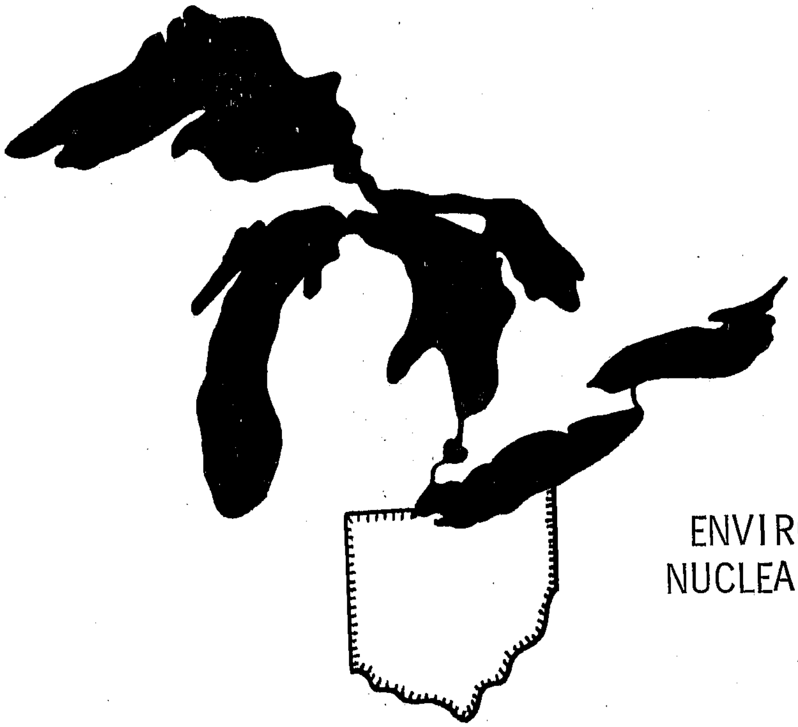
CLEAR TECHNICAL REPORT NO. 148



ENVIRONMENTAL EVALUATION OF A NUCLEAR POWER PLANT ON LAKE ERIE

ANNUAL REPORT - 1974
STUDY III
F-41-R-5

Prepared for

U. S. Fish and Wildlife Service
and
Ohio Department of Natural Resources
Division of Wildlife

Prepared by

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THE OHIO STATE UNIVERSITY
CENTER FOR LAKE ERIE AREA RESEARCH
COLUMBUS, OHIO

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F-41-R-5

STUDY III

The Ohio State University
Center for Lake Erie Area Research

ENVIRONMENTAL EVALUATION OF A NUCLEAR POWER PLANT ON LAKE ERIE

Federal Aid Project F-41-R-5

Performance Report

State: Ohio

Study No. III

Prepared by:
David C. Robb
Charles E. Herdendorf

Study Title: Model Development for Determination of Fish Reactions to Thermal Plumes

Period Covered: 1 June 1973 to 31 May 1974

ABSTRACT

A steady state model has been developed to predict fish behavior in the anticipated thermal plume from Unit 1 at the Davis-Besse Nuclear Power Station. A series of density function plots have been prepared which permit the determination of the probable location of individual species within the plume under given seasonal temperatures.

CONTENTS

STUDY OBJECTIVE

The study is designed to develop a reliable predictive model for use in fisheries management in areas of thermal discharge plume from nuclear power plants.

JOBS III-a and III-b

DESIGN OF A BASIC PREDICTIVE MODEL IN THE VICINITY OF THERMAL DISCHARGE PLUMES

REFINEMENT AND EXPANSION OF THE BASIC MODEL

Objectives

The initial model is intended to show the expected distribution of fish populations in the area under specified environmental conditions. This model will be computer generated from field sampling data and fish thermal preference data from Studies I and II of this project.

Procedures

The procedure for construction of the model was as follows. From a series of observations following the first appearance of the steady state, a mean preferred temperature and standard deviation were calculated. Then using this information, a normal curve was constructed and ordinate values for each centigrade temperature increment from $0^{\circ}C$ to $40^{\circ}C$ was calculated. This was done for all reliable data available for the species tested in study II. Data for the calculations were selected from study II data on the basis of completeness of observation, stability of the steady state, gradient stability, fish condition as evidenced by mortality and any other factors which might significantly have biased the results.

The above calculations formed the data base from which all subsequent reductions were made.

Perhaps the most obvious of these reductions are the contour plots of expected fish densities which were prepared in the following manner. First, a model of a typical thermal plume expected for a particular set of conditions was produced by phenomenological calculations based on temperature fall-off rates observed for several other operating power plants. An array of the temperatures at various points was used to select corresponding ordinate values from the above preference calculations. The ordinate value at the ambient temperature was used as the typical undisturbed lake value of density and was thus normalized to one. The same normalization factor was applied to all other ordinate values to give a set of multiplier values for fish density. These were then passed to a computer routine which performed the contour calculations and prepared the plots.

Findings

The application of the model is straight forward and will be presented in a stepwise form here.

Use of Contour Plots:

1) First determine the appropriate season class by consulting the chart on the first page of Appendix II and comparing it with the observed or expected lake temperature.

2) Next determine the species of interest.

3) Locate the density plots for the selected species in the appropriate season section. The order is winter, spring, summer, and fall, with a plot of plume thermal structure for the average conditions of that season being the last page of that season.

4) The plots may be rescaled as needed, but were initially drawn at 50 m/in.

5) The annotations in Appendix I should be checked to determine the the contour intervals and any other pertinent information.

6) To determine expected fish density at any point in the plume, the density value of that point taken directly from the plot should be used. This is then multiplied by the normal density of that species in the surrounding lake to obtain the expected density.

7) Consult the analysis section of this report for limitations on this estimate.

Use of the Ordinate Tables:

1) Steps 1 and 2 of the previous instructions should be followed to determine season and species.

2) The ordinate tables of Appendix III should be consulted for the species of interest in the appropriate season. The values given are the ordinates of the normal curve in 1°C increments beginning with 1.0. The E stands for Exponent e.g. .1359 E-03 = $.1359 \times 10^{-3}$.

3) Select the point in the table nearest to the desired ambient lake temperature. This is the ambient ordinate.

4) Select a second point for the temperature nearest the temperature of interest.

5) The density factor is calculated by dividing the ordinate of interest by the ambient ordinate.

6) Use this factor as in steps 6 and 7 of the previous instructions.

STUDY ANALYSIS

The steady state condition of a system is defined as that state wherein the mean and standard deviation of the observed distribution do not change significantly with time. That is, when all observed variables appear to stablize and remain constant or at most exhibit only minor fluctuations. An examination of study II data indicates that the mean observed temperature and the standard deviation about that mean for a group of fish in a thermal gradient stabilize after a period of about 24-72 hours depending on species. This then qualifies as a steady state condition. Further more, the distribution of fish about the mean preferred temperature appears to be, within statisical limits, a normal or Gaussian distribution. With this in mind a Gaussian steady state model was devised.

Application of the Steady State Model

The purpose of construction of a model is many faceted. Given the virtually infinite diversity of conditions in nature as well as the often frustrating uncontrollability of these conditions during experimentation, it is often desirable to have some system which mirrors the behavior and reactions of nature, but which allows control of conditions at the discretion of the experimenter. Also, the process of model construction may bring about awareness of hithertoo unseen processes or undiscovered relationships in that which is being modeled. Then there is the fact that it is certainly much less expensive both in terms of money and in the possibility of irrevocable errors to experiment on a model which accurately reflects a complex system than on the system itself. It is for these reasons that a steady state model of fish behavior in a thermal plume has been constructed. This hopefully will be a prelude to construction of a more refined model which would eliminate the flaws and inaccuracies in the present one.

There are several significant sources of error which can and do arise in the preparation and interpretation of these results. First, there is the normal statistical error arising from reduction of the raw data. This was minimized as much as possible by judicial selection of data and by application of appropriate techniques of data grouping and organization. Next, there is the possibility of calculational error. Use of a computer, and careful checking of all equations and their programmed equivalents assured that this error did not appear in any of the significant figures of the output. Finally, and most importantly, there occurs the problem of uncontrolled variables. Since only the behavior of a single species at a time in a linear thermal gradient was observed, there is no direct estimation of the magnitude of effect of other variables such as species interaction on the observed distribution. From background work and observation it should be noted that these other factors can have effects ranging from negligible to several orders of magnitude. Accordingly, the following limitations have been set on the results. Where the maximum density factor is less than ~ 50 times normal density, the estimations may be regarded as probably 80-90% accurate ($\pm$ 10-20%). Between 50 and 100, accuracy is probably 50-70%. For factors greater than 100, it is very probable that the influence of other variables would be at least as large as that of thermal preference and all that may be said is that qualitatively there will probably be a large increase in the numbers of that particular species in the area, but the exact magnitude cannot be estimated at this time.

STUDY RECOMMENDATIONS

It is suggested that this study be continued with the aim of producing a more comprehensive model of fish behavior which incorporates compensation for selected variables in addition to thermal preference. This would allow more accurate assessment of the power plant effects, thus aiding the job of fisheries management in the area.

APPENDICES

APPENDIX I

ANNOTATIONS AND COMMENTS

APPENDIX I

ANNOTATIONS AND COMMENTS

SEASON Species	Acclimation Temperature	Preferred Temperature	Contour Interval	Max. Density Factor
WINTER				
Perca flavescens	4.0	13.0	537.4	5374.8
Notropis atherinoides	4.0	6.5	71.8	719.2
Pomoxis nigromaculatus	5.0	21.5	12.7	128.0
Lepomis macrochirus	4.9	27.5	$.4\times10^{21}$	$.4\times10^{21}$
Notropis hudsonius	4.5	9.5	5.5	56.2
Pomoxis nigromaculatus	3.0	15.5	2.9×10^{4}	2.96×10^{5}
Plume maximum = 9.9°C				
Ambient = 1.2°C				
SPRING				
Cyprinus carpio	7.9	24.5	$.7\times10^{13}$	$.7\times10^{13}$
Pomoxis annularis	10.0	21.5	33.9	340.0
Ictalurus nebulosus	13.1	18.5	3.4	34.6
Lepomis gibbosus	9.0	25.5	8266.0	82670.0
Pomoxis annularis	16.5	16.6	.06	1.6
Ictalurus nebulosus	13.8	26.5	7173.0	71731.0
Plume maximum = 19.8°C				
Ambient = 10.3°C				
SUMMER				
Ictalurus nebulosus	20.4	21.5	.1	1.0
Ambloplites rupestris	20.3	18.5	.1	1.0
Perca flavescens	21.3	21.5	.1	1.0
Ictalurus punctatus	20.3	19.5	.1	1.0
Pomoxis nigromaculatus	20.7	24.5	.026	1.26
Notemigonus crysoleucas	19.6	20.5	.1	1.0
Ictalurus punctatus	24.2	21.5	.35	1.35
Aplodinotus grunniens	23.0	23.5	.013	1.13
Plume maximum = 28.2°C				
Ambient = 22.6°C				

(CONTINUES)

APPENDIX I (Continued)

ANNOTATIONS AND COMMENTS

SEASON Species	Acclimation Temperature	Preferred Temperature	Contour Interval	Max. Density Factor
FALL				
Perca flavescens	15.5	25.5	1.17×10^{4}	1.17×10^{5}
Pomoxis annularis	11.0	10.5	.1	1.0
Micropterus dolomieui	10.0	26.5	$.2 \times 10^{10}$	$.2 \times 10^{10}$
Ictalurus punctatus	20.0	20.5	.062	1.62
Perca flavescens	20.2	16.5	.077	1.77
Ictalurus nebulosus	9.0	23.5	.278	3.78
Plume maximum = 20.6°C Ambient = 11.1°C				

APPENDIX II

CHART 1. EXPECTED SEASONAL TEMPERATURE VARIATION

FISH DENSITY FUNCTION PLOTS

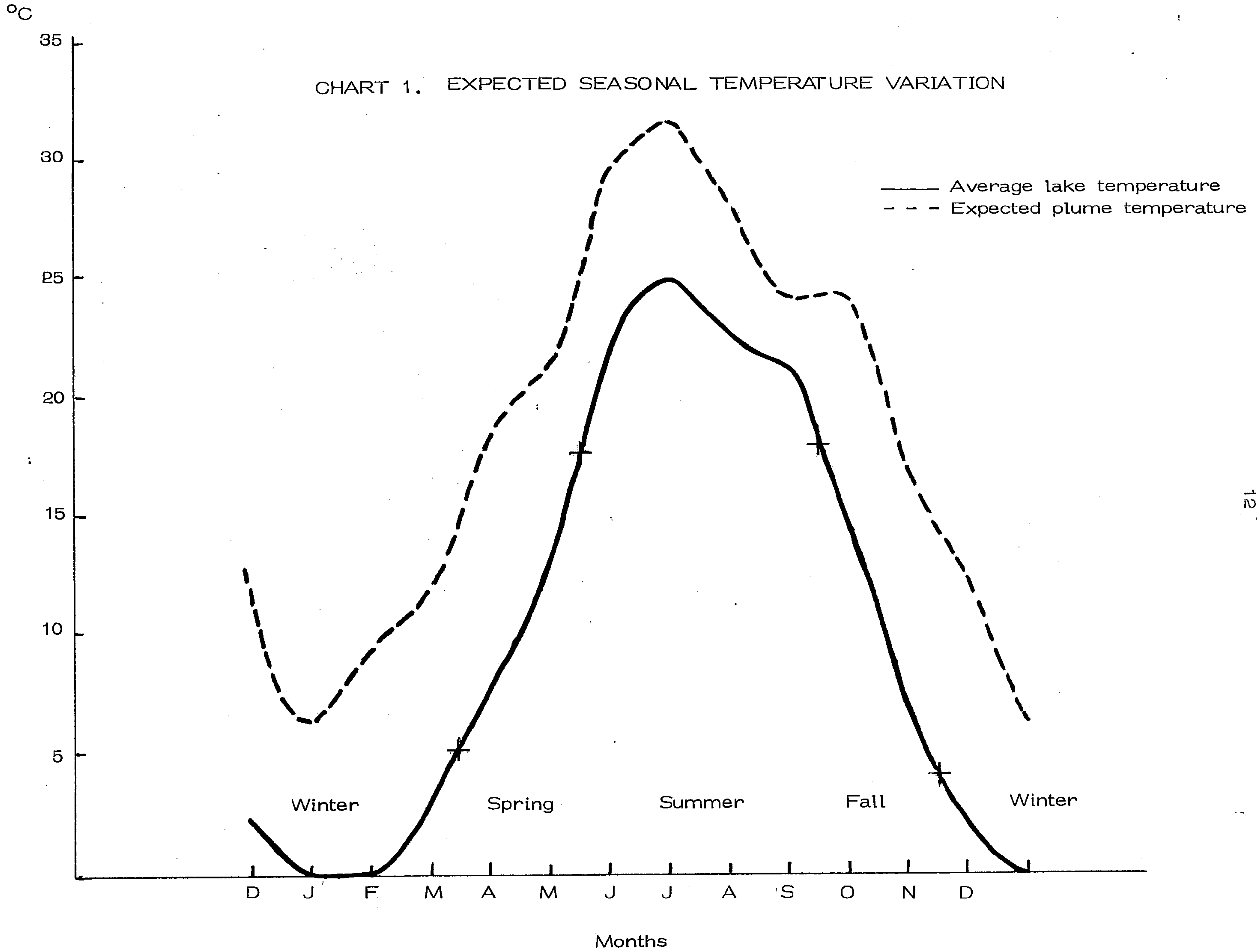

CHART 1. EXPECTED SEASONAL TEMPERATURE VARIATION

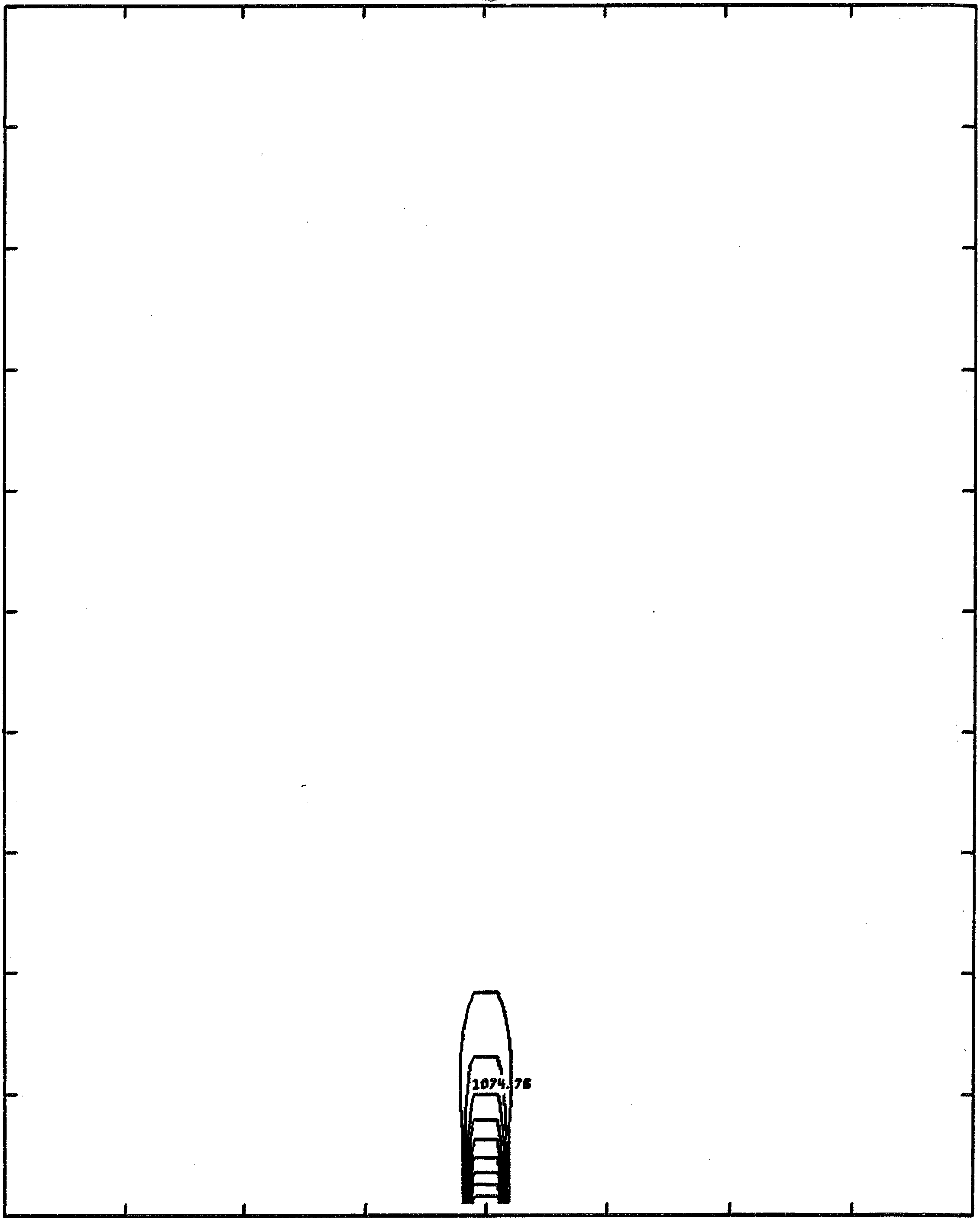

Fig. 1. Perca flavescens. Acclimation Temperature 4 ^{o}C. Run 12/7/72

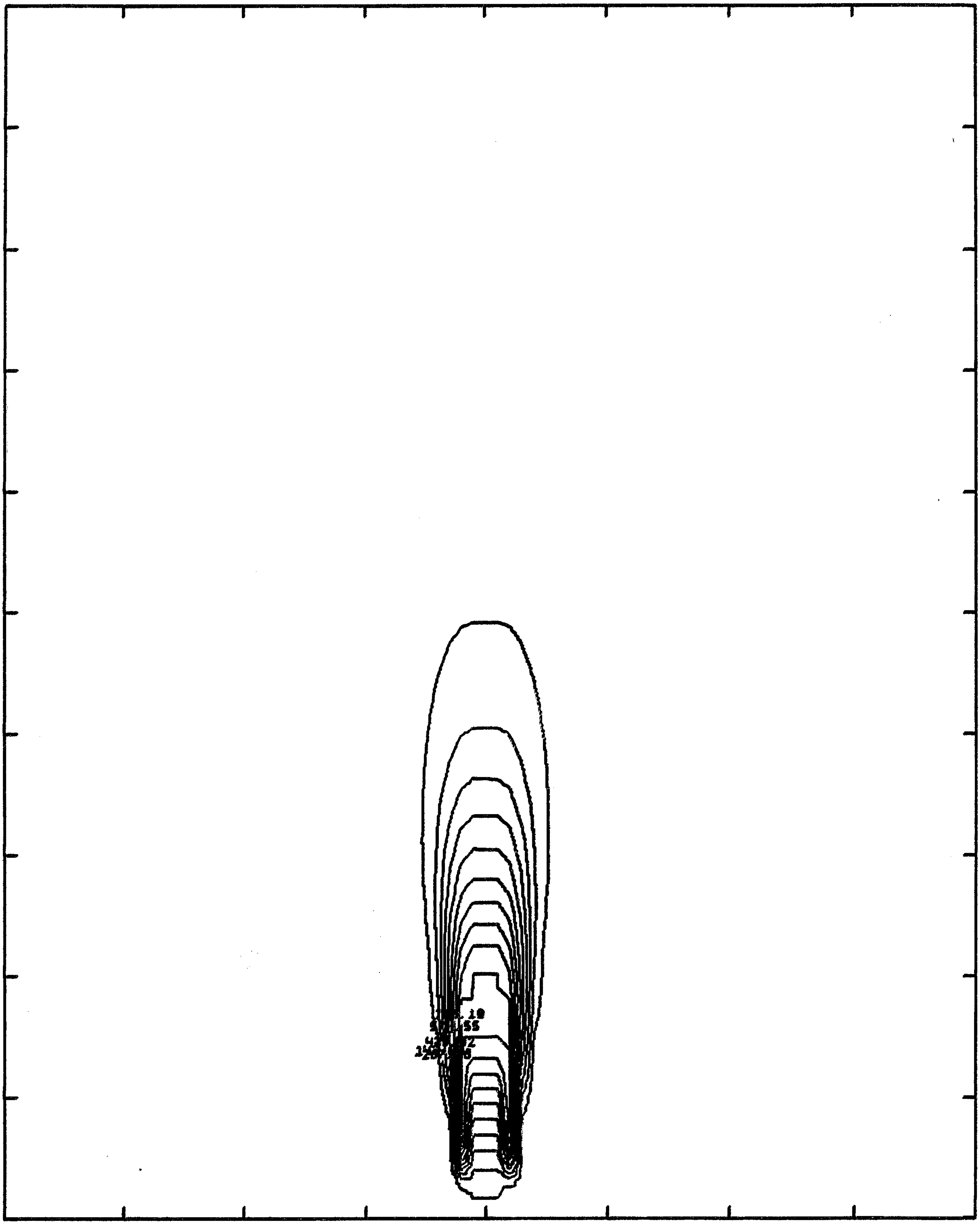

Fig. 2. <u>Notropis</u> <u>atherinoides.</u> Acclimation temp. 4°C. Run 1/22/73

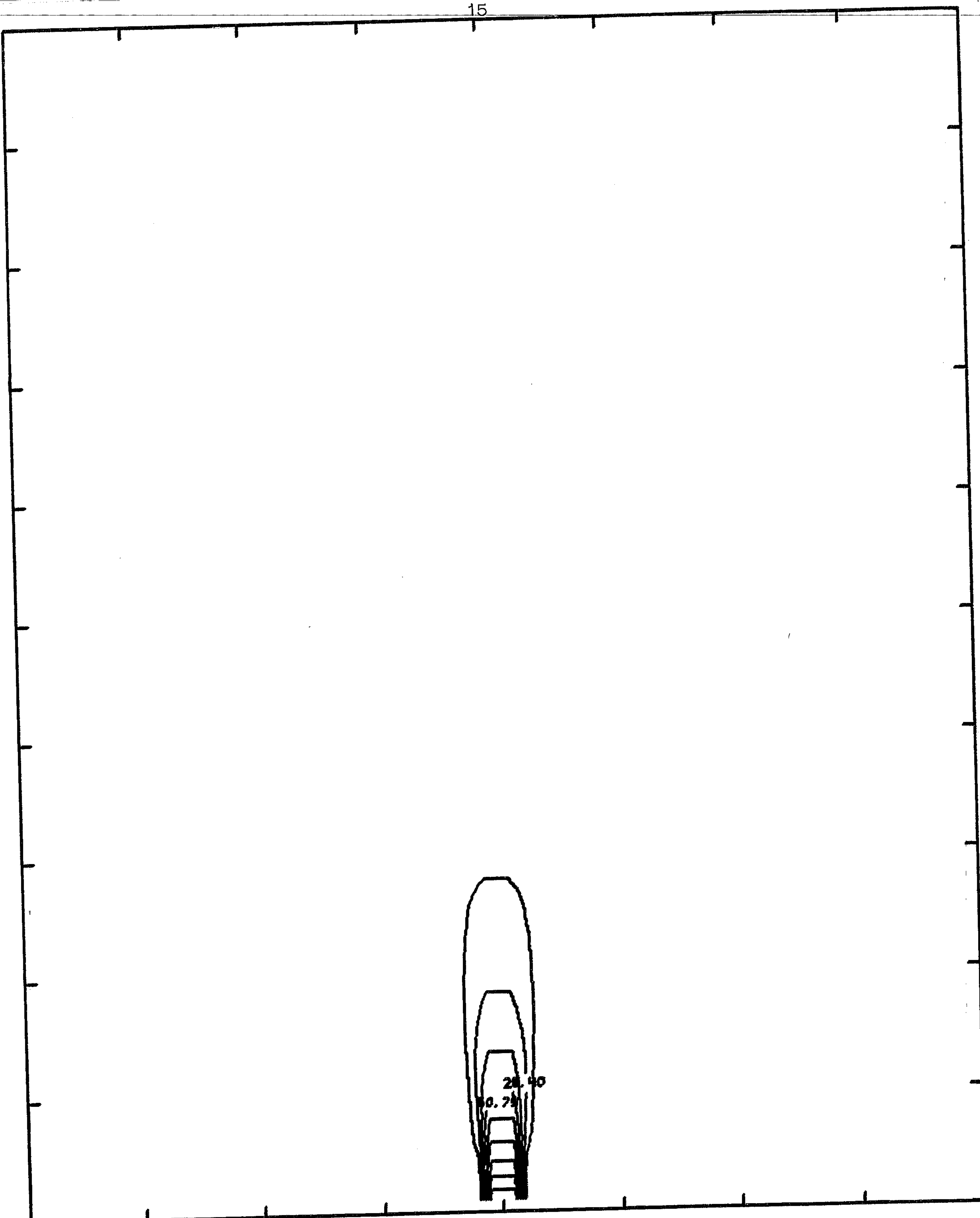

Fig. 3. Pomoxis nigromaculatus. Acclimation Temp. 5°C. Run 1/25/73

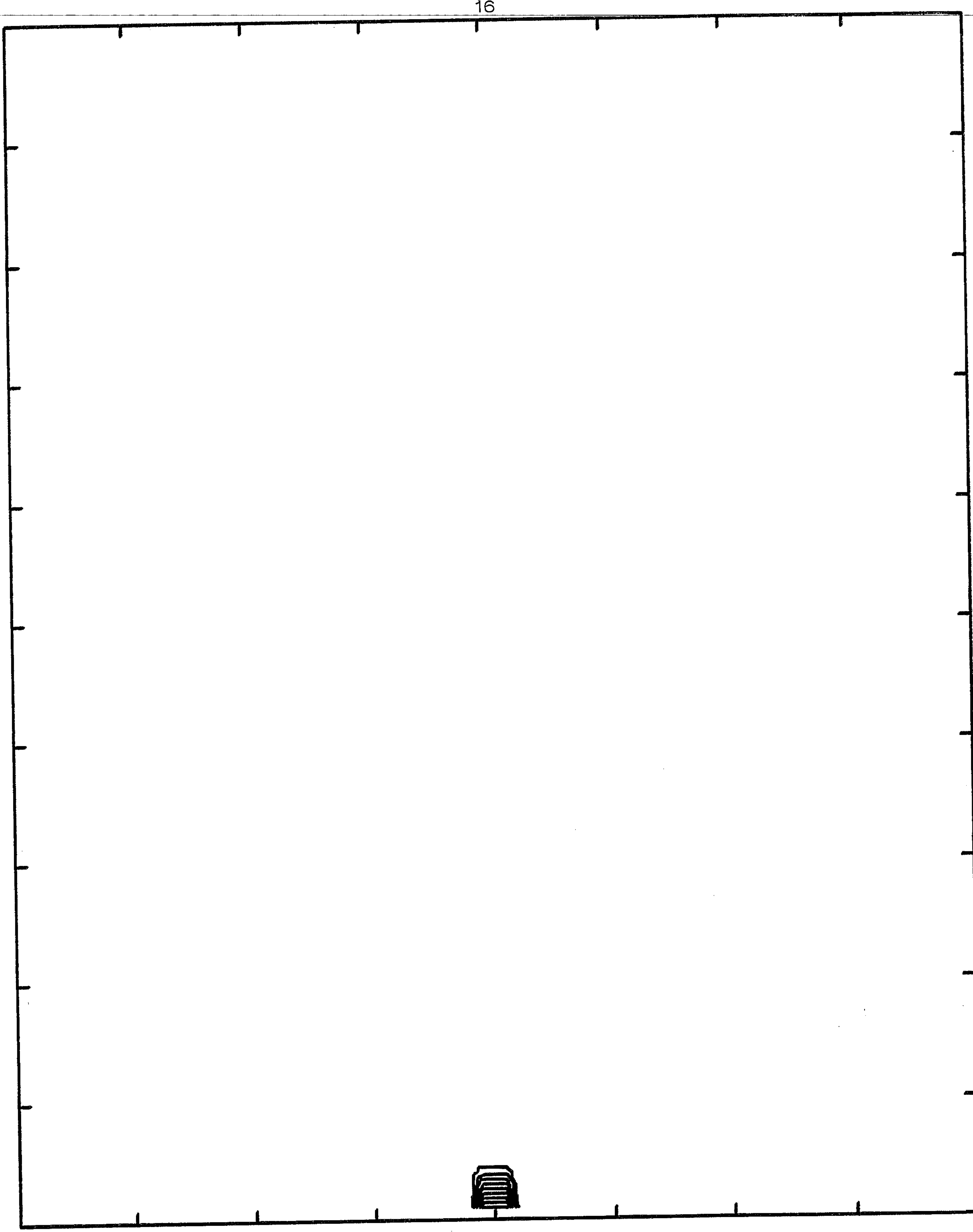

Fig. 4. Lepomis macrochirus. Acclimation temp. 4.9°C. Run 2/15/73

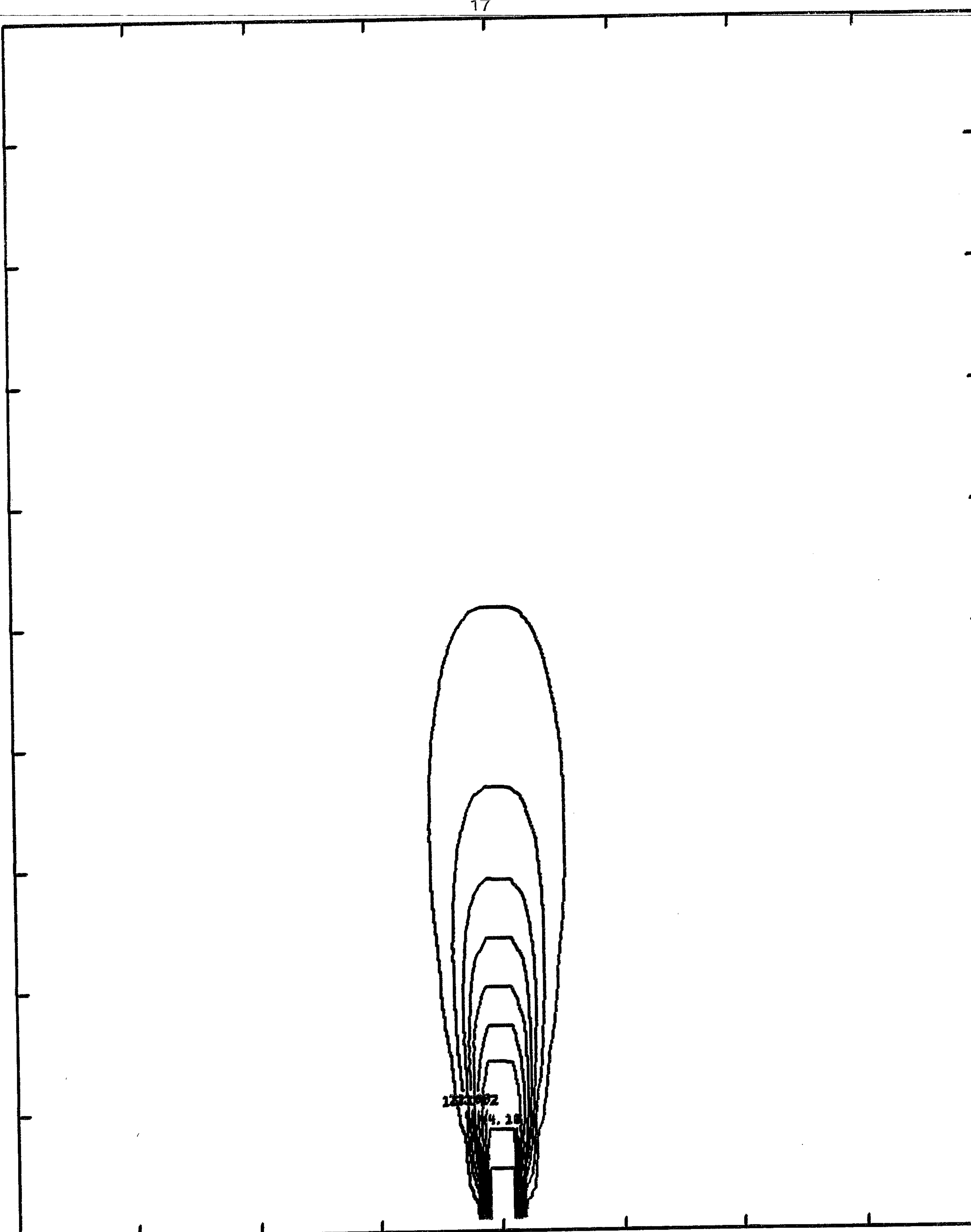

Fig. 5. Notropis hudsonius. Acclimation temp. 4.5°C. Run 3/2/73

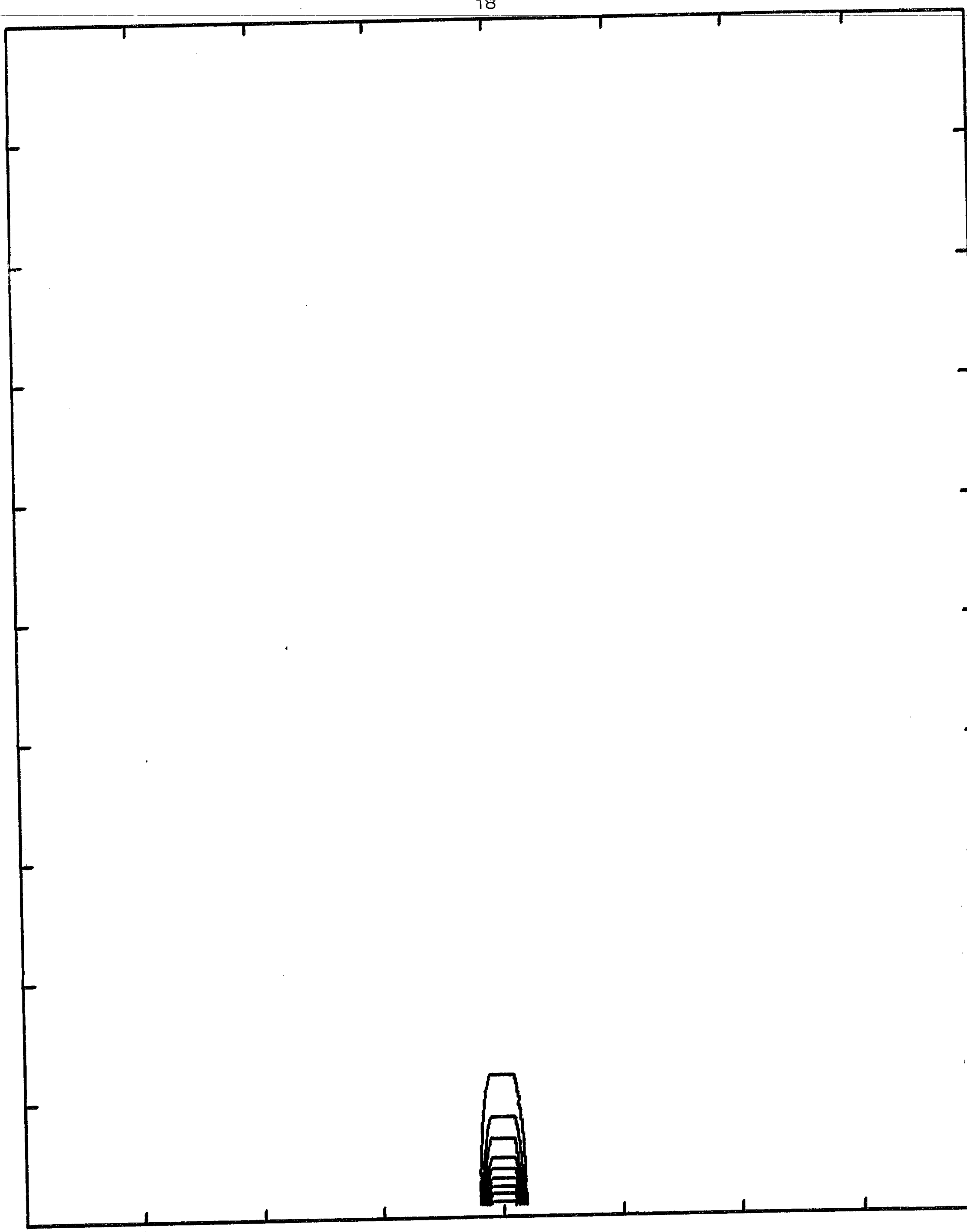

Fig. 6. Pomoxis nigromaculatus. Acclimation temp. 3.0°C. Run 2/8/73

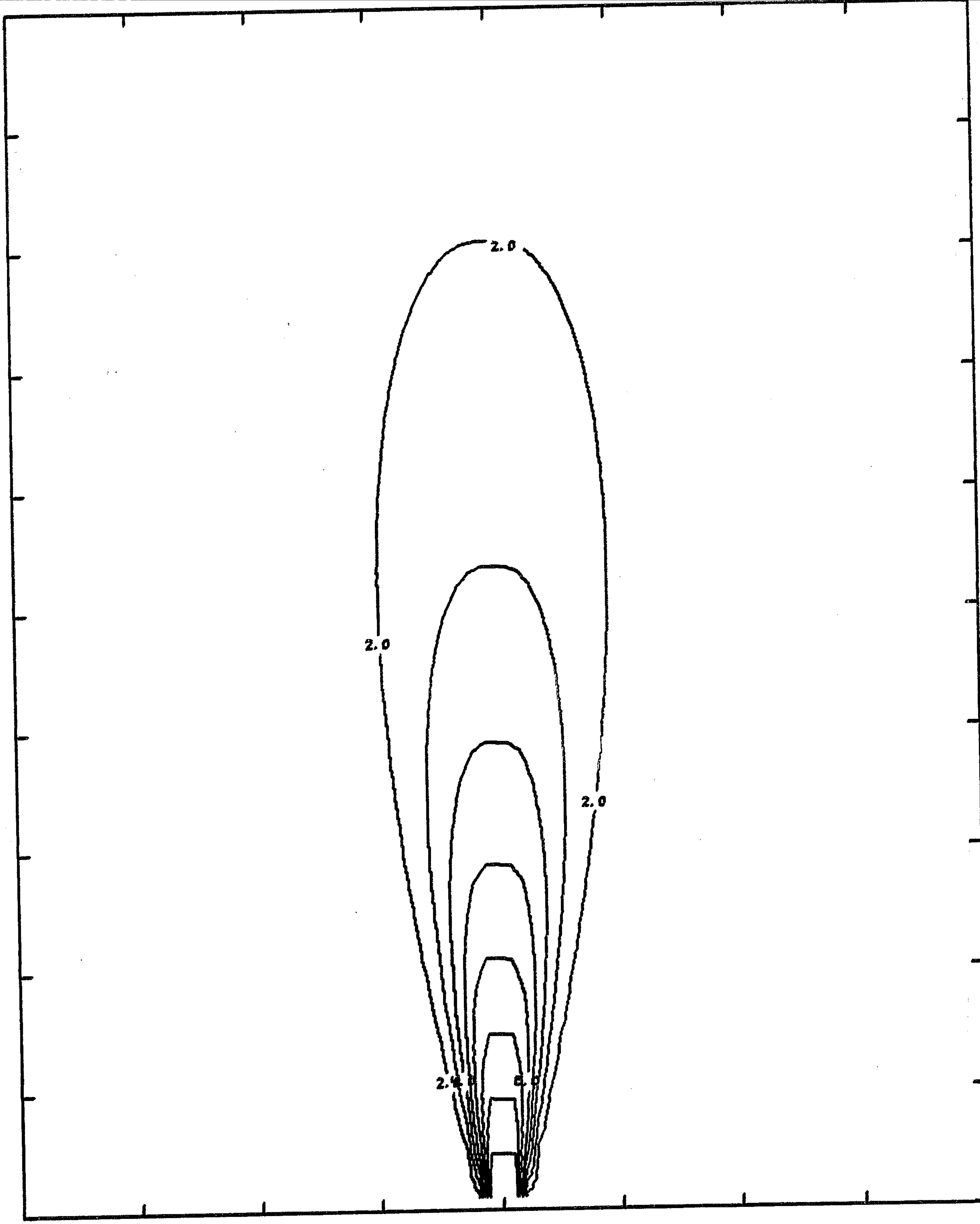

Fig. 7. Plume Thermal Structure for Winter.

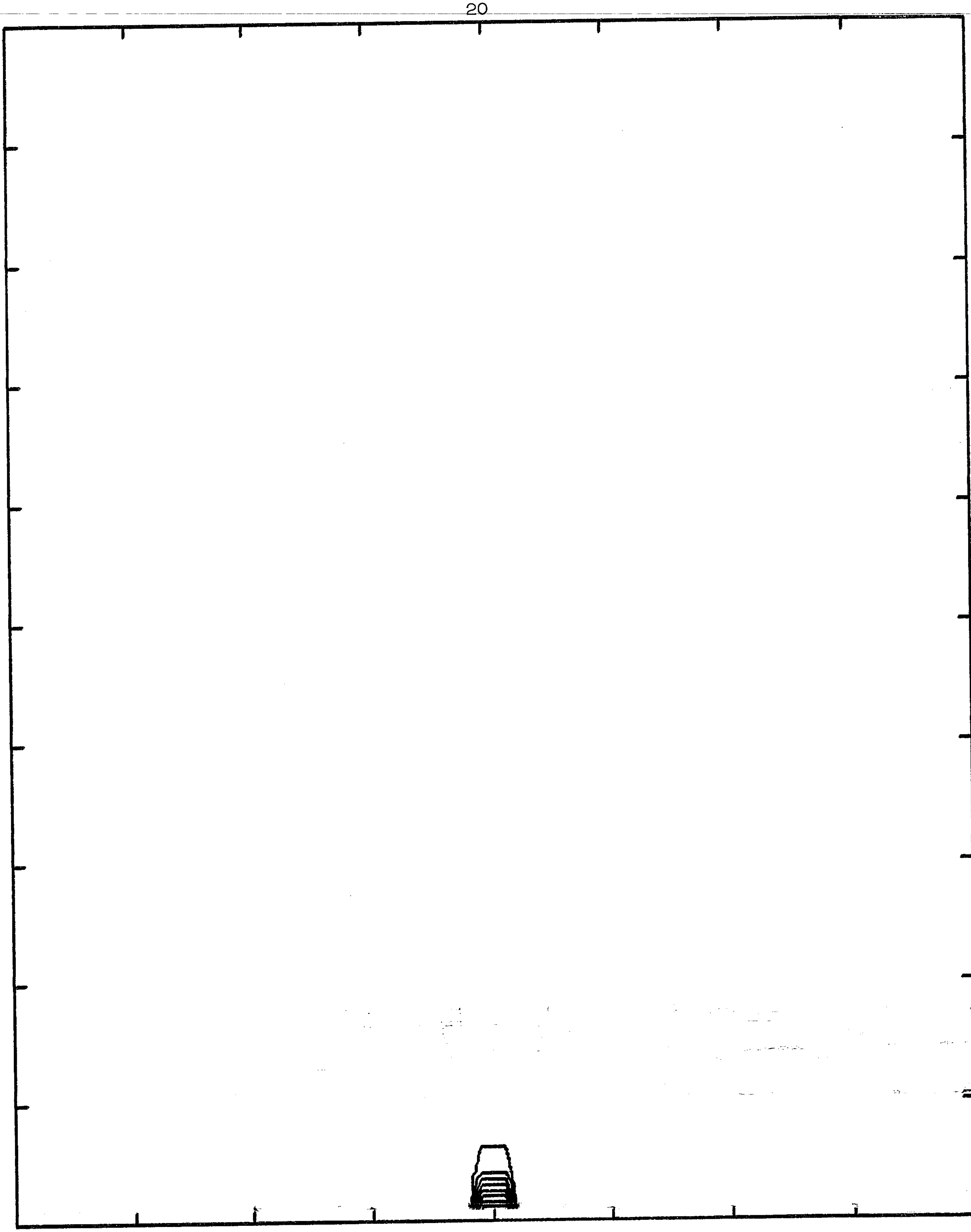

Fig. 8. *Cyprinus carpio*. Acclimation temp. 7.9°C. Run 3/22/73

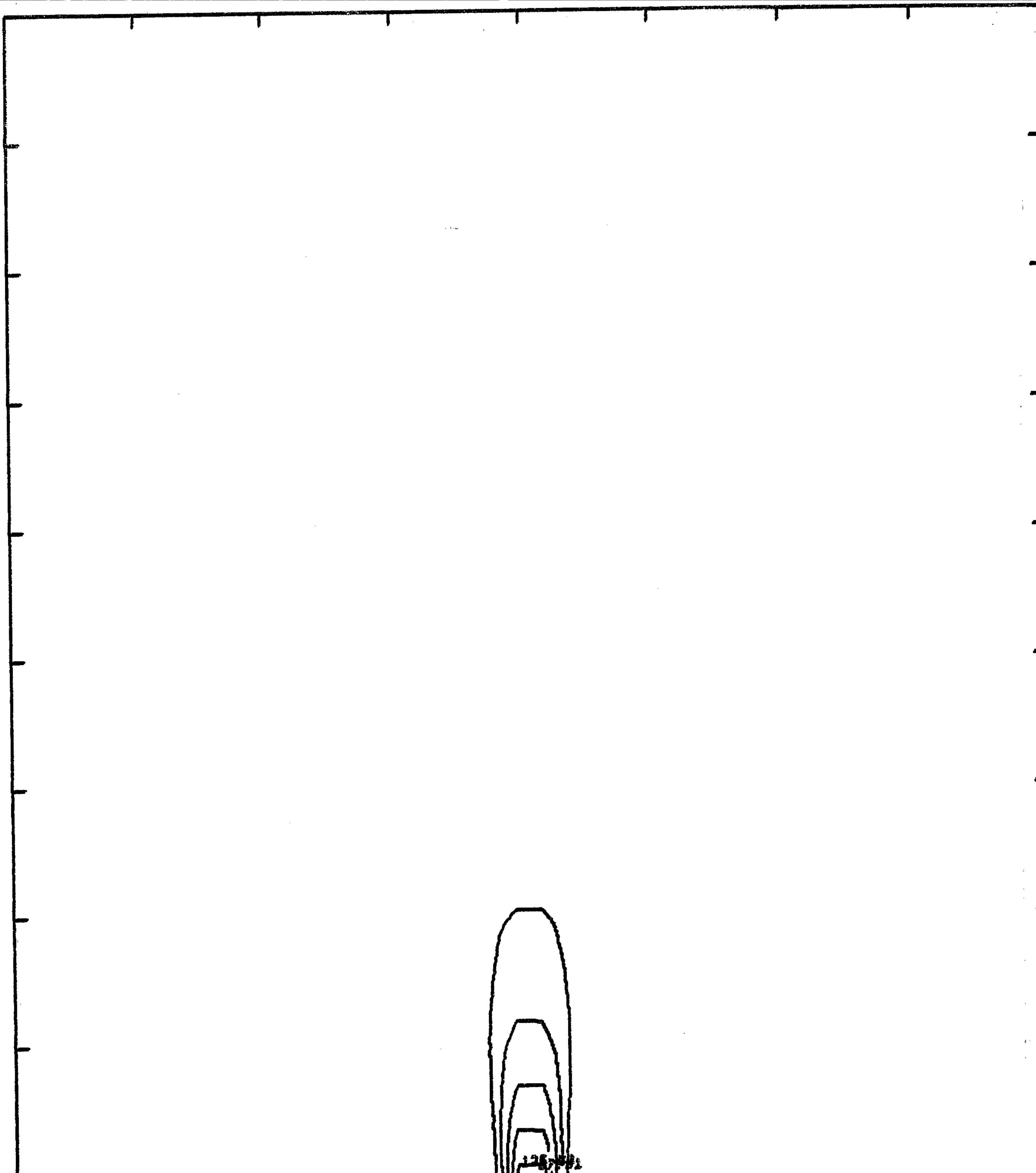

Fig. 9. Pomoxis annularis. Acclimation temp. 10°C. Run 4/19/73

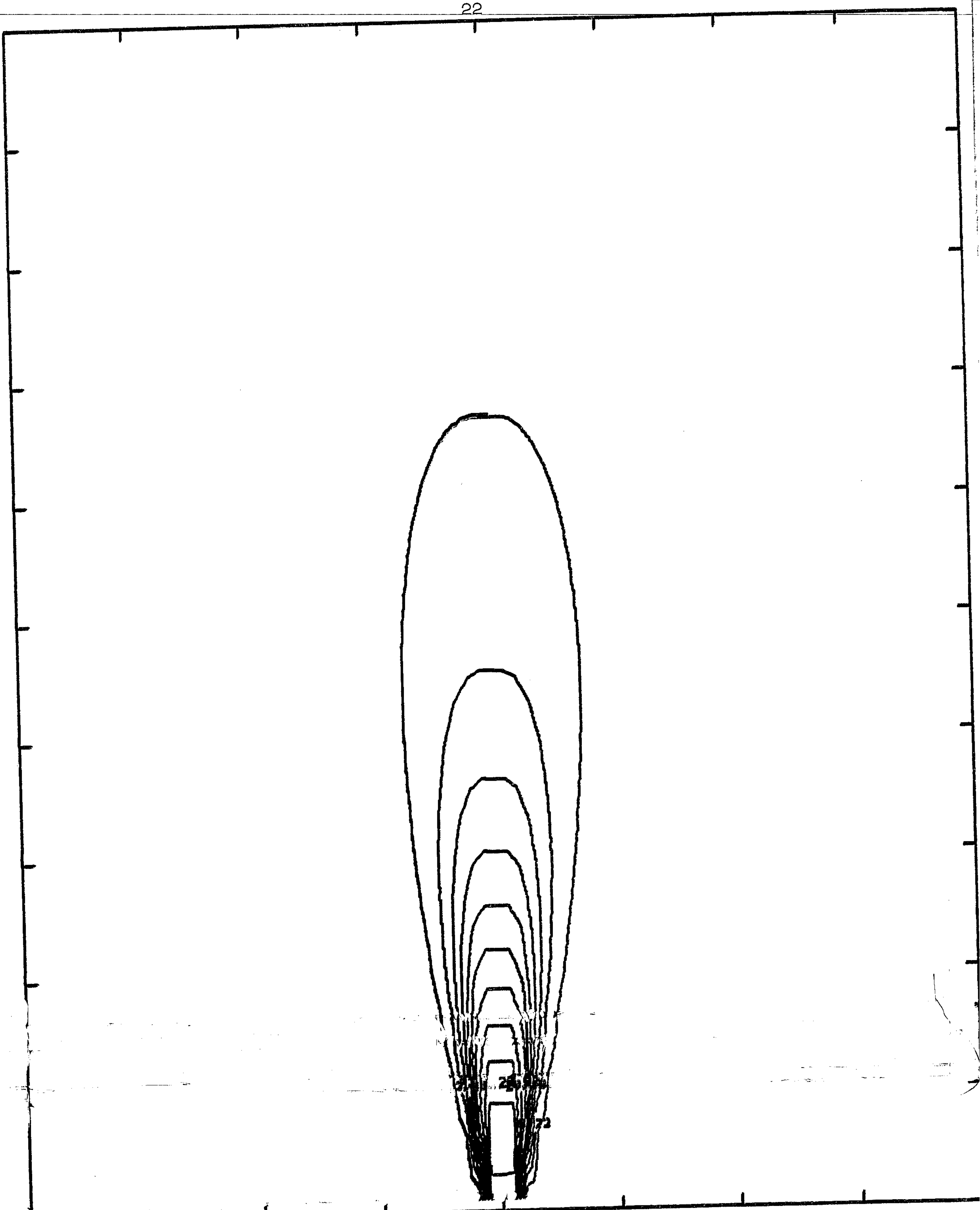

Fig. 10. <u>Ictalurus nebulosus</u>. Acclimation temp. 13.1°C. Run 5/20/73

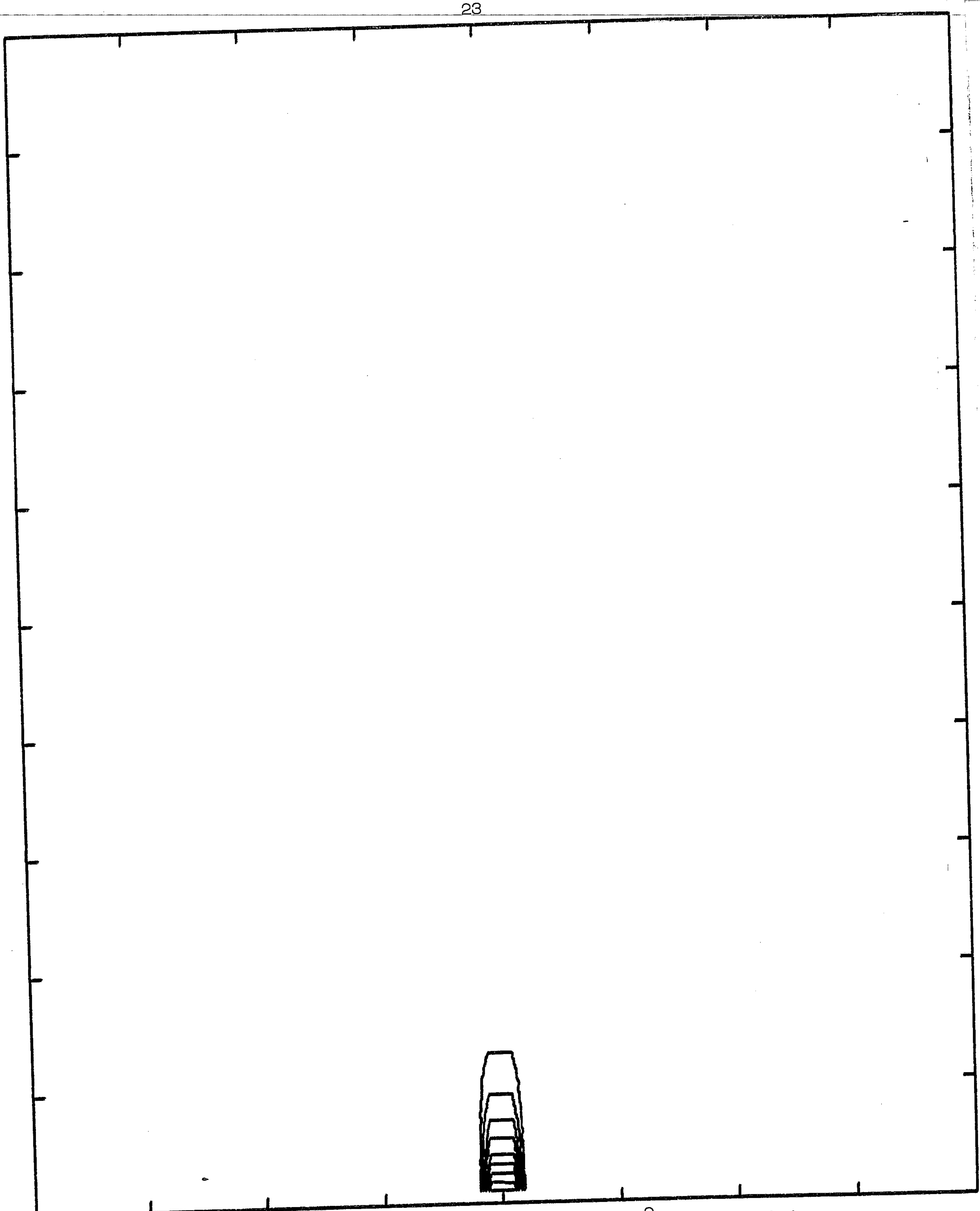

Fig. 11. *Lepomis gibbosus*. Acclimation temp. 9.0°C. Run 4/3/73

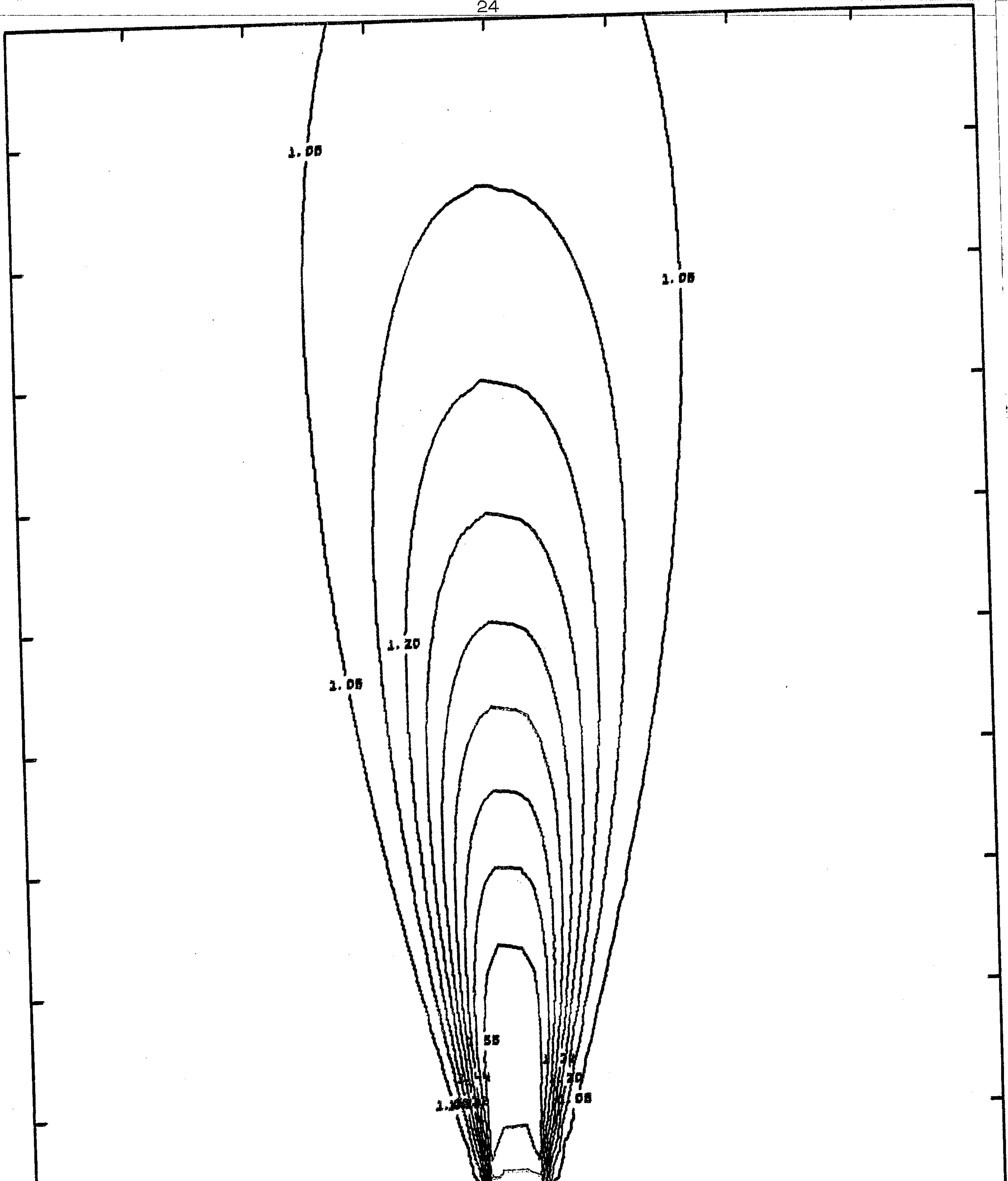

Fig. 12. Pomoxis annularis. Acclimation temp. 16.5°C Run 6/6/73

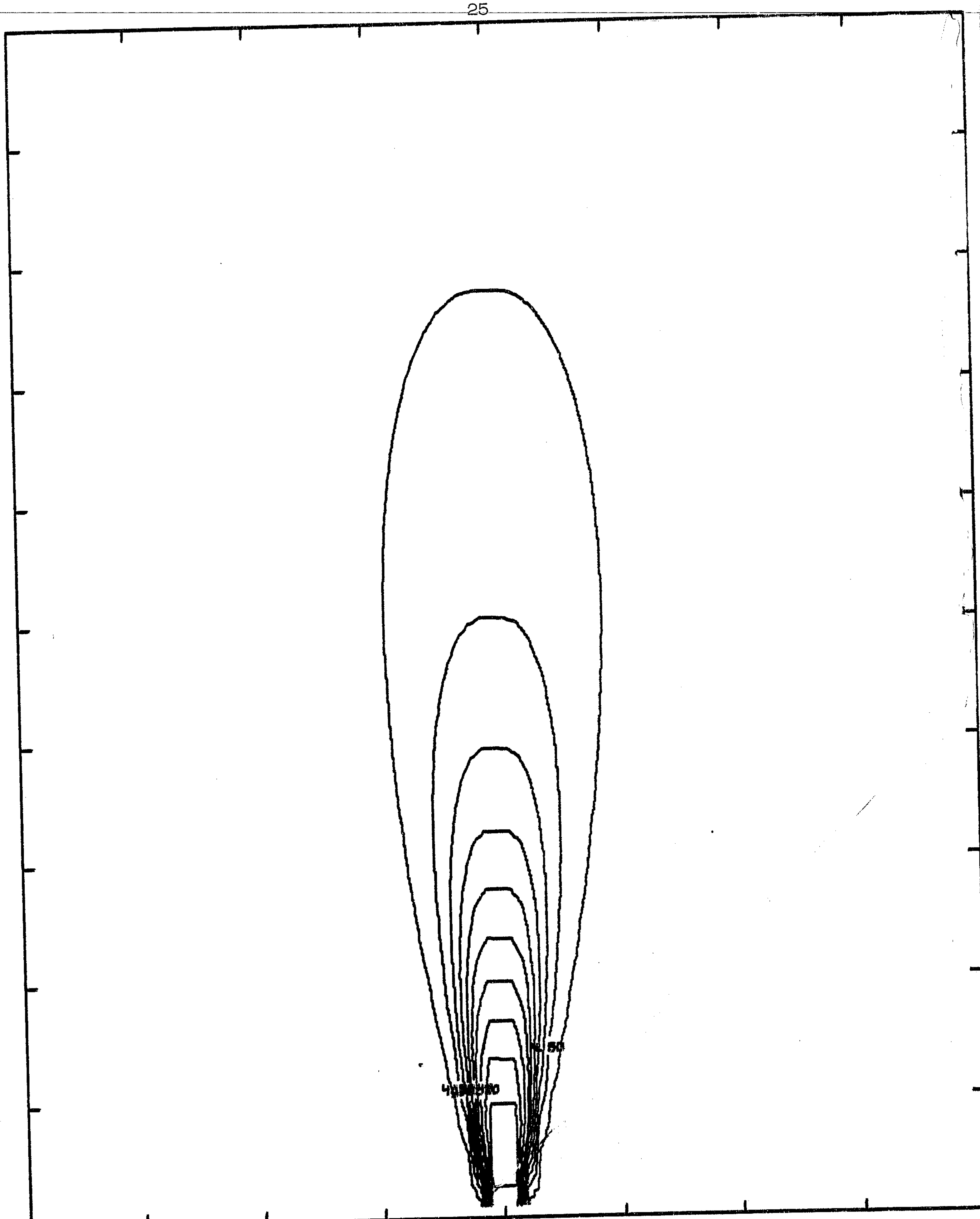

Fig. 13. Pomoxis nigromaculatus. Acclimation temp. 11.3°C. Run 4/22/73

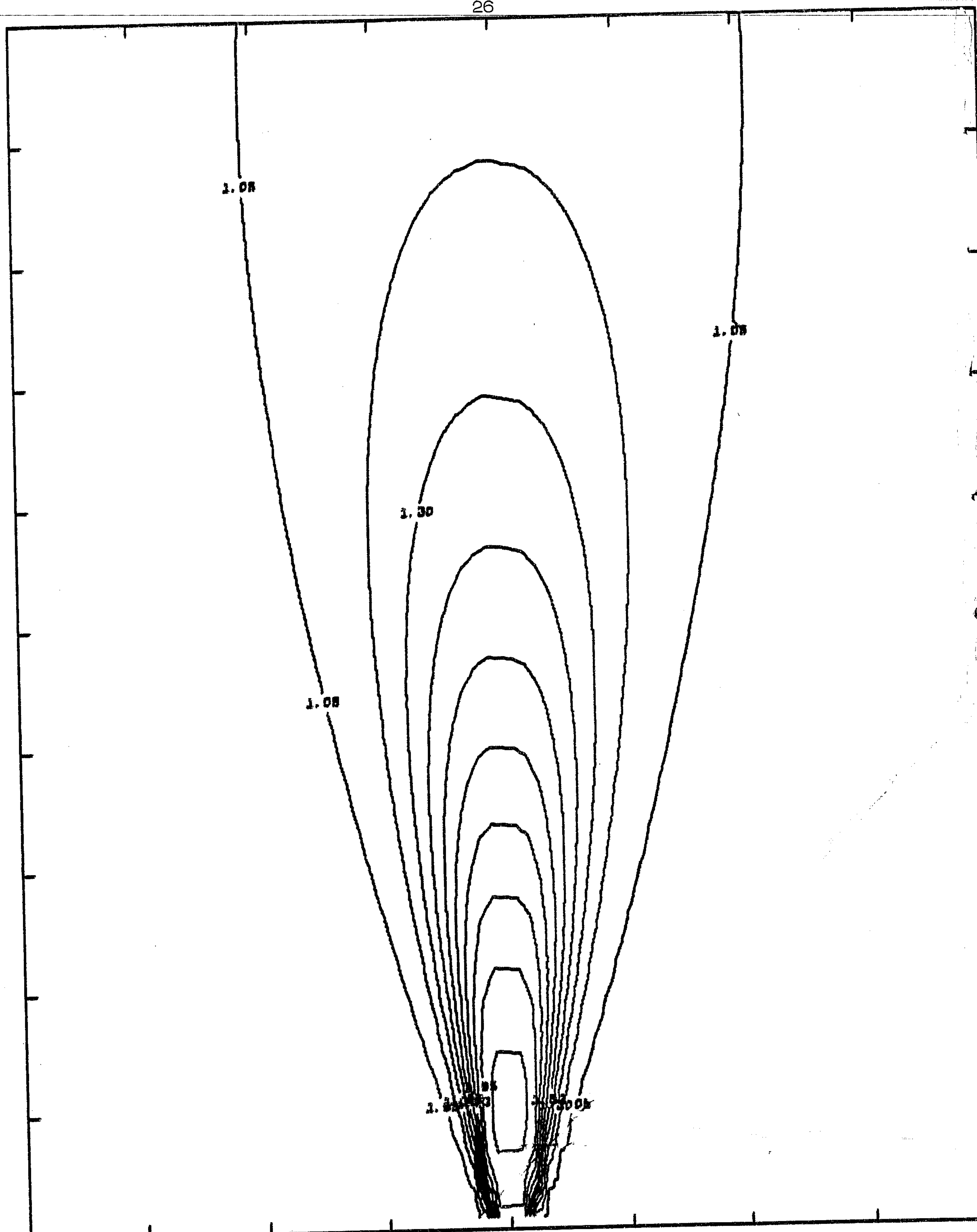

Fig. 14. Pomoxis annularis. Acclimation temp. 13.1°C. Run 5/16/73

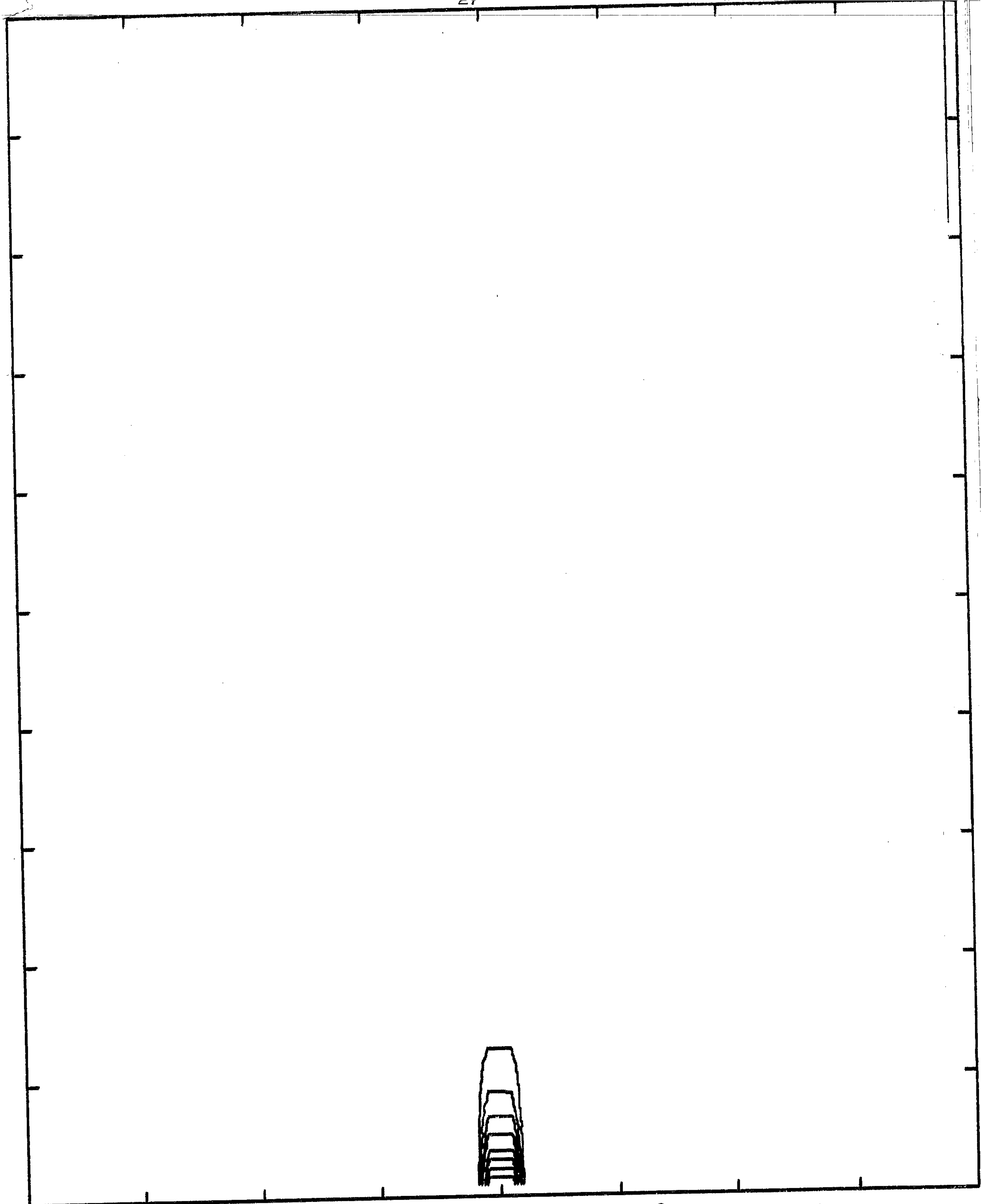

Fig. 15. Ictalurus nebulosus. Acclimation temp. 13.8°C. Run 5/24/73

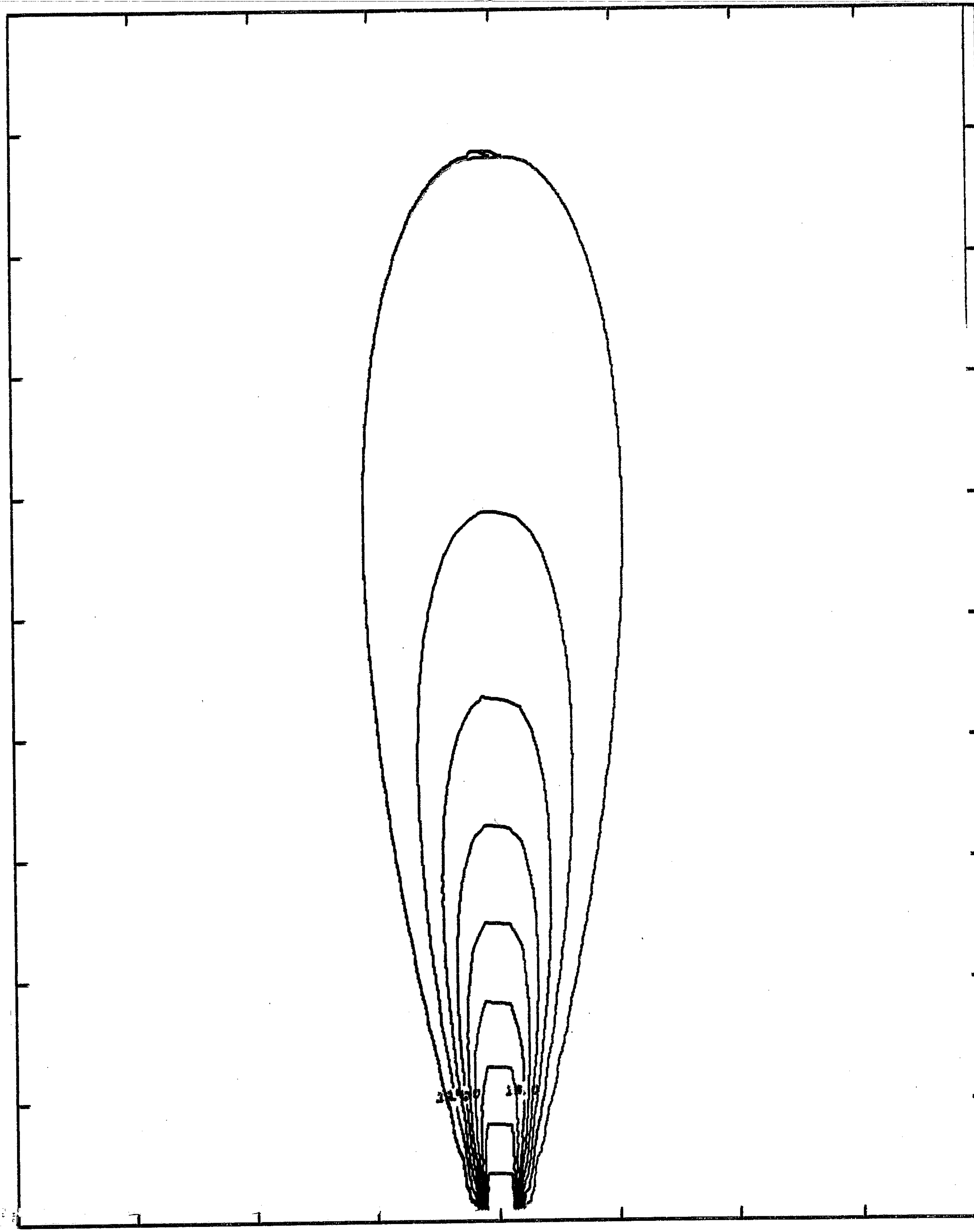

Fig. 16. Plume Thermal Structure for Spring.

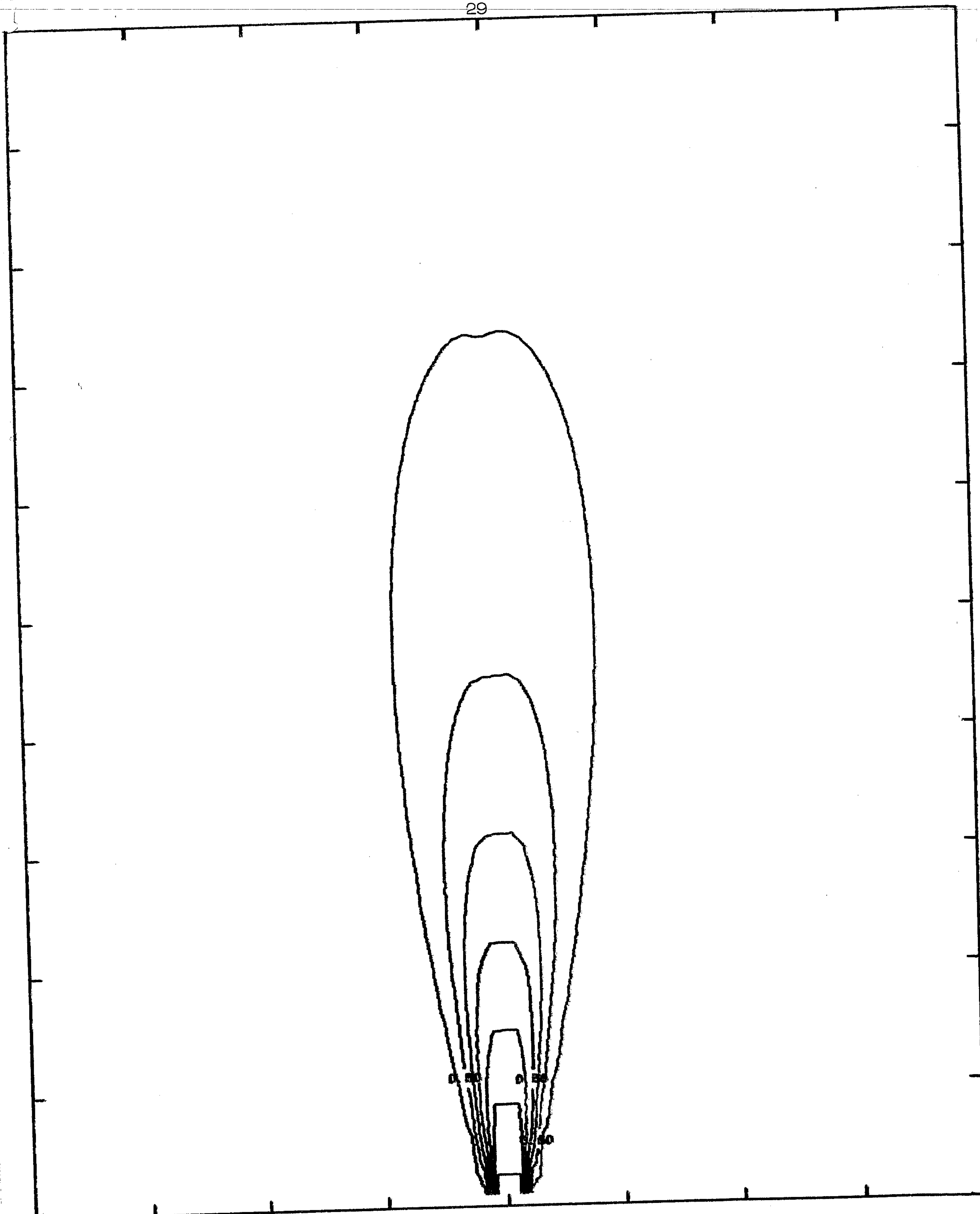

Fig. 17. Ictalurus nebulosus. Acclimation temp. 20.4°C. Run 6/4/73

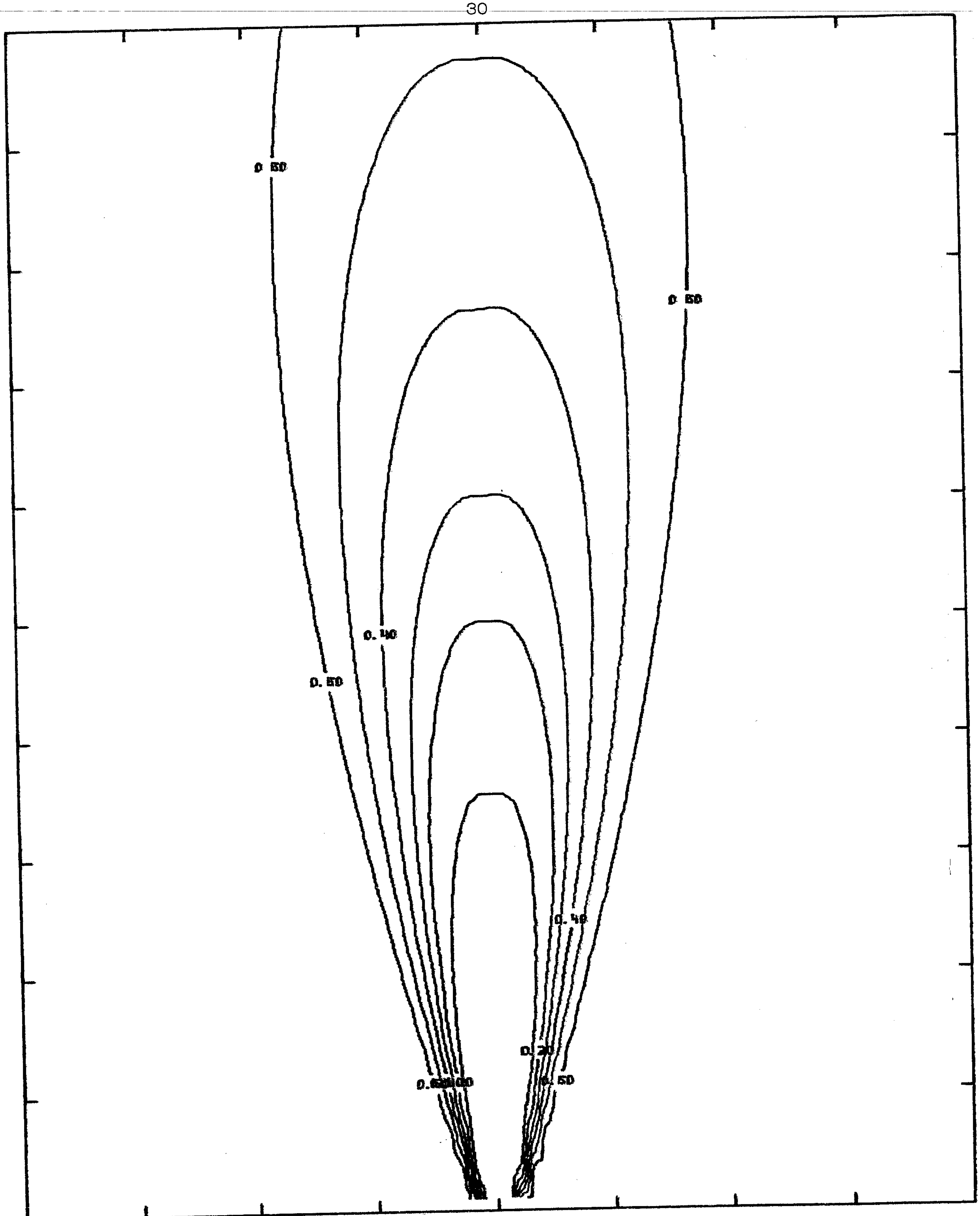

Fig. 18 Ambloplites rupestris. Acclimation temp. 20.3°C. Run 6/19/73

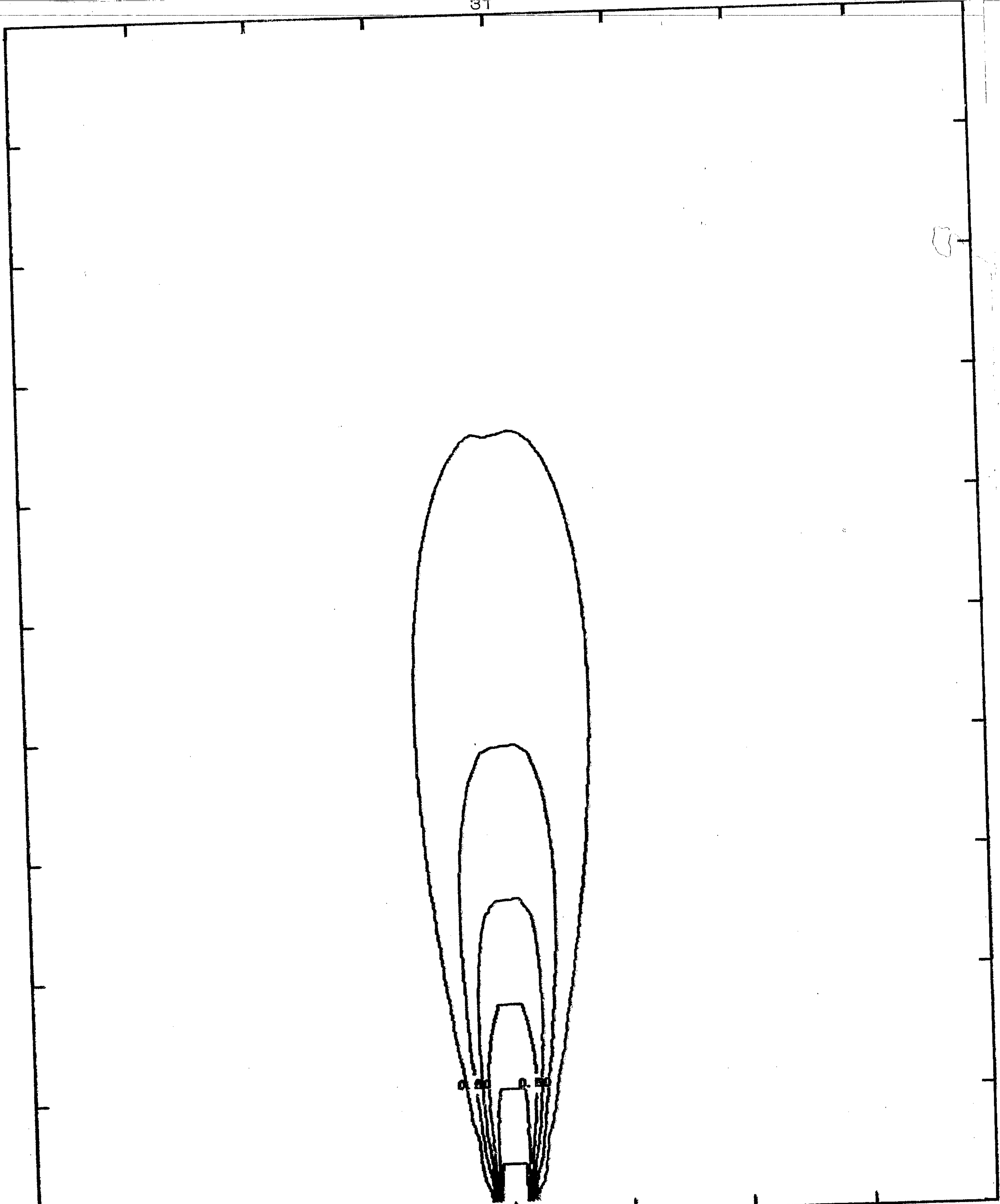

Fig. 19 Perca flavescens. Acclimation temp. 21.3°C. Run 9/12/73

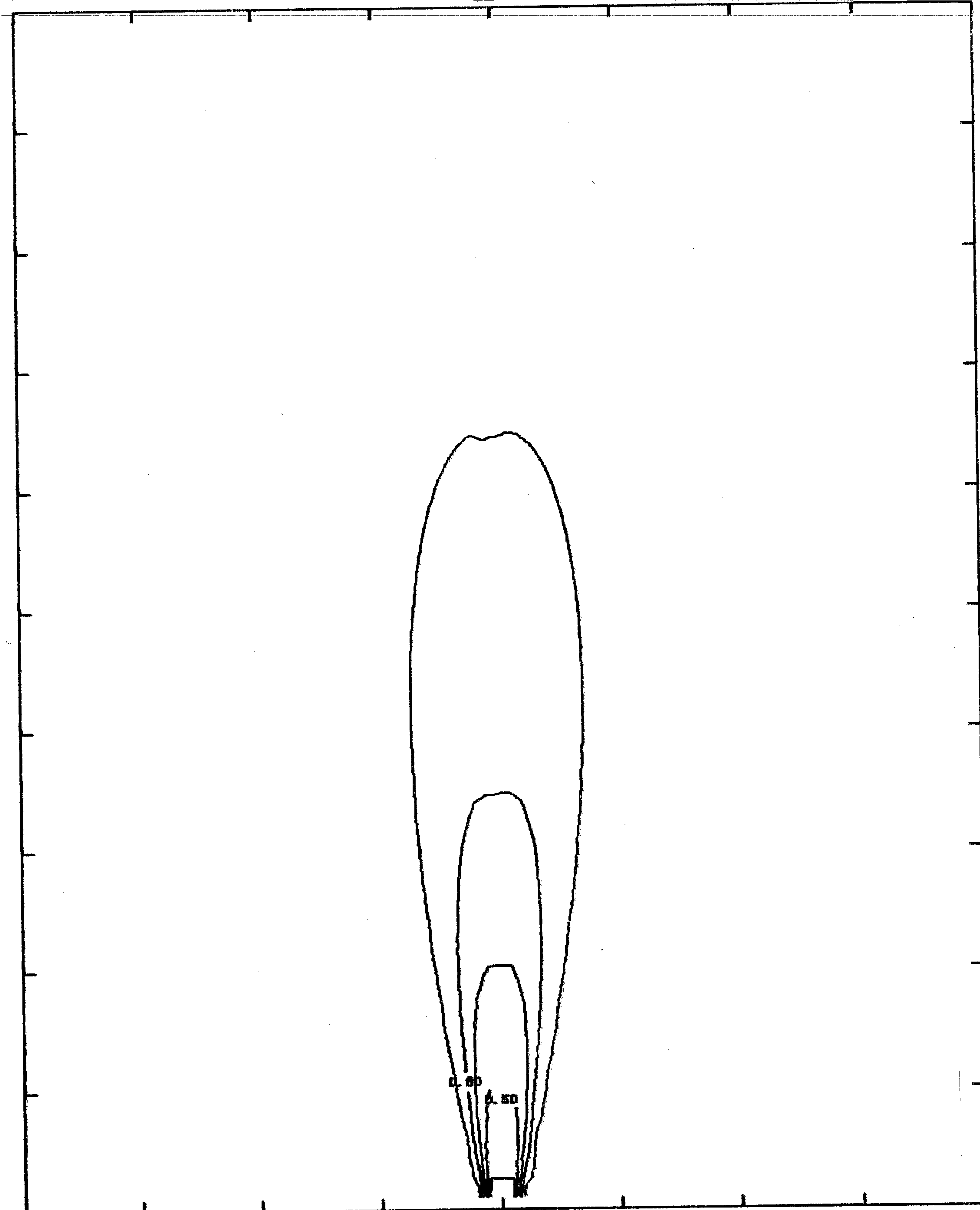

Fig. 20. Ictalurus punctatus. Acclimation temp. 20.3°C. Run 10/4/73

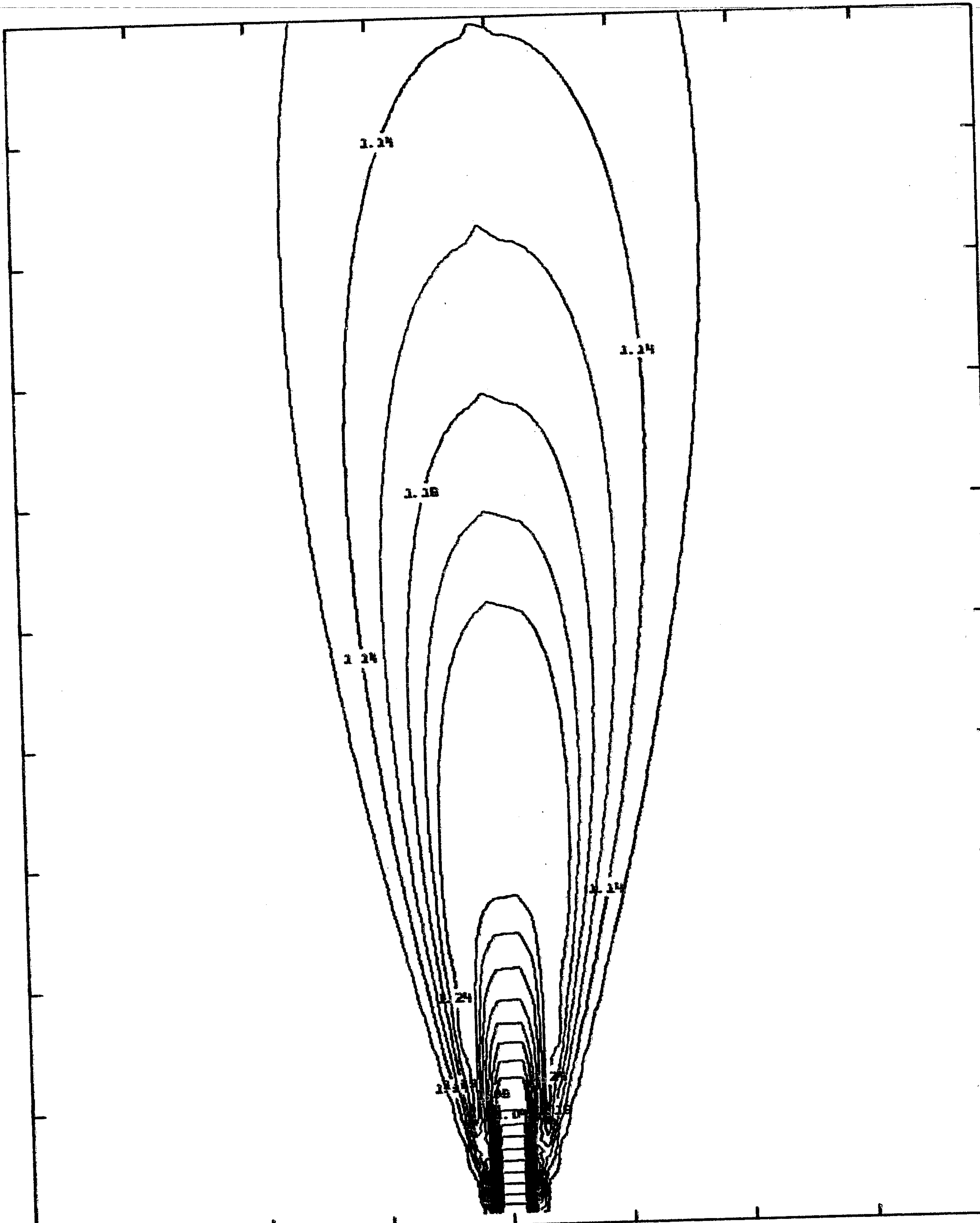

Fig. 21. Pomoxis nigromaculatus. Acclimation temp. 20.7°C. Run 10/9/73

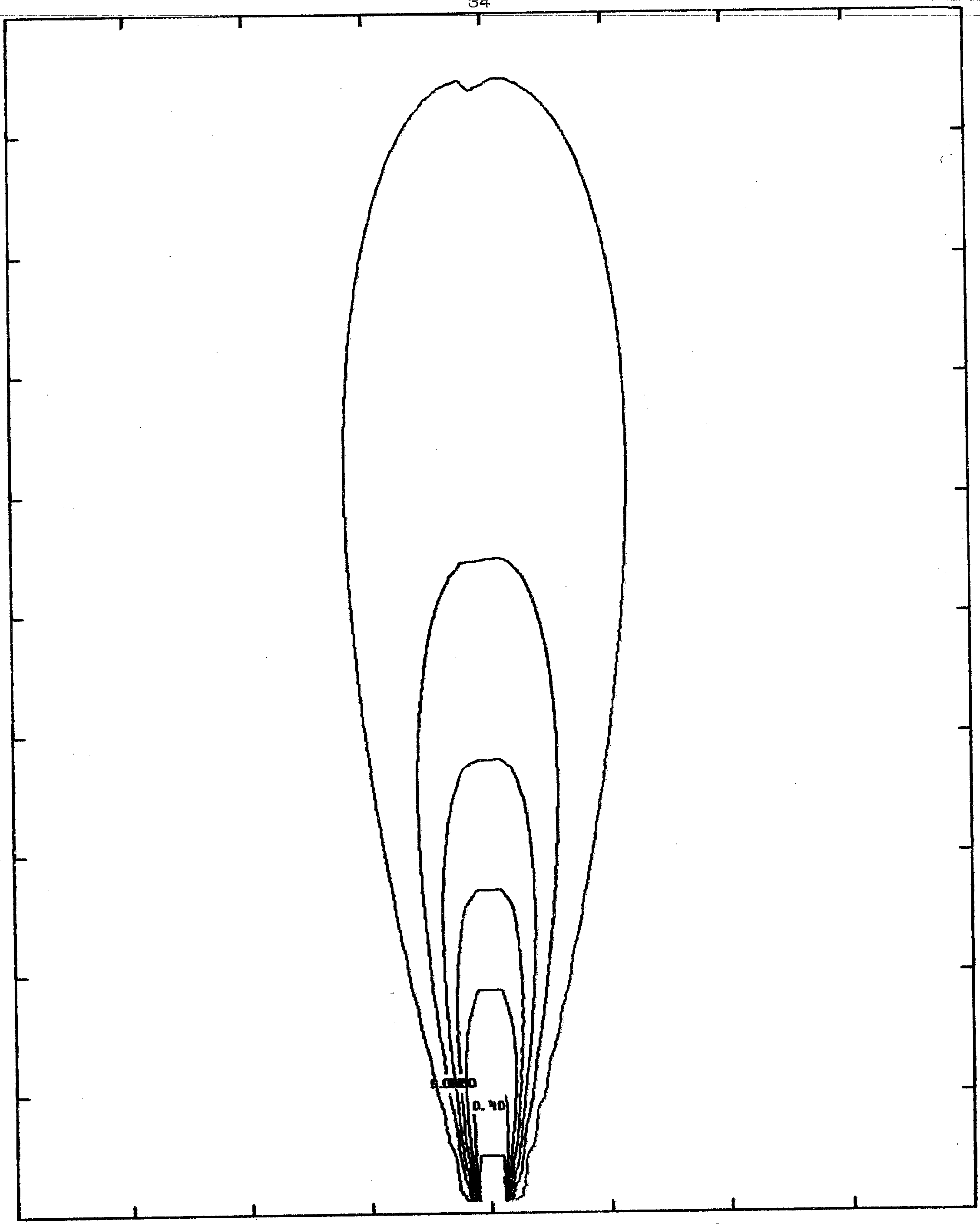

Fig. 22. Notemigonus crysoleucas. Acclimation temp. 19.6°C. Run 6/11/73

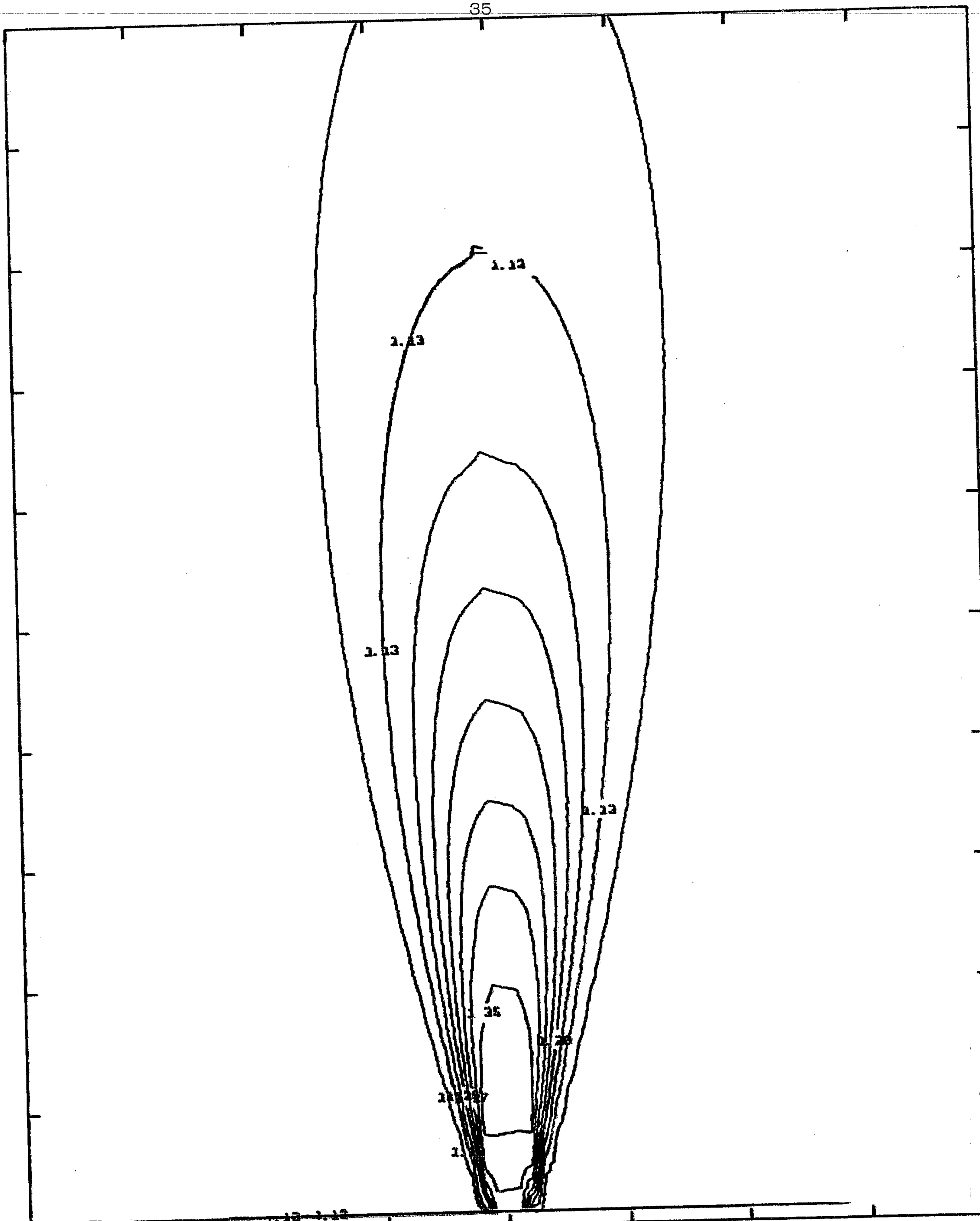

Fig. 23. Ictalurus punctatus. Acclimation temp. 24.2°C. Run 7/12/73

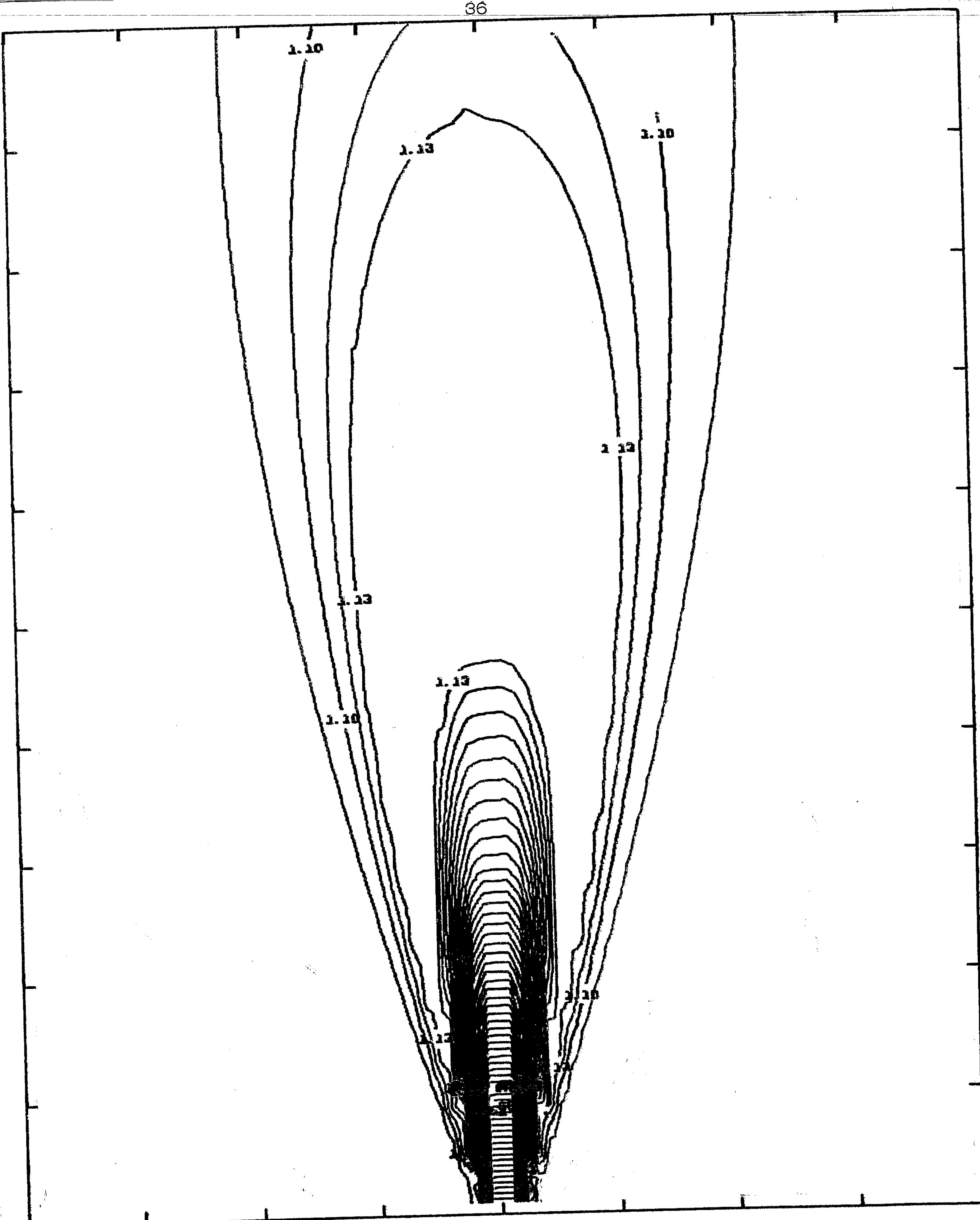

Fig. 24. Aplodinotus grunniens. Acclimation temp. 23.0°C. Run 8/1/73

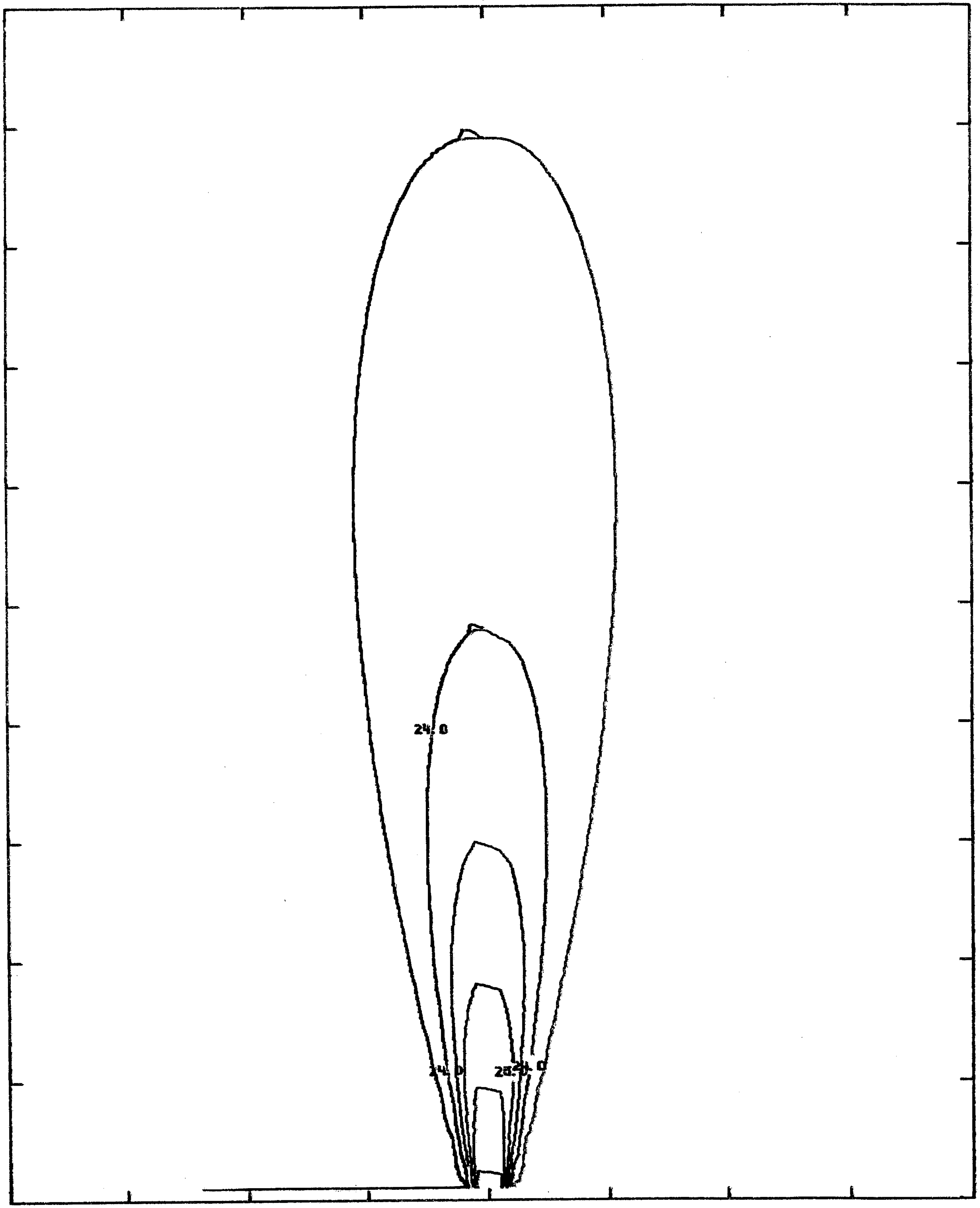

Fig. 25. Plume Thermal Structure for Summer.

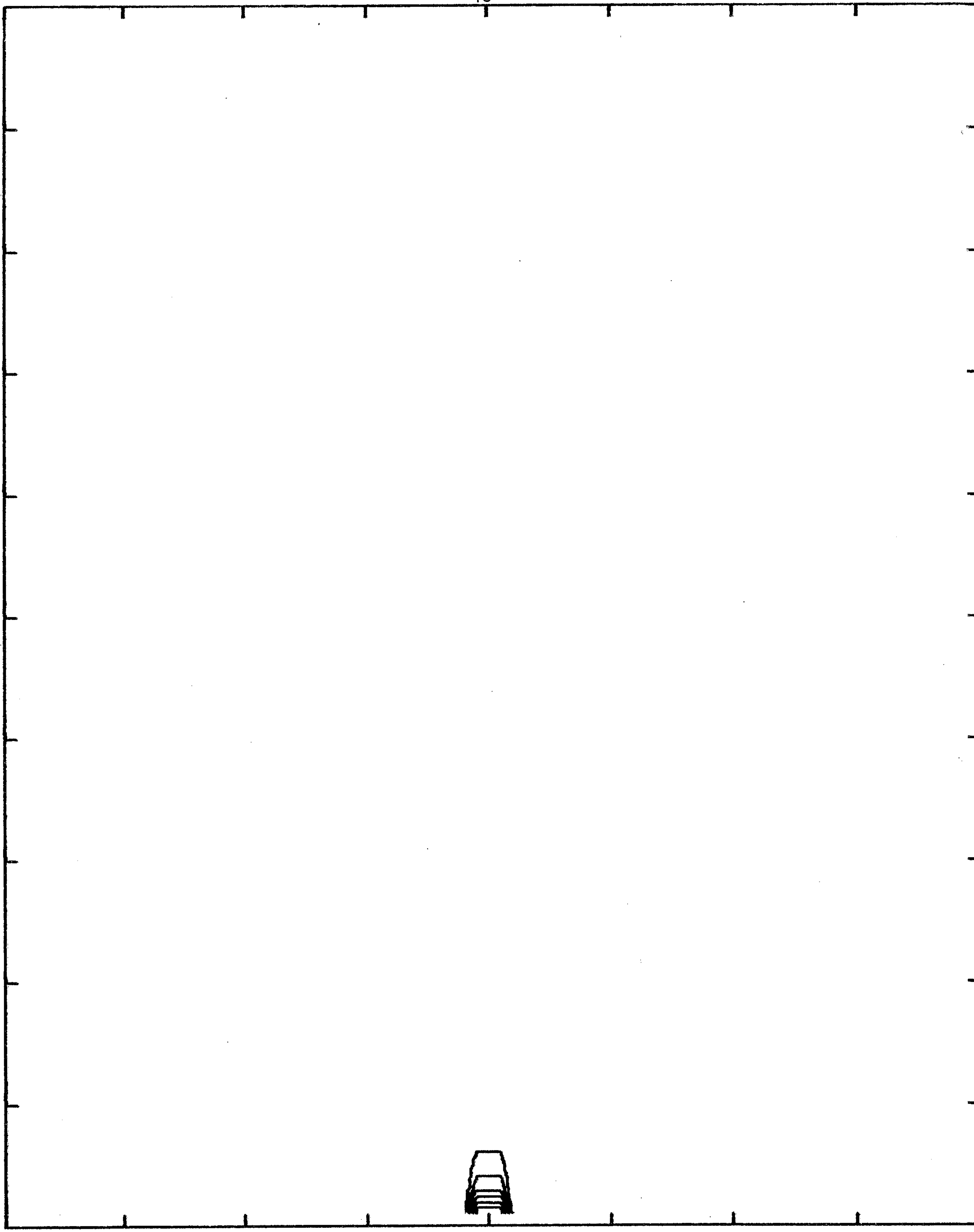

Fig. 28. Micropterus dolomieui. Acclimation temp. 10°C. Run 11/14/73

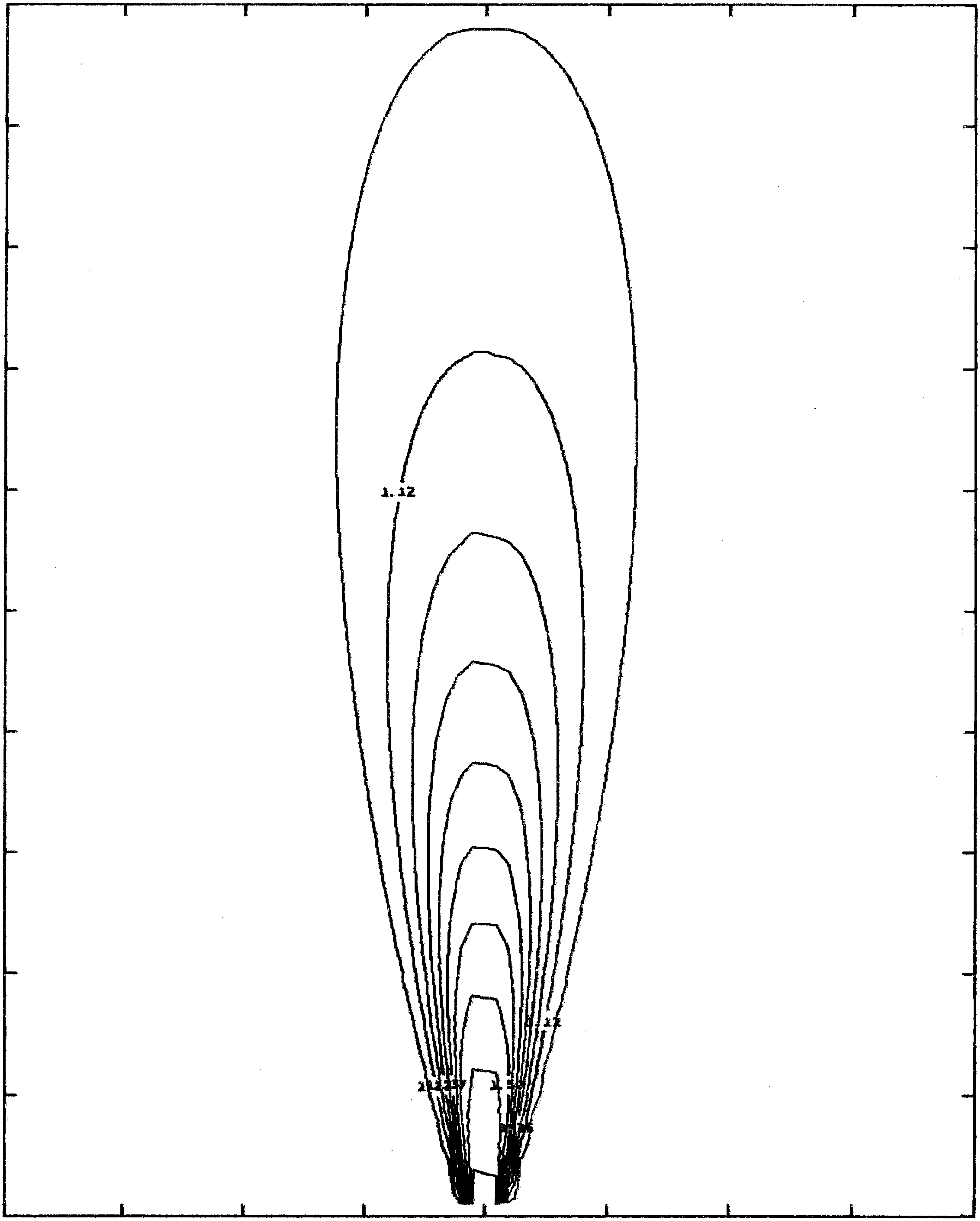

Fig. 29. Ictalurus punctatus. Acclimation temp. 20°C. Run 9/18/73

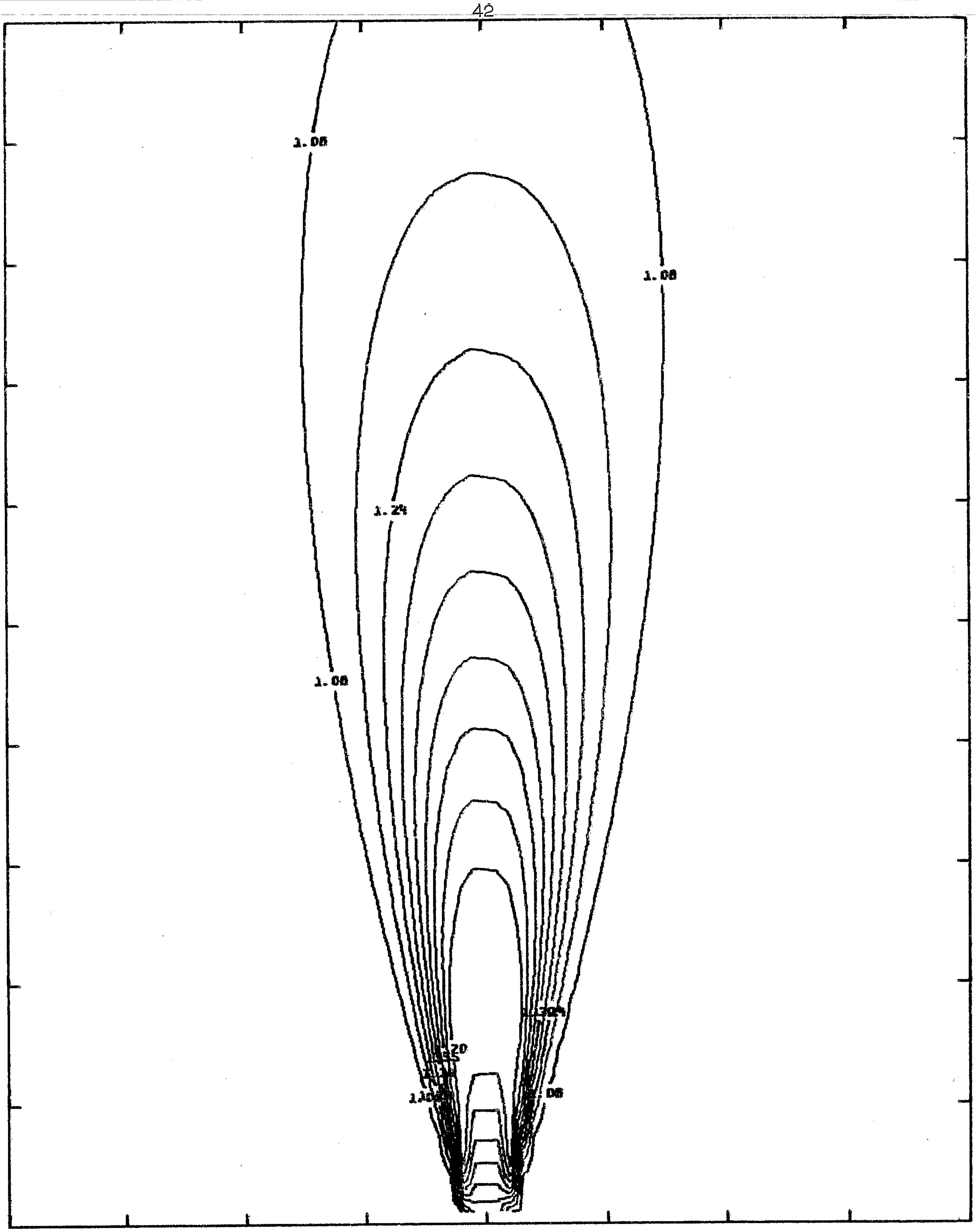

Fig. 30. Perca flavescens. Acclimation temp. 20.2°C. Run 10/2/73

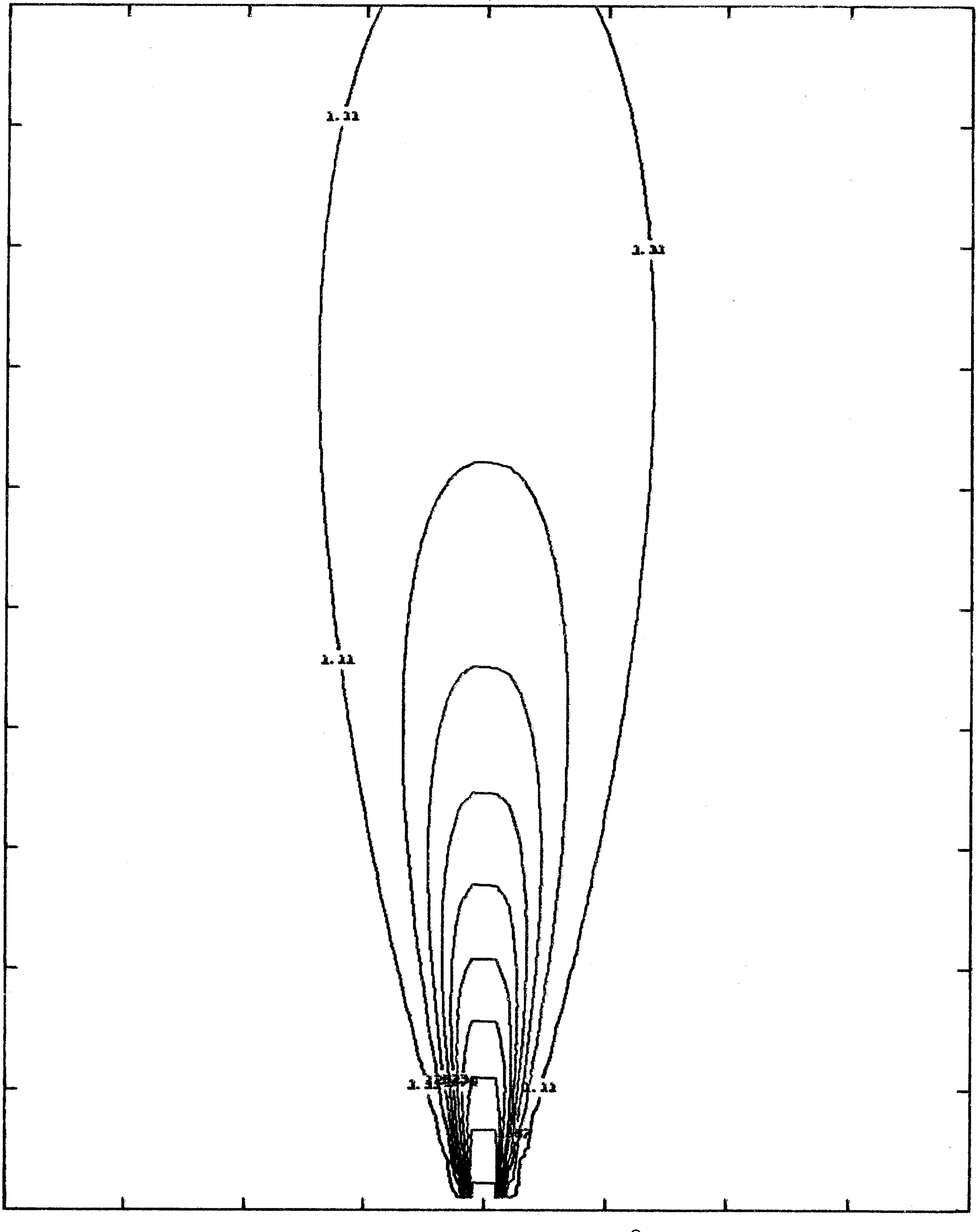

Fig. 31. Ictalurus nebulosus. Acclimation temp. 9.0°C. Run 11/22/72

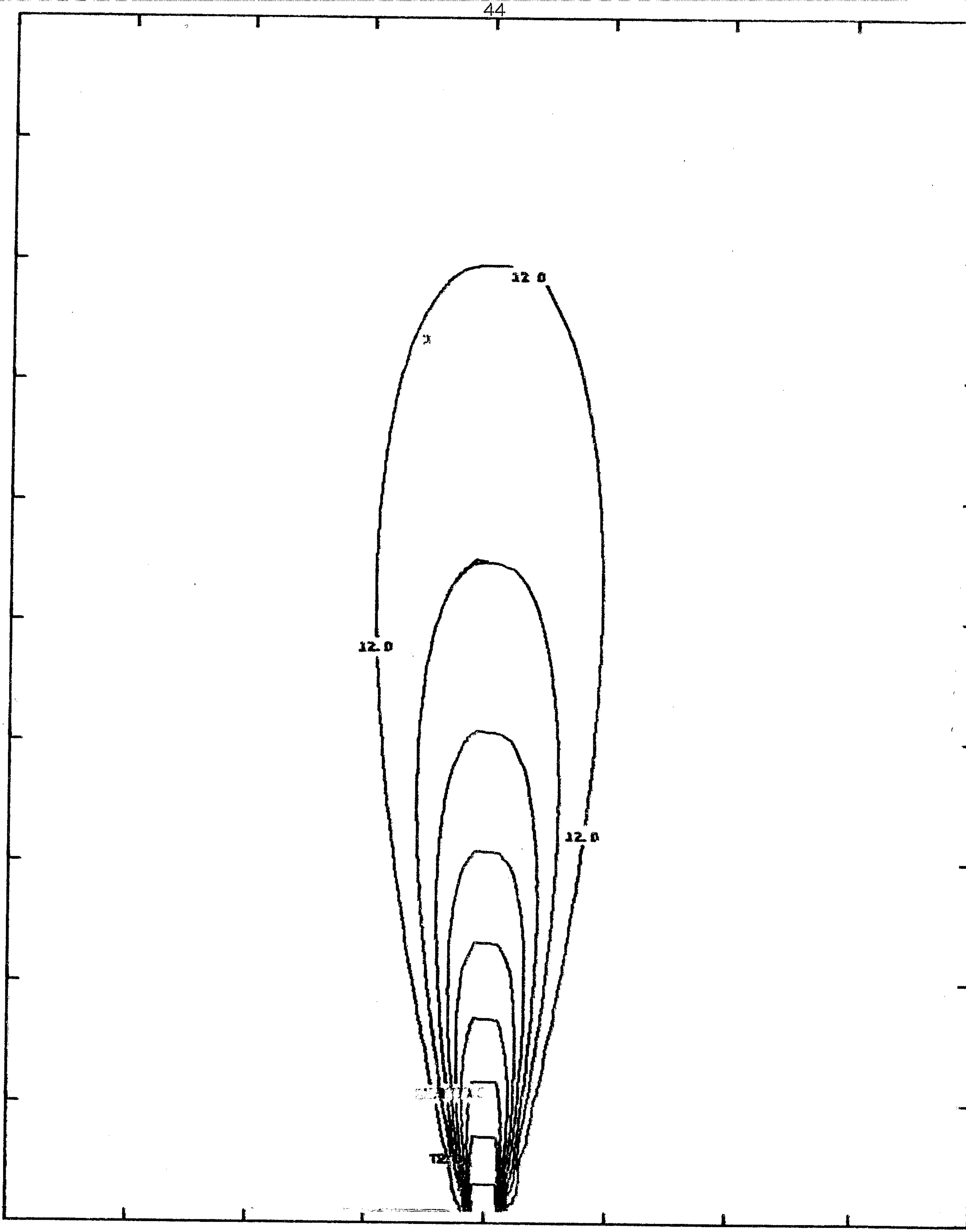

Fig. 32. Plume Thermal Structure for Fall.

APPENDIX III

ORDINATE TABLES

WINTER

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 WINTER
00010 PERCA FLAVESCENS, ACCLIMATION TEMPERATURE 4.  DEG.C.  RUN 12/7/72
00020  .1206E-04  .4907E-04  .1785E-03  .5803E-03  .1686E-02
00030  .4379E-02  .1017E-01  .2109E-01  .3911E-01  .6482E-01
00040  .9603E-01  .1271      .1505      .1505      .1271
00050  .9603E-01  .6482E-01  .3911E-01  .2109E-01  .1017E-01
00060  .4379E-02  .1686E-02  .5803E-03  .1785E-03  .4907E-04
00070  .1206E-04  .2649E-05  .5199E-06  .9122E-07  .1431E-07
00080  .2005E-08  .2512E-09  .2813E-10  .2815E-11  .2518E-12
00090  .2013E-13  .1439E-14  .9188E-16  .5245E-17  .2676E-18
00100 NOTROPIS ATHERINOIDES, ACCLIMATION TEMP. 4.  DEG. C. RUN 1/22/73
00110  .1834E-03  .1450E-02  .7868E-02  .2932E-01  .7505E-01
00120  .1319      .1319      .7505E-01  .2932E-01  .7868E-02
00130  .1450E-02  .1834E-03  .1593E-04  .9504E-06  .3893E-07
00140  .1095E-08  .2115E-10  .2806E-12  .2556E-14  .1598E-16
00150  .6864E-19  .2024E-21  .4099E-24  .5700E-27  .5442E-30
00160  .3568E-33  .1607E-36  .4967E-40  .1055E-43  .1537E-47
00170  .1539E-51  .1058E-55  .4994E-60  .1619E-64  .3603E-69
00180  .5506E-74  .0         .0         .0         .0
00190 POMOXIS NIGROMACULATUS, ACCLIMATION TEMP. 5.DEG.C. RUN 1/25/73
00200  .1183E-03  .2311E-03  .4370E-03  .7999E-03  .1417E-02
00210  .2429E-02  .4031E-02  .6474E-02  .1006E-01  .1514E-01
00220  .2205E-01  .3107E-01  .4238E-01  .5594E-01  .7148E-01
00230  .8839E-01  .1058      .1225      .1374      .1491
00240  .1566      .1566      .1491      .1374      .1225
00250  .1058      .8839E-01  .7148E-01  .5594E-01  .4238E-01
00260  .3107E-01  .2205E-01  .1514E-01  .1006E-01  .6474E-02
00270  .4031E-02  .2429E-02  .1417E-02  .7999E-03  .4370E-03
00280 LEPOMIS MACROCHIRUS, ACCLIMATION TEMP.4.9DEG.C.  RUN 2/15/73
00290  .1758E-39  .1195E-36  .6347E-34  .2637E-31  .8564E-29
00300  .2175E-26  .4318E-24  .6704E-22  .8136E-20  .7721E-18
00310  .5728E-16  .3323E-14  .1507E-12  .5343E-11  .1481E-09
00320  .3211E-08  .5442E-07  .7210E-06  .7469E-05  .6050E-04
00330  .3831E-03  .1897E-02  .7343E-02  .2222E-01  .5259E-01
00340  .9729E-01  .1407      .1407      .9729E-01  .5259E-01
00350  .2222E-01  .7343E-02  .1897E-02  .3831E-03  .6050E-04
00360  .7469E-05  .7210E-06  .5442E-07  .3211E-08  .1481E-09
00370 NOTROPIS HUDSONIUS, ACCLIMATION TEMP.  4.5DEG.  C.  RUN 3/2/73
00380  .2692E-02  .6338E-02  .1349E-01  .2596E-01  .4518E-01
00390  .7110E-01  .1011      .1301      .1513      .1513
00400  .1301      .1011      .7110E-01  .4518E-01  .2596E-01
00410  .1349E-01  .6338E-02  .2692E-02  .1034E-02  .3591E-03
00420  .1127E-03  .3201E-04  .8217E-05  .1907E-05  .4002E-06
00430  .7594E-07  .1303E-07  .2021E-08  .2835E-09  .3596E-10
00440  .4123E-11  .4275E-12  .4008E-13  .3397E-14  .2604E-15
00450  .1804E-16  .1131E-17  .6405E-19  .3281E-20  .1520E-21
00460 POMOXIS NEGROMACULATUS, ACCLIMATION TEMP.  3.0 DEG.C.  RUN 2/8/73
00470  .4871E-07  .3367E-06  .2037E-05  .1078E-04  .4996E-04
00480  .2026E-03  .7190E-03  .2233E-02  .6070E-02  .1444E-01
00490  .3006E-01  .5478E-01  .8735E-01  .1219      .1489
00500  .1489      .1219      .8735E-01  .5478E-01  .3006E-01
00510  .1444E-01  .6070E-02  .2233E-02  .7190E-03  .2026E-03
00520  .4996E-04  .1078E-04  .2037E-05  .3367E-06  .4871E-07
00530  .6168E-08  .6835E-09  .6629E-10  .5626E-11  .4179E-12
00540  .2717E-13  .1546E-14  .7697E-16  .3354E-17  .1279E-18
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SPRING

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SPRING
00010 CYPRINUS CARPIO, ACCLIMATION TEMP. 7.9DEG.C. RUN 3/22/73
00020  .1439E-37  .1516E-34  .1188E-31  .6922E-29  .2999E-26
00030  .9665E-24  .2316E-21  .4127E-19  .5469E-17  .5390E-15
00040  .3951E-13  .2153E-11  .8728E-10  .2631E-08  .5897E-07
00050  .9830E-06  .1219E-04  .1123E-03  .7702E-03  .3927E-02
00060  .1489E-01  .4198E-01  .8802E-01  .1372      .1372
00070  .8802E-01  .4198E-01  .1489E-01  .3927E-02  .7702E-03
00080  .1123E-03  .1219E-04  .9830E-06  .5897E-07  .2631E-08
00090  .8728E-10  .2153E-11  .3951E-13  .5390E-15  .5469E-17
00100 POMOXIS ANNULARIS, ACCLIMATION TEMP. 10.DEG.C. RUN 4/19/73
00110  .1687E-08  .9302E-08  .4719E-07  .2202E-06  .9458E-06
00120  .3737E-05  .1359E-04  .4545E-04  .1399E-03  .3961E-03
00130  .1032E-02  .2475E-02  .5459E-02  .1108E-01  .2069E-01
00140  .3555E-01  .5620E-01  .8175E-01  .1094      .1347
00150  .1527      .1527      .1347      .1094      .8175E-01
00160  .5620E-01  .3555E-01  .2069E-01  .1108E-01  .5459E-02
00170  .2475E-02  .1032E-02  .3961E-03  .1399E-03  .4545E-04
00180  .1359E-04  .3737E-05  .9458E-06  .2202E-06  .4719E-07
00190 ICTALURIS NEBULOSIS, ACCLIMATION TEMP. 13.1DEG.C. RUN 5/20/73
00200  .9261E-07  .4367E-06  .1885E-05  .7445E-05  .2691E-04
00210  .8903E-04  .2695E-03  .7469E-03  .1894E-02  .4396E-02
00220  .9336E-02  .1815E-01  .3229E-01  .5257E-01  .7833E-01
00230  .1068      .1333      .1523      .1523      .1333
00240  .1068      .7833E-01  .5257E-01  .3229E-01  .1815E-01
00250  .9336E-02  .4396E-02  .1894E-02  .7469E-03  .2695E-03
00260  .8903E-04  .2691E-04  .7445E-05  .1885E-05  .4367E-06
00270  .9261E-07  .1797E-07  .3192E-08  .5189E-09  .7719E-10
00280 LEPOMIS GIBBOSUS, ACCLIMATION TEMP. 9.0 DEG.C. RUN 4/3/73
00290  .1705E-14  .2123E-13  .2385E-12  .2418E-11  .2211E-10
00300  .1824E-09  .1357E-08  .9115E-08  .5522E-07  .3018E-06
00310  .1488E-05  .6619E-05  .2657E-04  .9619E-04  .3142E-03
00320  .9260E-03  .2462E-02  .5906E-02  .1278E-01  .2495E-01
00330  .4396E-01  .6985E-01  .1001      .1295      .1512
00340  .1512      .1295      .1001      .6985E-01  .4396E-01
00350  .2495E-01  .1278E-01  .5906E-02  .2462E-02  .9260E-03
00360  .3142E-03  .9619E-04  .2657E-04  .6619E-05  .1488E-05
00370 POMOXIS ANNULARIS, ACCLIMATION TEMP. 16.5 DEG.C. RUN 6/6/73
00380  .1294E-01  .1754E-01  .2331E-01  .3037E-01  .3880E-01
00390  .4861E-01  .5972E-01  .7195E-01  .8499E-01  .9845E-01
00400  .1118      .1246      .1361      .1457      .1530
00410  .1576      .1576      .1530      .1457      .1361
00420  .1246      .1118      .9845E-01  .8499E-01  .7195E-01
00430  .5972E-01  .4861E-01  .3880E-01  .3037E-01  .2331E-01
00440  .1754E-01  .1294E-01  .9367E-02  .6647E-02  .4625E-02
00450  .3156E-02  .2111E-02  .1385E-02  .8911E-03  .5622E-03
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SPRING (Continued)

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00460 POMOXIS NEGROMACULATUS, ACCLIMATION TEMP. 11.3 DEG.C. RUN 4/22/73
00470  .3471E-06  .1419E-05  .5353E-05  .1863E-04  .5984E-04
00480  .1773E-03  .4849E-03  .1223E-02  .2848E-02  .6116E-02
00490  .1212E-01  .2216E-01  .3739E-01  .5821E-01  .8361E-01
00500  .1108      .1355      .1529      .1529      .1355
00510  .1108      .8361E-01  .5821E-01  .3739E-01  .2216E-01
00520  .1212E-01  .6116E-02  .2848E-02  .1223E-02  .4849E-03
00530  .1773E-03  .5984E-04  .1863E-04  .5353E-05  .1419E-05
00540  .3471E-06  .7832E-07  .1631E-07  .3133E-08  .5555E-09
00550 POMOXIS ANNULARIS, ACCLIMATION TEMP. 13.1 DEG.C. RUN 5/16/73
00560  .5497E-02  .8074E-02  .1158E-01  .1624E-01  .2224E-01
00570  .2975E-01  .3889E-01  .4967E-01  .6197E-01  .7553E-01
00580  .8995E-01  .1047      .1190      .1321      .1433
00590  .1519      .1573      .1573      .1519      .1433
00600  .1321      .1190      .1047      .8995E-01  .7553E-01
00610  .6197E-01  .4967E-01  .3889E-01  .2975E-01  .2224E-01
00620  .1624E-01  .1158E-01  .8074E-02  .5497E-02  .3657E-02
00630  .2377E-02  .1509E-02  .9363E-03  .5674E-03  .3360E-03
00640 ICTALURIS NEBULOSIS, ACCLIMATION TEMP. 13.8 DEG.C. RUN5/24/73
00650  .3352E-14  .3607E-13  .3536E-12  .3158E-11  .2569E-10
00660  .1904E-09  .1286E-08  .7912E-08  .4434E-07  .2264E-06
00670  .1053E-05  .4464E-05  .1724E-04  .6063E-04  .1943E-03
00680  .5673E-03  .1509E-02  .3657E-02  .8072E-02  .1624E-01
00690  .2975E-01  .4966E-01  .7553E-01  .1046      .1321
00700  .1519      .1519      .1321      .1046      .7553E-01
00710  .4966E-01  .2975E-01  .1624E-01  .8072E-02  .3657E-02
00720  .1509E-02  .5673E-03  .1943E-03  .6063E-04  .1724E-04
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SUMMER

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SUMMER
00010 ICTALURIS NEBULOSIS, ACCLIMATION TEMP. 20.4 DEG.C. RUN 6/4/73
00020  .1914E-05  .5487E-05  .1494E-04  .3866E-04  .9499E-04
00030  .2217E-03  .4917E-03  .1036E-02  .2072E-02  .3939E-02
00040  .7111E-02  .1220E-01  .1987E-01  .3075E-01  .4520E-01
00050  .6312E-01  .8374E-01  .1055      .1263      .1436
00060  .1551      .1551      .1436      .1263      .1055
00070  .8374E-01  .6312E-01  .4520E-01  .3075E-01  .1987E-01
00080  .1220E-01  .7111E-02  .3939E-02  .2072E-02  .1036E-02
00090  .4917E-03  .2217E-03  .9499E-04  .3866E-04  .1494E-04
00100 AMBLOPLITES RUPESTRIS, ACCLIMATION TEMP. 20.3 DEG.C. RUN 6/19/73
00110  .6320E-13  .1381E-11  .2532E-10  .3890E-09  .5011E-08
00120  .5412E-07  .4900E-06  .3720E-05  .2368E-04  .1263E-03
00130  .5652E-03  .2120E-02  .6667E-02  .1758E-01  .3885E-01
00140  .7200E-01  .1119      .1457      .1457      .1119
00150  .7200E-01  .3885E-01  .1758E-01  .6667E-02  .2120E-02
00160  .5652E-03  .1263E-03  .2368E-04  .3720E-05  .4900E-06
00170  .5412E-07  .5011E-08  .3890E-09  .2532E-10  .1381E-11
00180  .6320E-13  .2424E-14  .7795E-16  .2102E-17  .4750E-19
00190 PERCA FLAVESCENS, ACCLIMATION TEMP. 21.3 DEG.C. RUN 9/12/13
00200  .1452E-04  .3448E-04  .7849E-04  .1713E-03  .3584E-03
00210  .7189E-03  .1382E-02  .2549E-02  .4505E-02  .7633E-02
00220  .1240E-01  .1931E-01  .2883E-01  .4126E-01  .5662E-01
00230  .7448E-01  .9393E-01  .1136      .1316      .1463
00240  .1558      .1558      .1463      .1316      .1136
00250  .9393E-01  .7448E-01  .5662E-01  .4126E-01  .2883E-01
00260  .1931E-01  .1240E-01  .7633E-02  .4505E-02  .2549E-02
00270  .1382E-02  .7189E-03  .3584E-03  .1713E-03  .7849E-04
00280 ICTALURIS PUNCTATUS, ACCLIMATION TEMP. 20.3 DEG.C. RUN 10/4/73
00290  .4684E-02  .6723E-02  .9463E-02  .1306E-01  .1768E-01
00300  .2347E-01  .3055E-01  .3900E-01  .4882E-01  .5993E-01
00310  .7215E-01  .8519E-01  .9862E-01  .1120      .1247
00320  .1361      .1458      .1531      .1576      .1576
00330  .1531      .1458      .1361      .1247      .1120
00340  .9862E-01  .8519E-01  .7215E-01  .5993E-01  .4882E-01
00350  .3900E-01  .3055E-01  .2347E-01  .1768E-01  .1306E-01
00360  .9463E-02  .6723E-02  .4684E-02  .3201E-02  .2144E-02
00370 POMOXIS NEGROMACULATUS, ACCLIMATION TEMP. 20.7 DEG.C. RUN 10/9/73
00380  .9638E-08  .3741E-07  .1370E-06  .4739E-06  .1547E-05
00390  .4766E-05  .1386E-04  .3805E-04  .9860E-04  .2412E-03
00400  .5569E-03  .1214E-02  .2497E-02  .4848E-02  .8886E-02
00410  .1537E-01  .2511E-01  .3871E-01  .5633E-01  .7737E-01
00420  .1003      .1228      .1418      .1546      .1546
00430  .1418      .1228      .1003      .7737E-01  .5633E-01
00440  .3871E-01  .2511E-01  .1537E-01  .8886E-02  .4848E-02
00450  .2497E-02  .1214E-02  .5569E-03  .2412E-03  .9860E-04
00460 NOTEMIGONUS CRYSOLEUCAS, ACCLIMATION TEMP. 19.6 DEG.C. RUN 6/11/73
00470  .1929E-04  .4646E-04  .1070E-03  .2356E-03  .4957E-03
00480  .9971E-03  .1917E-02  .3524E-02  .6192E-02  .1040E-01
00490  .1670E-01  .2563E-01  .3760E-01  .5273E-01  .7069E-01
00500  .9058E-01  .1110      .1299      .1454      .1556
00510  .1556      .1454      .1299      .1110      .9058E-01
00520  .7069E-01  .5273E-01  .3760E-01  .2563E-01  .1670E-01
00530  .1040E-01  .6192E-02  .3524E-02  .1917E-02  .9971E-03
00540  .4957E-03  .2356E-03  .1070E-03  .4646E-04  .1929E-04
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SUMMER (Continued)

00550	ICTALURIS PUNCTATUS, ACCLIMATION TEMP. 24.2 DEG.C. RUN 7/12/73				
00560	.3113E-04	.5928E-04	.1101E-03	.1993E-03	.3520E-03
00570	.6059E-03	.1017E-02	.1665E-02	.2656E-02	.4133E-02
00580	.6271E-02	.9277E-02	.1338E-01	.1882E-01	.2581E-01
00590	.3451E-01	.4500E-01	.5721E-01	.7091E-01	.8570E-01
00600	.1010	.1161	.1300	.1421	.1513
00610	.1572	.1572	.1513	.1421	.1300
00620	.1161	.1010	.8570E-01	.7091E-01	.5721E-01
00630	.4500E-01	.3451E-01	.2581E-01	.1882E-01	.1338E-01
00640	APLODINOTUS GRUNNIENS, ACCLIMATION TEMP. 23.0 DEG.C. RUN 8/1/73				
00650	.3568E-10	.2362E-09	.1438E-08	.8045E-08	.4139E-07
00660	.1958E-06	.8516E-06	.3406E-05	.1252E-04	.4233E-04
00670	.1316E-03	.3760E-03	.9879E-03	.2386E-02	.5301E-02
00680	.1082E-01	.2032E-01	.3509E-01	.5569E-01	.8128E-01
00690	.1091	.1345	.1526	.1526	.1345
00700	.1091	.8128E-01	.5569E-01	.3509E-01	.2032E-01
00710	.1082E-01	.5301E-02	.2386E-02	.9879E-03	.3760E-03
00720	.1316E-03	.4233E-04	.1252E-04	.3406E-05	.8516E-06

FALL

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 FALL
00010 PERCA FLAVESCENS, ACCLIMATION TEMP. 15.5 DEG.C. RUN  10/29/73
00020  .2290E-16  .3998E-15  .6210E-14  .8585E-13  .1056E-11
00030  .1156E-10  .1126E-09  .9757E-09  .7524E-08  .5163E-07
00040  .3153E-06  .1713E-05  .8282E-05  .3563E-04  .1364E-03
00050  .4646E-03  .1408E-02  .3798E-02  .9116E-02  .1947E-01
00060  .3699E-01  .6256E-01  .9412E-01  .1260      .1501
00070  .1501      .1260      .9412E-01  .6256E-01  .3699E-01
00080  .1947E-01  .9116E-02  .3798E-02  .1408E-02  .4646E-03
00090  .1364E-03  .3563E-04  .8282E-05  .1713E-05  .3153E-06
00100 POMOXIS ANNULARIS, ACCLIMATION TEMP. 11. DEG.C. RUN 11/6/73
00110  .1773E-02  .4166E-02  .8949E-02  .1757E-01  .3153E-01
00120  .5170E-01  .7750E-01  .1062      .1330      .1522
00130  .1522      .1330      .1062      .7750E-01  .5170E-01
00140  .3153E-01  .1757E-01  .8949E-02  .4166E-02  .1773E-02
00150  .6894E-03  .2450E-03  .7960E-04  .2364E-04  .6414E-05
00160  .1591E-05  .3607E-06  .7473E-07  .1415E-07  .2450E-08
00170  .3875E-09  .5603E-10  .7404E-11  .8943E-12  .9872E-13
00180  .9961E-14  .9186E-15  .7742E-16  .5964E-17  .4199E-18
00190 MICROPTERUS DOLOMIEUI, ACCLIMATION TEMP. 10. DEG.C. RUN 11/14/73
00200  .3236E-32  .7960E-30  .1578E-27  .2521E-25  .3245E-23
00210  .3366E-21  .2813E-19  .1895E-17  .1029E-15  .4499E-14
00220  .1586E-12  .4503E-11  .1031E-09  .1900E-08  .2824E-07
00230  .3382E-06  .3263E-05  .2538E-04  .1590E-03  .8028E-03
00240  .3267E-02  .1071E-01  .2830E-01  .6024E-01  .1033
00250  .1429      .1429      .1033      .6024E-01  .2830E-01
00260  .1071E-01  .3267E-02  .8028E-03  .1590E-03  .2538E-04
00270  .3263E-05  .3382E-06  .2824E-07  .1900E-08  .1031E-09
00280 ICTALURIS PUNCTATUS, ACCLIMATION TEMP. 20. DEG.C. RUN 9/18/73
00290  .2246E-01  .2719E-01  .3259E-01  .3868E-01  .4546E-01
00300  .5290E-01  .6097E-01  .6959E-01  .7865E-01  .8802E-01
00310  .9755E-01  .1071      .1163      .1252      .1334
00320  .1408      .1472      .1523      .1561      .1584
00330  .1584      .1561      .1523      .1472      .1408
00340  .1334      .1252      .1163      .1071      .9755E-01
00350  .8802E-01  .7865E-01  .6959E-01  .6097E-01  .5290E-01
00360  .4546E-01  .3868E-01  .3259E-01  .2719E-01  .2246E-01
00370 PERCA FLAVESCENS, ACCLIMATION TEMP. 20.2 DEG.C. RUN 10/2/73
00380  .2402E-02  .3991E-02  .6418E-02  .9989E-02  .1504E-01
00390  .2193E-01  .3093E-01  .4222E-01  .5578E-01  .7132E-01
00400  .8825E-01  .1057      .1225      .1373      .1491
00410  .1566      .1566      .1491      .1373      .1225
00420  .1057      .8825E-01  .7132E-01  .5578E-01  .4222E-01
00430  .3093E-01  .2193E-01  .1504E-01  .9989E-02  .6418E-02
00440  .3991E-02  .2402E-02  .1399E-02  .7885E-03  .4301E-03
00450  .2270E-03  .1160E-03  .5735E-04  .2744E-04  .1271E-04
00460 ICTALURIS NEBULOSIS, ACCLIMATION TEMP. 9.0 DEG.C. RUN 11/22/72
00470  .1949E-02  .2835E-02  .4055E-02  .5703E-02  .7890E-02
00480  .1074E-01  .1436E-01  .1890E-01  .2447E-01  .3115E-01
00490  .3900E-01  .4801E-01  .5814E-01  .6925E-01  .8111E-01
00500  .9343E-01  .1059      .1180      .1293      .1393
00510  .1477      .1539      .1578      .1578      .1539
00520  .1477      .1393      .1293      .1180      .1059
00530  .9343E-01  .8111E-01  .6925E-01  .5814E-01  .4801E-01
00540  .3900E-01  .3115E-01  .2447E-01  .1890E-01  .1436E-01
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