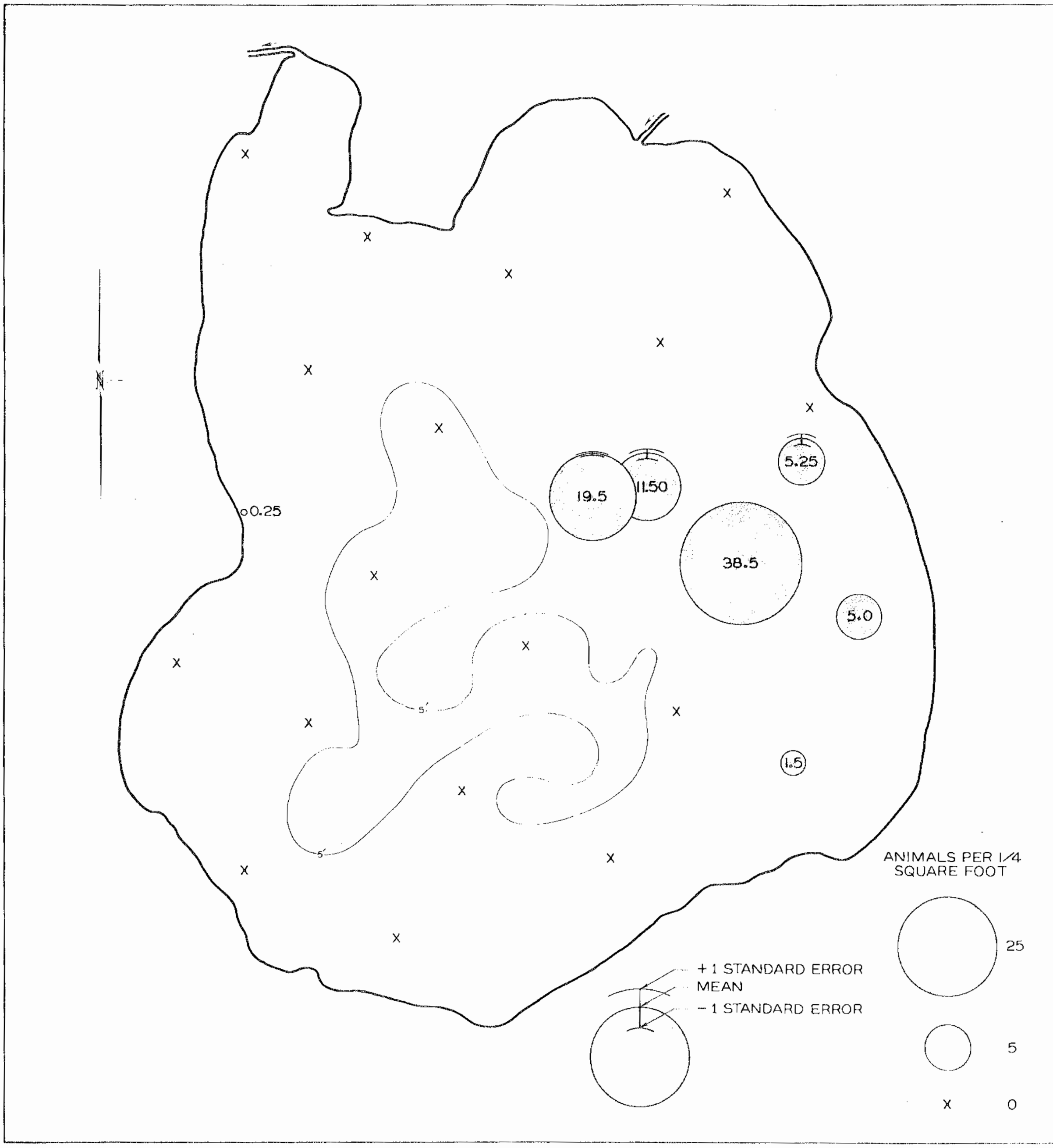

Fig. 71

Fig. 8. Benthic associations of the littoral zone of Sugarloaf Lake. Frequency and density of twelve of the more abundant invertebrates are shown for each association.

FREQUENCY—DENSITY GRAPH OF BENTHIC ASSOCIATIONS

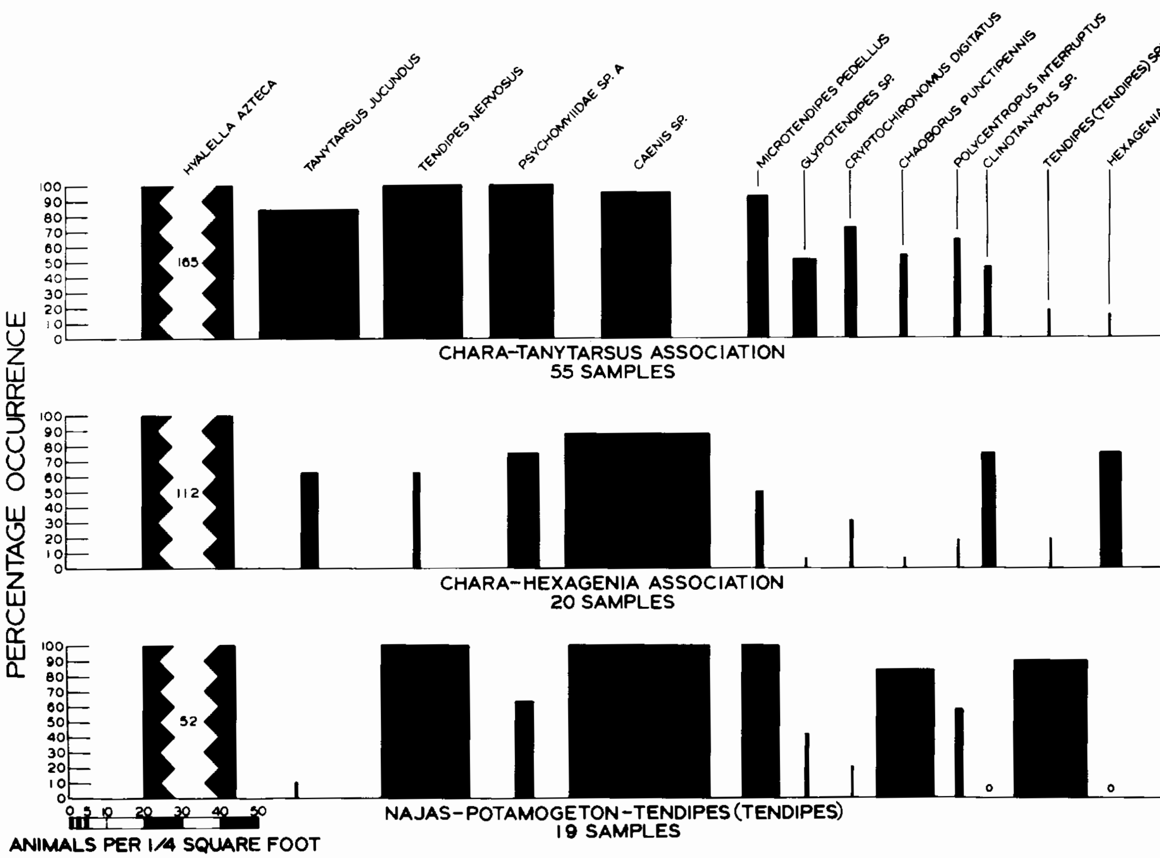

Fig. 9. Distribution and abundance of *Polycentropus interruptus* at 25 stations in Sugarloaf Lake. (For explanation see Figure 3.)

POLYCENTROPUS INTERRUPTUS

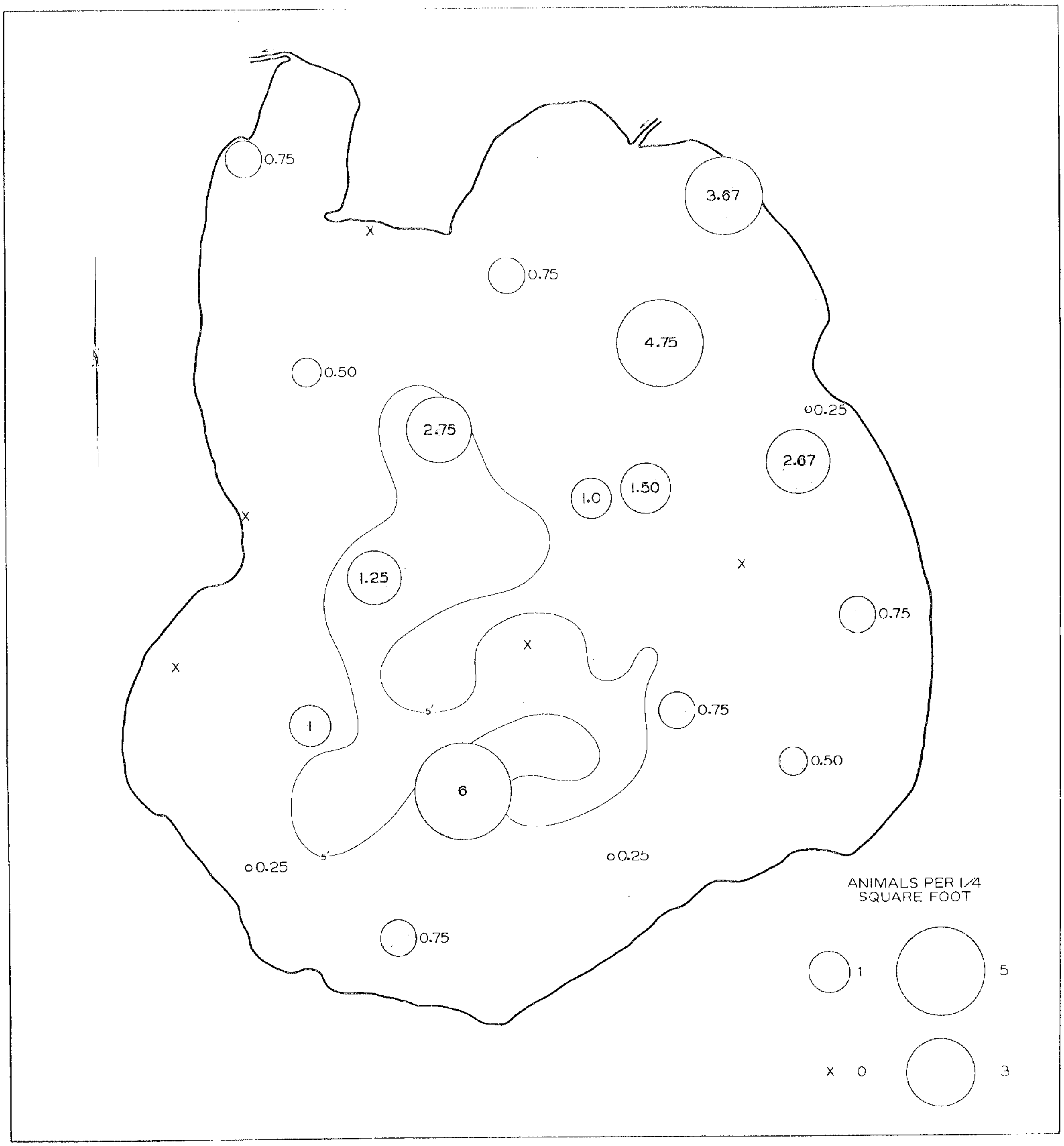

Fig. 9

Fig. 10. Distribution and abundance of Psychomyiid Genus A at 25 stations in Sugarloaf Lake. (For explanation see Figure 3.)

PSYCHOMYIID GENUS A

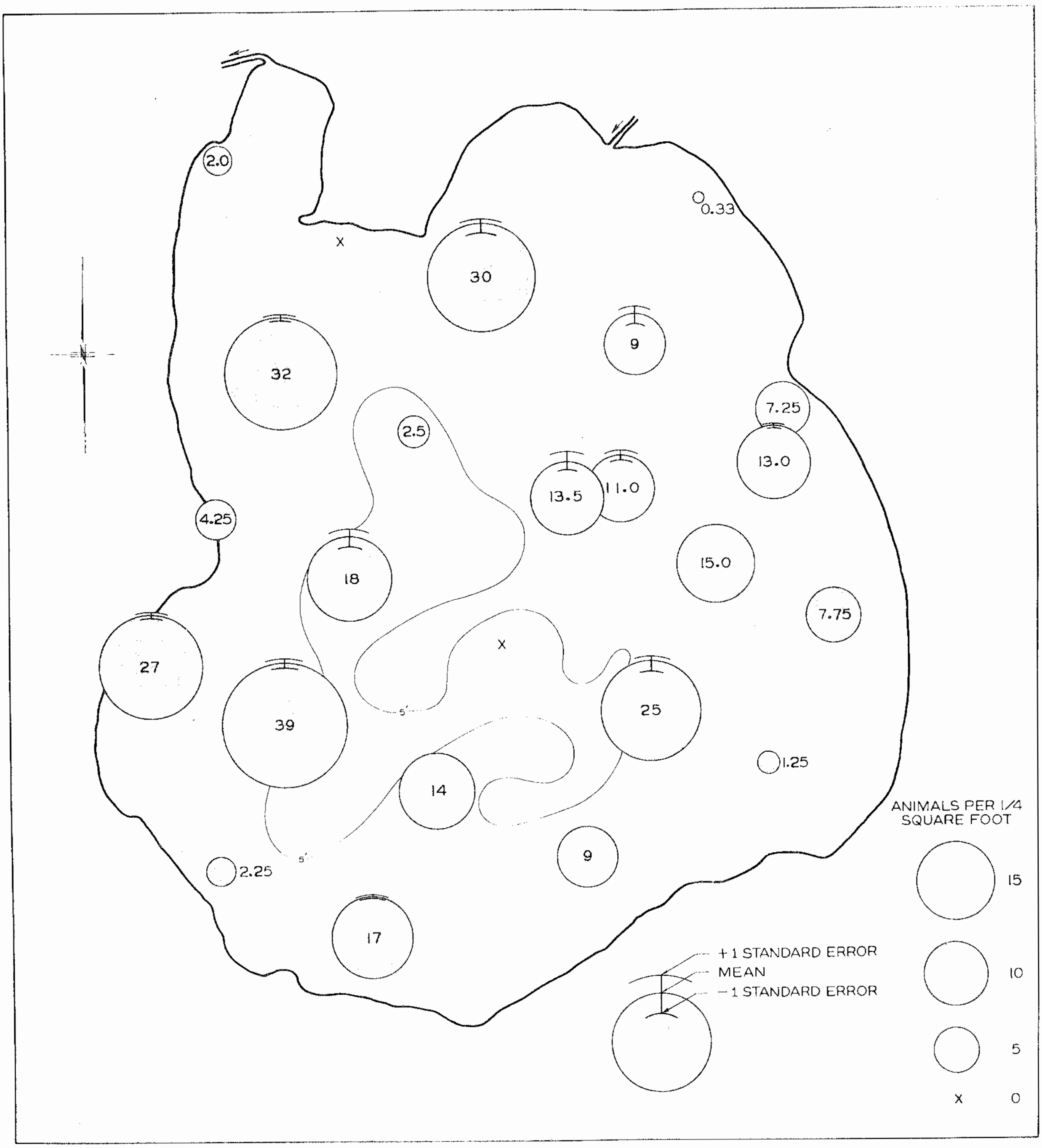

Fig. 10

Fig. 11. Distribution and abundance of _Tendipes_ (_Limnochironomus_) _nervosus_ at 25 stations in Sugarloaf Lake. (For explanation see Figure 3.)

TENDIPES (LIMNOCHIRONOMUS) NERVOSUS

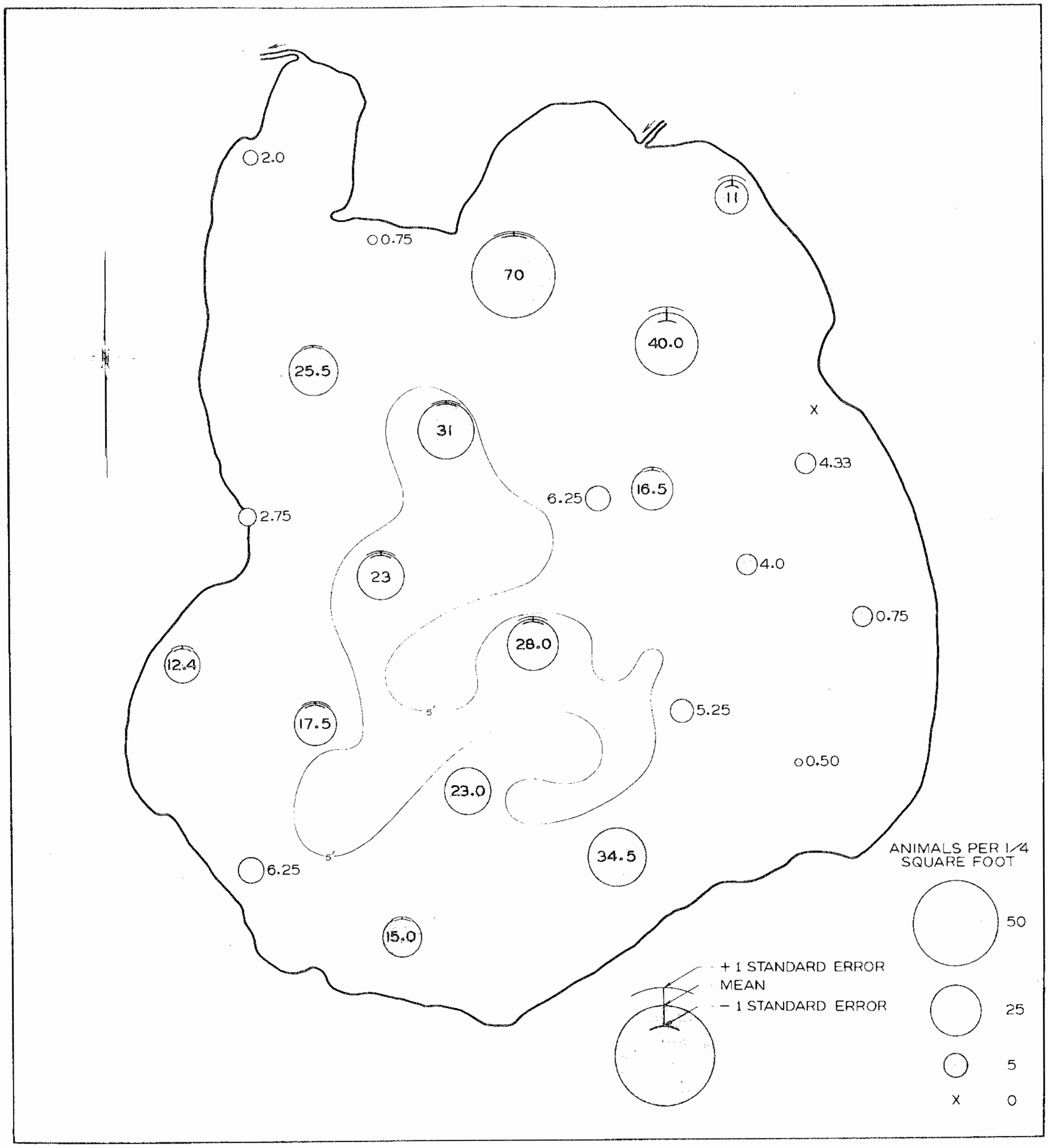

Fig. 11

Fig. 12 Distribution and abundance of *Microtendipes pedellus* at 25 stations in Sugarloaf Lake. (For explanation see Figure 3.)

MICROTENDIPES PEDELLUS

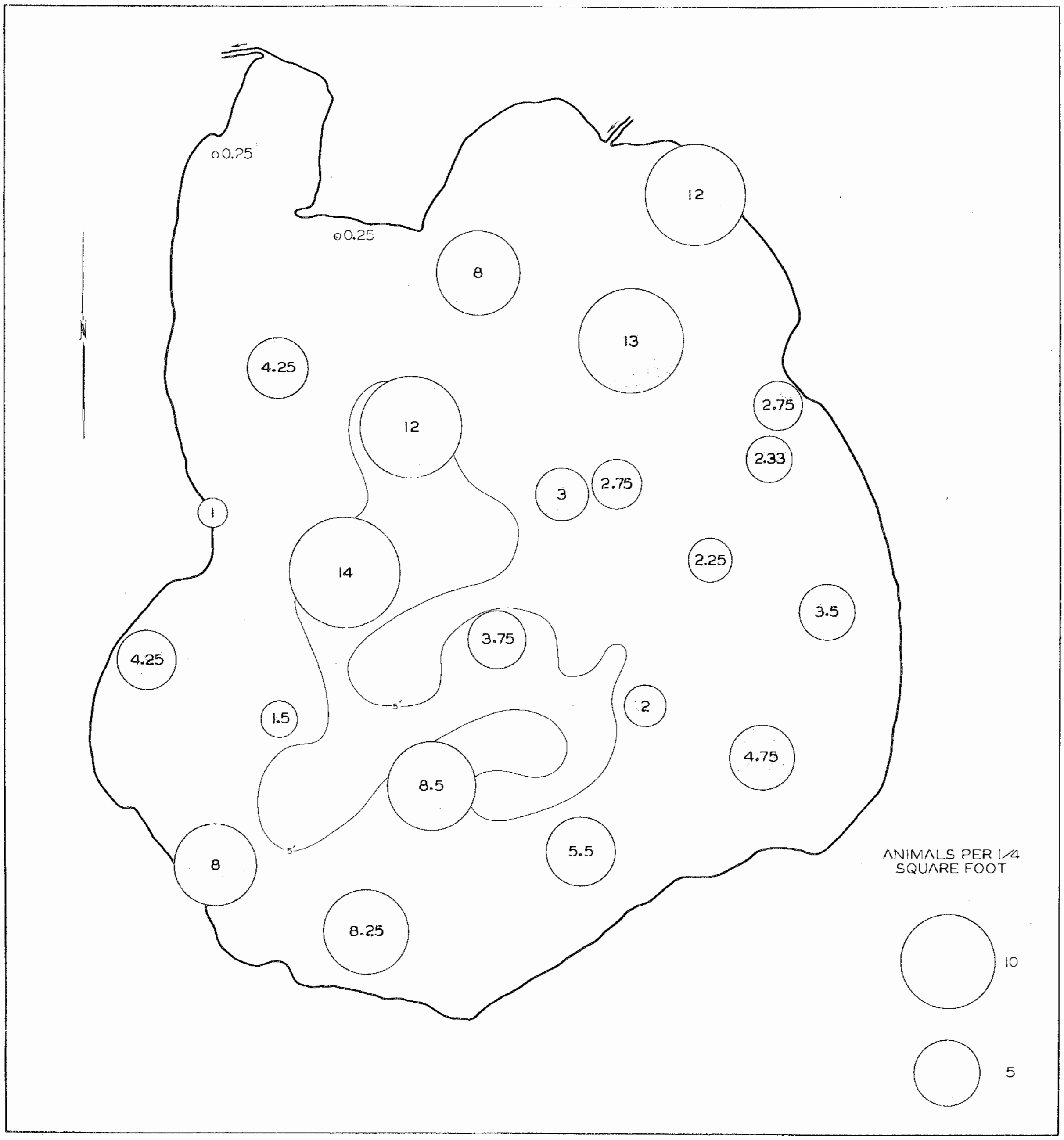

Fig. 12