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Dennis Kenji Shiozawa
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THE POPULATION DYNAMICS OF TANYPUS STELLATUS COQUILLET
(DIPTERA: CHIRONOMIDAE) IN GOSHEN BAY OF UTAH LAKE

A Thesis

Presented to the
Department of Zoology
Brigham Young University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
Dennis Kenji Shiozawa

April, 1975

This thesis, by Dennis Kenji Shiozawa, is accepted in its present form by the Department of Zoology of Brigham Young University as satisfying the thesis requirement for the degree of Master of Science.

8/15/74
Date

Typed by Janet Y. Shiozawa

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INTRODUCTION

The population dynamics of a species is related to environmental conditions as they exist within the geographic area of the population. The benthic community of a relatively uniform aquatic environment, such as a saline or eutrophic system, will be less complex since fewer niches are available or exploited. Williams (1972) discussed the lower complexity of salt lake ecosystems, and the decreased species diversity found in eutrophic and polluted waters is a well known occurrence. Jonasson (1965, 1972) selected a eutrophic lake (Lake Esrom) for his studies on benthic populations because of the uniform environment associated with this community.

Utah Lake, somewhat eutrophic and slightly saline at times, has a homogeneous benthic environment. The high turbidity of the lake makes the majority of the benthic community heterotrophic, since light can penetrate only a few feet. Most of the substrate is a soft, silty-clay in which the dominant macroinvertebrates are oligochaetes and chironomids. While some work has been done on this community (Barnes, et al., 1974), most of the in-depth work with the benthic macroinvertebrate populations of Utah Lake has been confined to the narrow eulittoral zone (Toole, 1974; Tillman and Barnes, 1973). This study is the first attempt to investigate, in detail, the population dynamics of a dominant chironomid, Tanypus stellatus, from the silty-clay community of Utah Lake.

DESCRIPTION OF STUDY SITE

Utah Lake is located in central Utah and covers an area of 388 square kilometers (Brown, 1969). In the past 40 years, the lake has been filling with sediment at an average rate of 3.3 centimeters per year (Brimhall, 1972). The lake is shallow; the average depth is 2.4 meters, and the deepest areas are no deeper than 3.7 meters (Bingham, 1974). It is polymictic, never stratifying during the ice free periods of the year. As a result of the continual mixing, the water is highly turbid. Secchi disk readings average 24 centimeters and range from about 50 centimeters to 12 centimeters or less. Yearly temperatures range from 0° C. to 30° C. (Tillman and Barnes, 1973). Ten to 15 centimeters of ice usually covers the lake from mid-December to late February (Barnes, et al., 1974).

Numerous saline springs flow into the lake basin, and the water exhibits both a high sulfate and carbonate content. The total dissolved solids of Utah Lake from 1961 to 1968 ranged from 795 milligrams per liter to 1,650 milligrams per liter (Bradshaw, et al., 1969). With the present conductivity level (1,400 micromhos) of the lake and assuming that the same ion is present, the total dissolved solids level is presently about 900 milligrams per liter. The U. S. Geological Survey (Hem, 1970) describes slightly saline lakes as having between 1,000 and 3,000 milligrams of dissolved solids per liter. It is apparent that in some years Utah Lake can be classified as a slightly saline lake.

In the past, the lake has been classified as being highly eutrophic. Studies now indicate that the lake's algal flora are not in

compliance with severe eutrophic conditions, especially the diversity of diatom species (Rushforth, 1974, personal communication). The lake is undoubtedly in some stage of eutrophication but not in the late stages as was previously believed. Goshen Bay, the southwest arm of Utah Lake, was selected as the study area (Figure 1). The substrate is composed of clayey, silty, lime mud with a few gastropod and bivalve shells present. Organic matter makes up 1.32 percent of the total weight of the top five centimeters. Sand makes up 3.29 percent by weight, and the remaining is silt and clay particles with a diameter of 0.062 millimeters (62 microns) or less (Bingham, 1974).

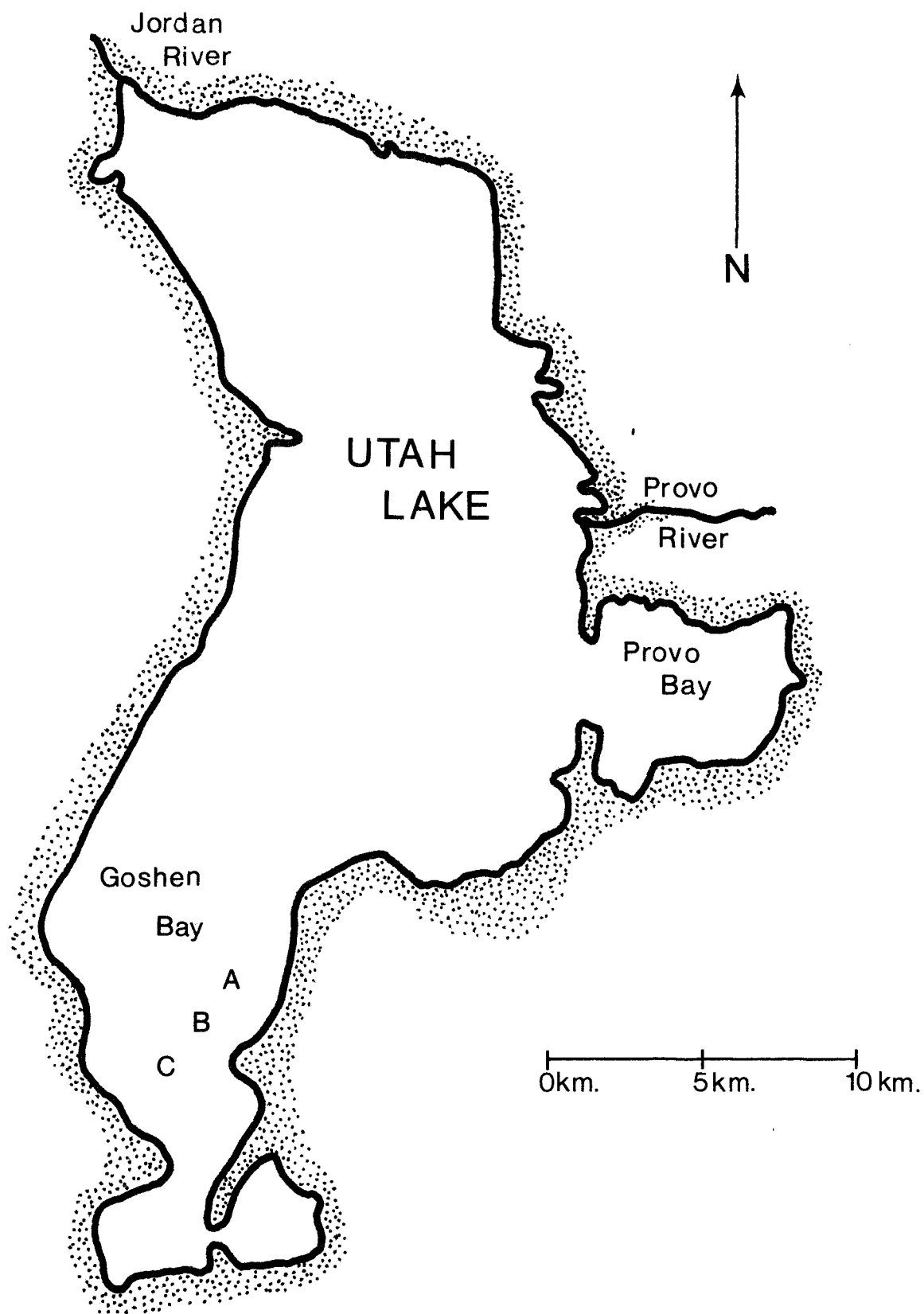


Figure 1

Map of Utah Lake Showing the Sampling Stations
A, B, and C in Goshen Bay

METHODS

Three sampling stations were established in Goshen Bay (Figure 1). Station A was sampled from July 18, 1973, to August 5, 1974. This station was sampled at weekly intervals, except during late fall and early spring. No samples were taken during the period of ice cover from December, 1973, to March, 1974. Two other stations, B and C, were sampled less frequently to help establish the general population trends in Goshen Bay.

Five replicate Ekman grab samples were taken at each station. The five replicates were sufficient to give a total population estimate (all species) within 20 percent of the mean, 95 percent of the time.

The samples were transported to the laboratory in buckets. The silt and clay were then removed by washing the sample through a 110 micron mesh nitex screen. This screen size will quantitatively retain all but the first instar larvae. The material was then live floated using a sucrose solution with a specific gravity of 1.12 (Anderson, 1959). Detergent was added to the sucrose solution to prevent the flotation of hydrophobic particles, such as empty ostracod shells (Schwoerbel, 1970).

The floated samples were preserved in a ten percent formalin solution with fast green stain added. All samples were handpicked under a dissecting scope at 15 times magnification. Larvae, egg cases, and pupae were preserved in 70 percent ethyl alcohol. Later they were separated to instar using head capsule measurements. While being measured, the larvae were sorted to species. Specimens from one Ekman sample were mounted in Hoyer's medium (Roback, 1971) to confirm identification.

K-B core samples were taken monthly at stations A, B, and C to determine the vertical distribution of the chironomid larvae in the substrate and to compare the corer efficiency to the efficiency of the Ekman grab in sampling the Tanytus population. Five replicate samples were taken at each station. Removable plastic tube liners were used with the corer. The core was sectioned immediately to minimize vertical movement of the larvae. Each core was sectioned into ten parts. The first eight sections were 2.5 centimeters in length, and the last two were five centimeters long. The samples were washed through a 110 micron mesh screen and then preserved in a ten percent formalin solution with fast green stain added. Further processing followed the same procedures used with the Ekman samples

Water temperatures were taken with a YSI temperature-conductivity meter.

RESULTS AND DISCUSSION

Vertical Distribution

The vertical distribution of Tanypus stellatus instars is given in Table 1. Ninety-six percent of the T. stellatus larvae are located in the top five centimeters of the mud. Second instar larvae were found as deep as 15 centimeters, and fourth instar larvae were found as deep as 17.5 centimeters. Ninety-nine percent of the total T. stellatus population was found less than ten centimeters deep. These findings agree with previous work on the vertical distribution of chironomids (Ford, 1962; Cole, 1953; Kajak and Dusoge, 1971).

The purpose in determining vertical distribution was to evaluate the efficiency of the Ekman grab in collecting Tanypus stellatus larvae. Consideration of the vertical distribution of an organism is an important part of a quantitative sampling program (Ford, 1962). The Ekman grab penetrated to a depth of 12 to 15 centimeters which was sufficient to collect over 99 percent of the larvae.

Spatial Distribution

The spatial distribution of the various instars on the bottom is another important consideration in a life history study. Not only will it be related to the accuracy of the sampling program (Patterson and Fernando, 1971), but it may also indicate the relationships between various instars. As previously stated, the five Ekman samples per station were sufficient to estimate the total dominant chironomid population, which consists of three species, within 20 percent of the mean,

Table 1
The Vertical Distribution* of Tanypus stellatus
in the Bottom Sediments of
Goshen Bay, Utah Lake

Depth (cm.)	1st	2nd	Instar 3rd	4th	Pupae	Total
0-2.5	615	206	58	8	1	888
2.5-5.0	38	30	17	25	0	110
5.0-7.5	0	1	3	17	0	21
7.5-10.0	3	1	2	2	0	8
10.0-12.5	0	1	0	3	0	4
12.5-15.0	0	1	0	1	0	2
15.0-17.5	0	0	0	1	0	1
17.5-20.0	0	0	0	0	0	0
20.0-25.0	0	0	0	0	0	0
25.0-30.0	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>
INSTAR TOTALS	656	240	80	57	1	1,034

*These data are summed for 105 cores taken on the following dates:
September 13, 1973; October 18, 1973; November 15, 1973; April 5, 1974;
May 1, 1974; June 5, 1974; and July 1, 1974.

95 percent of the time. Less accuracy can be expected when looking at a single species. Tables 2, 3, 4, and 5 give the mean population estimate per square meter and the spatial distribution of each instar of Tanypus stellatus for each sampling date. Randomness of each instar on a given sampling date was determined using the variance to mean ratio (Elliott, 1971). Standard methods were used to determine the confidence levels for randomly distributed instars. The contagious samples were first transformed with a $\log (X + 1)$ transformation, and the resulting geometric confidence value was applied to the arithmetic mean (Elliott, 1973, personal communication).

Approximately one-half of the samples of first instar larvae showed a contagious distribution. This contagious distribution is more frequent when the first instar population is at high density levels. Clumping could be caused by a tendency for the first instar to remain near the egg masses. Laboratory studies have shown that first instar larvae of some chironomids tend to be free-swimming for a time after hatching (Oliver, 1971; Danks, 1971a), and if this is so, clumping could be due to the larvae selecting certain substrate types after a short pelagic existence. If so, the swimming response could not be photaxic (Oliver, 1971; Danks, 1971a), since no light penetrates to the bottom of Utah Lake. A third, and possibly more important factor, is that the screen size used in this study did not quantitatively retain the first instar larvae. It is highly probable that early first instar larvae were lost, and older first instar larvae were retained, since the diameter of the body increases with age.

One-sixth of the second instar had a contagious distribution. Clumping of the second instar also occurs during higher population den-

Table 2

Population Estimates and Spatial Distribution of
First Instar Tanypus stellatus Larvae

Date	Mean Number/m ²	95% Confidence Level	Spatial Distribution
7-18-73	62	23-103	Contagious
7-26-73	114	0-233	Random
8-1-73	248	0-558	Random
8-8-73	77	0-392	Random
8-15-73	361	160-817	Contagious
8-22-73	330	0-926	Random
8-29-73	733	248-2,163	Contagious
9-8-73	877	278-1,476	Random
9-13-73	702	89-1,315	Random
9-20-73	1,600	763-3,352	Contagious
9-27-73	2,890	1,965-4,248	Contagious
10-18-73	1,362	656-2,830	Contagious
11-8-73	3,612	1,738-5,490	Contagious
3-26-74	1,567	1,004-2,445	Contagious
4-5-74	2,023	744-3,302	Random
4-17-74	1,125	655-1,932	Contagious
4-24-74	1,437	907-2,276	Contagious
5-1-74	3,185	2,062-4,920	Contagious
5-8-74	1,229	495-1,963	Random
5-15-74	2,398	1,383-3,412	Random
5-23-74	2,043	1,133-3,683	Contagious
5-29-74	2,458	1,477-3,440	Random
6-5-74	459	0-973	Random
6-12-74	173	0-523	Random
6-19-74	35	0-135	Random
6-26-74	0	-----	-----
7-1-74	0	-----	-----
7-11-74	35	0-88	Random
7-16-74	35	0-135	Random
7-23-74	147	0-308	Random
7-30-74	658	322-1,344	Contagious
8-5-74	156	0-480	Random

Table 3

Population Estimates and Spatial Distribution of
Second Instar Tanypus stellatus Larvae

Date	Mean Number/m ²	95% Confidence Level	Spatial Distribution
7-18-73	144	0-401	Random
7-26-73	227	0-467	Random
8-1-73	454	0-1,022	Random
8-8-73	310	0-829	Random
8-15-73	248	61-434	Random
8-22-73	423	0-1,075	Random
8-29-73	330	0-690	Random
9-8-73	485	0-1,063	Random
9-13-73	826	340-1,311	Random
9-20-73	1,022	364-1,479	Random
9-27-73	1,300	930-1,671	Random
10-18-73	1,373	159-2,586	Random
11-8-73	1,434	337-2,532	Random
3-26-74	1,203	849-1,558	Random
4-5-74	1,818	1,095-3,017	Contagious
4-17-74	935	135-1,735	Random
4-24-74	1,304	812-1,797	Random
5-1-74	710	348-1,450	Contagious
5-8-74	892	556-1,227	Random
5-15-74	1,021	191-1,852	Random
5-23-74	1,091	563-2,111	Contagious
5-29-74	1,705	1,066-2,344	Random
6-5-74	2,579	1,920-3,466	Contagious
6-12-74	2,753	2,068-3,664	Contagious
6-19-74	935	343-1,527	Random
6-26-74	32	0-184	Random
7-1-74	0	-----	-----
7-11-74	78	0-178	Random
7-16-74	26	0-92	Random
7-23-74	208	0-619	Random
7-30-74	770	48-1,493	Random
8-5-74	563	0-2,125	Random

Table 4

Population Estimates and Spatial Distribution of
Third Instar Tanypus stellatus Larvae

Date	Mean Number/m ²	95% Confidence Level	Spatial Distribution
7-18-73	144	25-264	Random
7-26-73	477	194-1,172	Contagious
8-1-73	454	83-825	Random
8-8-73	555	0-1,269	Random
8-15-73	506	215-1,187	Contagious
8-22-73	258	0-526	Random
8-29-73	402	92-713	Random
9-8-73	41	0-198	Random
9-13-73	21	0-78	Random
9-20-73	62	0-126	Random
9-27-74	77	2-153	Random
10-18-73	62	0-126	Random
11-8-73	72	0-200	Random
3-26-74	9	0-62	Random
4-5-74	87	0-338	Random
4-17-74	78	0-178	Random
4-24-74	26	0-133	Random
5-1-74	17	0-125	Random
5-8-74	43	0-92	Random
5-15-74	17	0-83	Random
5-23-74	104	0-255	Random
5-29-74	302	48-558	Random
6-5-74	710	248-1,172	Random
6-12-74	1,082	258-1,906	Random
6-19-74	3,601	2,804-4,624	Contagious
6-26-74	2,026	761-3,290	Random
7-1-74	554	294-814	Random
7-11-74	69	0-193	Random
7-16-74	95	0-293	Random
7-23-74	104	0-334	Random
7-30-74	364	0-898	Random
8-5-74	1,238	289-2,186	Random

Table 5

Population Estimates and Spatial Distribution of
Fourth Instar Tanypus stellatus Larvae

Date	Mean Number/m ²	95% Confidence Level	Spatial Distribution
7-18-73	662	274-1,050	Random
7-26-73	539	0-1,232	Random
8-1-73	1,201	425-1,976	Random
8-8-73	1,108	712-1,504	Random
8-15-73	1,066	775-1,357	Random
8-22-73	920	499-1,341	Random
8-29-73	516	0-1,153	Random
9-8-73	381	126-637	Random
9-13-73	269	0-569	Random
9-20-73	146	0-355	Random
9-27-73	56	0-212	Random
10-18-73	34	0-173	Random
11-8-73	11	0-81	Random
3-26-74	0	-----	-----
4-5-74	0	-----	-----
4-17-74	0	-----	-----
4-24-74	0	-----	-----
5-1-74	0	-----	-----
5-8-74	0	-----	-----
5-15-74	0	-----	-----
5-23-74	0	-----	-----
5-29-74	9	0-62	Random
6-5-74	9	0-62	Random
6-12-74	17	0-83	Random
6-19-74	528	135-921	Random
6-26-74	1,872	1,379-2,541	Contagious
7-1-74	2,640	2,010-3,270	Random
7-11-74	2,199	1,636-2,954	Contagious
7-16-74	1,688	777-2,599	Random
7-23-74	857	626-1,088	Random
7-30-74	528	0-1,100	Random
8-5-74	615	212-1,017	Random

sities. This clumping could be a carry-over from the first instar distribution. Both third and fourth instar larvae show about one-tenth of the samples contagiously distributed. These, too, occur during periods of highest density.

The general distributional pattern of this species appears to be one of a contagious distribution in early instars, during periods of highest numbers, with a gradual randomization of the later instars possibly due to water movement caused by the wind, feeding activity, and competition with other larvae. By the time the fourth instar is reached, the larvae are exploiting most of the habitat available to them.

Population Dynamics

The population trends of the different instars of Tanypus stellatus are shown in Figure 2 (see also Tables 2, 3, 4, and 5). The populations at stations B and C show higher numbers in both the first and second instars than are found at station A. This is also true for the third and fourth instars during 1973. The third and fourth instar trends for 1974 at B and C show a lag when compared with station A. Because fewer samples were taken at stations B and C, only a rough estimation of the population trends can be made from these areas. The general trends do appear to be the same as found at station A, but slight time differences are apparent.

Since station A was the most intensively studied of the three sites, emphasis will be placed on the analysis of the Tanypus stellatus population from this area (Figure 2). When sampling began on July 18, 1973, fourth instar larvae were predominant. The presence of first and second instar larvae indicated an emergence prior to this time. The

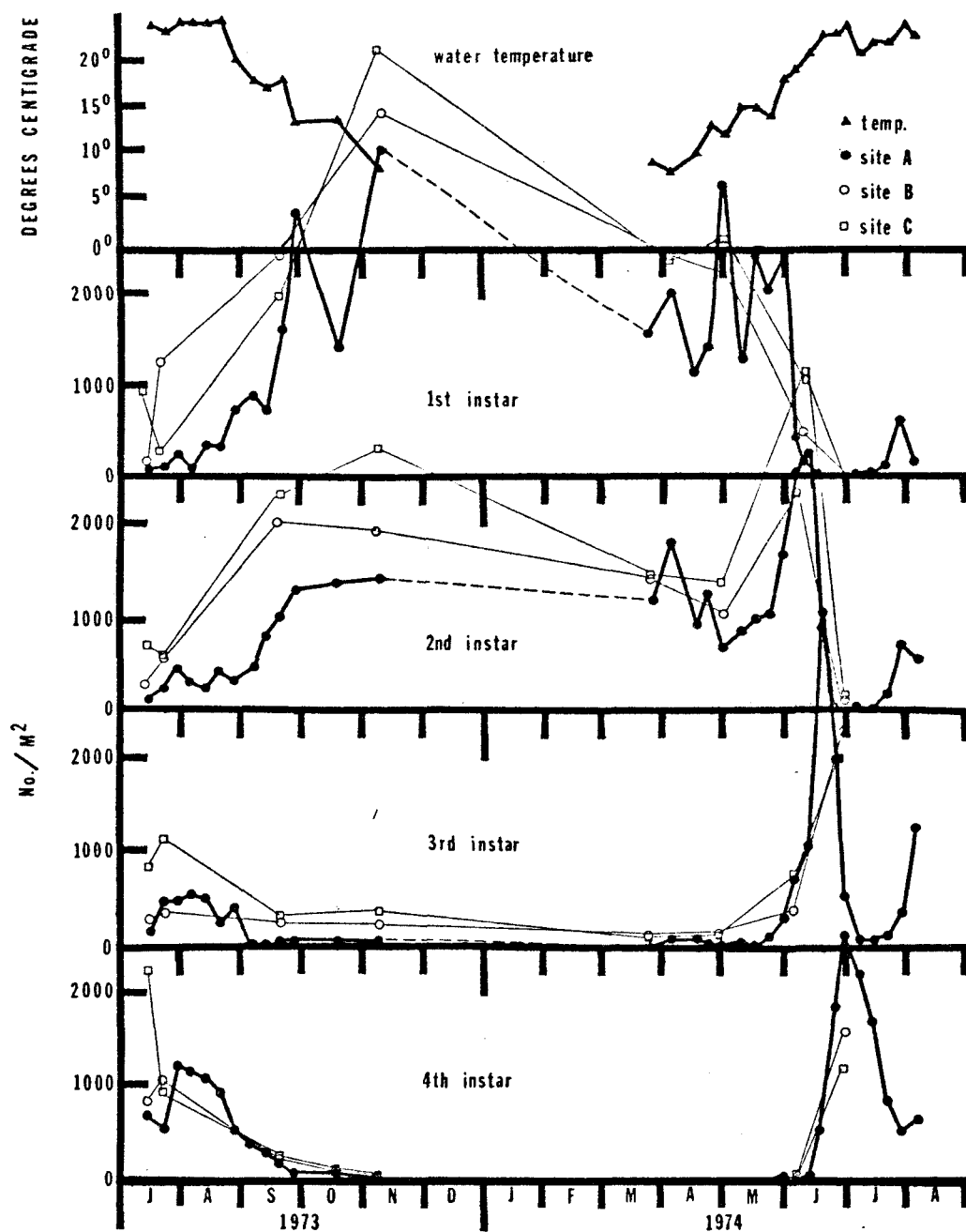


Figure 2

Instar Density of *Tanypus stellatus* and Water Temperature
in Goshen Bay, Utah Lake from
July, 1973 to August, 1974

fourth instar increased until August 1, 1973, after which a steady decline in numbers occurred. This decline was due to an emergence which lasted through September and possibly into early October. The numbers of third instar larvae during this same period showed an increase in early August and then decrease into early September. This instar was lower in numbers than the fourth instar which could be due to a rapid growth rate into and out of the third instar and a longer fourth stadium. Both the first and second instars are of short duration during periods of high temperature in the lake. This is indicated by a slow increase in density of these two instars, while the third and especially fourth instars show a rapid increase in numbers.

In late August when the temperature of the lake begins to decrease (Figure 2), the numbers of early instars begins to increase. This is due to longer early instar stadiums at lower temperatures. Coinciding with the increased numbers of early instars are a decrease in numbers of both third and fourth instars due to the above mentioned emergence and reduced recruitment into these life stages. The change from first to second instar continues, however, and both groups show a rapid increase in numbers into late September. When the water reaches a temperature of 13° C. in late September, recruitment into the second instar stops. The large fluctuations in numbers of first instars at this time is due to a high tendency towards a contagious distribution (Table 2). Both the third and fourth instar groups are in very low numbers at this time and show no significant increase into November.

The overwintering of chironomids in more than one instar is often found, though one instar may predominate (Danks, 1971b) and which instar may depend on when decreasing temperatures arrest their growth. In Utah

Lake, this temperature appears to be around 13° C. Overwintering in 1973 occurred mainly in the first and second instar stages and also in a minimal number of third instars. Heuschele (1969) felt that Tanypus stellatus laid an overwintering egg which hatched in the spring. The screen used in washing had a mesh opening of 0.42 millimeters. This may not quantitatively retain even the third instar of T. stellatus which has a head capsule width of about .25 millimeters. Heuschele's conclusion, based on the use of a relatively large sieve, is partially in error since first and second instars were not collected.

When sampling resumed on March 26, 1974, the density of the first instar had decreased by about 800 per square meter, and the second instars had decreased by about 200 per square meter from the last sample taken previous to the lake freezing or icing over. Third instars were collected in numbers of nine per square meter, down from 72 per square meter in November. Fourth instar larvae were absent from the population at this time. The first and second instar populations continued to decrease in numbers into late April. On May 1st, the numbers of first instars began to increase. Whether this is due to the migration of larvae from surrounding areas, the contagious distribution of the population, the growth to catachable size, or hatching of overwintering eggs is not known. It is interesting to note that at this time, the lake temperature was 13° C., which was the temperature at which growth was arrested in the fall. Following May 1st, the second instar population also began to increase in numbers. During the first week of June with water temperature around 16° C., the numbers of first instars decreased, and the second instars increased rapidly. Maximum numbers of second instars were found one week later. At this time, the numbers of third instars

began to increase. Fourth instar larvae were also beginning to be collected but at very low numbers.

On June 19th, one week after the numbers of the second instar peaked, their numbers decreased by two-thirds, and the third instar reached their maximum density. The water temperature at this time was 23° C. Two weeks later, on July 1st, maximum numbers of fourth instars were collected. At this time, no first or second instar larvae were present. A large emergence began in the first week of July, and the numbers of fourth instar larvae continued to decrease until the end of July. During this same period, the numbers of first, second, and third instars began to increase rapidly and tended to parallel the densities recorded a year ago. The numbers should build to a second emergence in August. This pattern of a large July emergence and a smaller August-September emergence agrees with Heuschele (1969) and may be a general pattern for Tanypus stellatus found in shallow, temperate lakes.

CONCLUSIONS

The Ekman grab is suitable for collecting Tanypus stellatus quantitatively in Utah Lake since 99 percent of the larvae are less than ten centimeters deep.

The first instar larvae, when at high densities, are contagiously distributed. This distribution becomes more random as the later instars are reached. By the third and fourth instar, the population has become essentially randomly distributed.

The basic population trends seen at station A are also present at stations B and C, though differing slightly in densities and later instars. From this, it appears that the population trends shown here are applicable throughout Goshen Bay.

In the Goshen Bay area, Tanypus stellatus overwinters as first and second instar larvae with the majority of the population being in the first instar. Some eggs may overwinter, but this is not definitely known. Development in the spring does not occur to a great extent until late April when the temperature increases to 13° C. At this time, an increase in the first instar population can be seen.

The developmental rates of the instars increase with increasing temperature, and by June, distinct first, second, and third instar pulses can be seen. By early July, the first summer emergence is underway. There is a period of two weeks when no first instars are present. Then the first, second, and third instars begin to increase rapidly. Instar duration is less than a week at this time due to high water temperature.

These give rise to a second generation in August. This second generation emerges in mid-August to late September and produces the larvae which overwinter as first and second instar.

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THE POPULATION DYNAMICS OF TANYPUS STELLATUS COQUILLET

(DIPTERA: CHIRONOMIDAE) IN GOSHEN BAY OF UTAH LAKE

Dennis Kenji Shiozawa

Department of Zoology

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ABSTRACT

The population dynamics of Tanypus stellatus in Goshen Bay of Utah Lake was investigated from July 18, 1973, to August 5, 1974. Samples were collected from three stations with an Ekman grab and a K-B corer. The samples were washed in a 110 micron nitex screen and then floated in a sucrose solution. The K-B core was used to determine the vertical distribution of Tanypus stellatus. Ninety-six percent of the Tanypus stellatus larvae are located in the top five centimeters; 99 percent are less than ten centimeters deep.

The Ekman grab was used to study the population dynamics of the larvae. The population trends observed are likely true for the entire bay and possibly the lake also. Early instar larvae tend to be contagiously distributed and later instars are more randomly distributed. Two emergence periods occurred. One in July and one in August. Larvae overwintered in the first and second instar. Possible temperature relationships are also discussed.

COMMITTEE APPROVAL:

VITAE