A STUDY OF DROUGHT FREQUENCIES FOR THE LOWER PENINSULA OF MICHIGAN

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Theodore W. Cahow

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This is to certify that the

thesis entitled

"A Study of Drought Frequencies for the
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E H Kidder
Major professor

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A STUDY OF DROUGHT FREQUENCIES FOR THE LOWER
PENINSULA OF MICHIGAN

by

Theodore W. Cahow

An Abstract

Submitted to the School of Graduate Studies of
Michigan State College of Agriculture and Applied
Science in partial fulfillment of the requirements
for the degree of

Master of Science

Approved E H Kidder

Department of Agricultural Engineering

The study of drought frequencies, while not a new subject, has not been undertaken on any large scale. A knowledge of how often droughts of a damaging duration might occur, however, would be of great value to the growers of many of our cash crops. It is the purpose of this project, then, to determine the frequency and intensity of droughts over the lower peninsula of Michigan. To do this, the precipitation data for the months of May through September at each of 37 stations was tabulated and carefully analyzed for both the frequency and duration of drought periods.

Close study of these drought periods show that no definite pattern exists over the lower peninsula of the state. The data does clearly show, however, that the months of July and August are more likely to have the long severe droughts while the months of May and September will have more frequent droughts.

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INTRODUCTION

One of the major problems that has confronted the farmer almost since the beginning of civilization has been that of obtaining adequate moisture for plant growth. Some of these farmers have depended entirely on the natural supply in the form of precipitation and have found it adequate. Others, in drier climates, have endeavored to furnish the needed moisture by artificial means and have met with varying degrees of success. It has been shown by many people, however, that irrigation, as this artificial application is called, can be profitable to the farmer if it is handled intelligently. Many books have been written on the subject and men interested in the science have developed many different methods in which to carry on the practice. Each of these methods is designed to meet a different set of conditions. Many of these same men also pointed out that in certain parts of the country, continuous irrigation was needed; while in others, it would only be needed to supplement the natural supply. In these areas, then, where nature furnished part of the required moisture, another problem arose. It concerned itself with weather and its unpredictable nature. When would the farmer receive a natural supply and when would he have to apply the water himself? This is the problem that is taken up in this research paper.

REVIEW OF LITERATURE

As supplemental irrigation is of primary interest throughout this region, it is important that the meaning be clearly understood. Staebner(1) defines it as "the artificial watering of crops in regions where rainfall is ordinarily depended on for moisture." Israelsen(2) looks upon it as the artificial application of water by man with which he attempts to supplement the natural supply. Both of these men look upon the subject from the same point of view. That is, a plant requires a certain amount of water during the growing period. If nature supplies only part of this moisture, then man must furnish the rest. This brings up the question as to when or how often it is necessary to supplement the natural supply. The answer to this depends upon many factors. Among these are the type of crop and its stage of maturity. Another would be the temperature and humidity of the atmosphere. There would also be the factor of the physical properties of the soil. It is common knowledge that plants receive most of their water supply from the soil. Soils men have termed this supply, available moisture, in that it can be used by the plants. Millar and Turk(3) state that the more important factors influencing the quantity of available moisture in the soil are texture, structure, organic matter content, aeration, and position of the water table. In regards to texture, these same authors point out that fine soils,

such as clay, will hold between 4 and 5 times as much available moisture as will the lighter soils, such as sand. The effect of organic matter content on the amount of available moisture is much the same as for texture. In general, the more organic matter present in a soil, the more water the soil will hold. It is logical to assume, then, that a heavy soil or soil of high organic matter content, will be able to hold more water from a given rain than will a light soil or a soil of low organic matter content. This being the case, it can be expected that a sandy soil would require more artificially applied water than would a heavy soil, the crop being the same in both cases.

The aforementioned factors are only a few of the many that should be considered in the study of drought effects or the control of droughts. Nevertheless, they serve to point out that a drought of a given severity might be damaging in one instance and not in another. However, if it could be determined with a reasonable degree of certainty when and how often droughts of varying intensity were to occur in any given locality, then we could better judge the need and value of supplemental irrigation. The best way to do this would be to analyze past weather records. A few analyses of this type have been undertaken by other men, but on a rather limited scale. Carreker and Liddell(4) used 6 locations in Georgia and studied

the rainfall records for thepast 25 years. Similar work was undertaken by Staebner(5) over the upper and lower peninsula of Michigan. In the work of Carreker and Liddell, 0.25 inches of rain in 24 hours was set as the minimum requirement for plant growth in a two week period. Staebner chose to use .1 inch per day. While this value has its good points, it has not been widely accepted.

PROCEDURE OF WORK

As was pointed out earlier, the amount of water necessary to maintain plant growth varies not only with the plant, but also with the soil and with other climatic conditions. To use Staebner's value of .1 inch per day would be satisfactory under some conditions and not under others. It could very well be, for example, that .1 inch of rain falling each day on a heavy soil might evaporate before it ever reached the root zone. Unfortunately, the use of any set value could well prove erroneous under certain conditions. Nevertheless, it offers the only practical solution in a problem of this kind. The use of a number of values, each established for a different set of variables, would be much more accurate, but would develop into an almost endless task. It remains then, for the research worker to choose a value that he feels best suits the conditions and needs of the problem he has undertaken. In this paper, then, a drought is defined as "a period constituting 7 days or more in which less than 0.25 inches of

precipitation has occurred in 24 hours." It has been observed that amounts of less magnitude rarely reach the root zone, while greater amounts usually have a beneficial effect on plant growth. It should be kept in mind, however, that under certain instances, amounts of 0.20 or even 0.15 of an inch can be beneficial to the plant. Such a case might result when one of these rains occurred a day or two after a heavy rain. Analysis of the data collected, however, reveals that these cases rarely occur.

Now that the definition of a drought has been established, any future predictions should be based on an analysis of past long term records. The data from 37 stations in the lower peninsula of Michigan was tabulated for this project. These stations were chosen both for their location and their length of record. It was desired to have a complete as well as accurate coverage of the state. With one exception, they all have from 36 to 51 years of rainfall data with 27 of the stations having over 46 years of records. The location of each station is shown in Figure 1.

The daily rainfall records for each of these stations were taken from the published "Climatological Data" of the Weather Bureau of the United States Department of Commerce, and tabulated in sequence order of the day, month, and year of its occurrence. Only the months of May through September were included as this analysis is intended to cover only the growing season. The data were then

studied for the occurrence of droughts of varying length and frequency.

These droughts were then tabulated in groups according to the month in which they occurred and their duration. For example, all droughts lasting from 7 to 14 days in the month of May were placed in one group, while those lasting for the same period in the month of June were placed in another. The reason for tabulating according to month is that the degree of drought resistance in many plants varies with their stage of maturity. May and June droughts may be of concern to small fruit growers, while July and August droughts could be serious to producers of later maturing crops, such as tomatoes.

The groups were set up in 7 day increments from 7 days up to 35 days. Droughts lasting 35 days or longer were all placed in one group. It is felt that a complete analysis of droughts lasting over 5 weeks is not of primary importance in this instance. Few crops in Michigan can withstand droughts of 35 days without damage unless some supplemental irrigation is applied.

In analyzing the data in this way, there were many times when one period would extend from one month into the next. When this occurred, the period was charged to the month which had the most days in the particular period. For example, if a 21 day drought occurred, with 11 days in May and 10 in June, then May would be credited with the entire drought. If each month had the same number of days in a drought period, then it would

be charged to the month in which it originated. There would, however, be one exception in this case. Assume that a drought started on the 26th of May and continued on through June and for 30 days into July. This would mean that the period lasted 6 days in May, 30 days in June and 30 days in July, for a total of 66 days. The drought in this case, would be charged to the month of June. June is the critical month in that the drought will have had a major effect before July began.

DISCUSSION OF RESULTS

In order to best show the results of this study, a series of maps and charts were made to illustrate the pertinent findings.

Figures 2 through 26 are drawn on the basis of number of droughts occurring in the average 10 year period. Figure 2, page 16, for example, shows the frequency with which 1 to 2 week droughts occur in the month of May. A line labeled with the number 9 passes through all points having on the average of 9 droughts lasting from 1 to 2 weeks in a 10 year period. The line 8 indicates that 8 droughts occur in 10 years.

One would naturally expect the more severe droughts to occur less frequently than droughts of less duration. This is brought out clearly in the maps. The lines on Figure 21, page 25, for instance, are labeled with numbers of less than one. This means that these droughts will occur less than once every 10 years. A line marked

0.5 indicates 1 drought in 20 years while 0.2 indicates one in every 50 years.

Figures 27 through 63 show the cumulative frequency of the droughts. The charts are drawn for each station and each of the 5 months under study. Figure 27, page 29, for example, covers the 5 months for the station at Adrian, Michigan. This chart contains five separate groups of bar graphs. Each group covers one of the 5 months under study. Looking at the graphs for May, it can be seen that there were 74 droughts lasting 7 days or longer. In other words, there were a total of 74 May droughts during the 50 year record of the station. The graphs further show that there were 28 droughts lasting 14 days or longer. To determine the exact number of 1 to 2 week droughts, we have only to subtract 28 from 74, which shows that 46 of these droughts occurred.

These charts, if studied closely, will give more detailed information at the various stations than will the maps. For example, let us assume that a farmer wishes to grow strawberries near Traverse City. The soil in this particular area is a light sandy loam and is not capable of retaining moisture for any period of time. The strawberries which will be grown here can be expected to mature around the latter part of May and the early part of June. During this fruiting period, they require an abundance of water if they are to produce a berry of a marketable nature. The moisture requirement of the fruit then, along with the nature of the soil, indicates that short droughts lasting 7 or 8 days can be damaging. By looking

at Figure 60, page 45, for the month of May, it can be seen that 71 droughts lasting 7 days or longer have occurred in the past 47 years. This is an average of 1.5 droughts in the month of May each year. In June, 70 droughts occurred in 48 years. Here again the average is 1.5 each year. This would indicate that supplemental irrigation would be advisable to this farmer, especially if the success or failure of the crop would have a pronounced effect on his economic stability.

ANALYSIS OF DATA

When we are confronted with a problem or phenomenon over which we have no control, we study to see if it follows any set routine or pattern. Weather, unfortunately, rarely follows a pattern in any given locality. In analyzing the data, however, some interesting points have been found that should be brought out. These are as follows:

1. Droughts of 1 to 2 weeks during May, Figure 2, page 16, appear to be fairly uniform throughout the state. The average in this month is 10 droughts in 10 years. A slight increase to 12 in 10 years can be seen around Ludington and Muskegon, while the southeastern and southwestern area shows a decrease to 9 in 10 years.

   The June average, Figure 3, page 16, drops to 8 droughts in 10 years with the southeastern area at 10 in 10 years being above the average. The

rest of the state remains fairly uniform.

In July, Figure 4, page 17, the average rises again to almost 9 in 10 years with the above average areas of 10 in 10 years centering around Port Huron and East Tawas. The western shoreline and the area around East Lansing, Flint and Detroit are slightly below average with 8 in 10 years.

In August, Figure 5, page 17, the average again drops to 8 in 10 years with the southern counties and the Port Huron area having 9 in 10 years and the East Tawas area having 6 in 10 years.

In September, Figure 6, page 18, the average is 9 in 10 years with the extreme southwestern area having 11 droughts in 10 years and the East Lansing, Alma, Bay City area being low or below average with 8 in 10 years.

2. Droughts of 2 to 3 weeks occur much less frequently than those of 1 to 2 weeks. The average for the month of May, Figure 7, page 18, is slightly less than 4 in 10 years. The lower peninsula is fairly uniform with a high of 5 in 10 years centered around Harbor Beach.

In June, Figure 8, page 19, the average drops to a little better than 3 droughts in 10 years. Here the high areas are widely scattered. The southeast and southwest, the area around Ludington, and the area around Mackinaw City, average

over 4 while the area around Grayling averages less than 2 droughts in 10 years.

In July, Figure 9, page 19, the average rises slightly to between 3 and 4 droughts in 10 years. The only area varying appreciably from the average is between Traverse City and Grayling. Here the average drops to 2 in 10 years.

In August, Figure 10, page 20, the average again drops to the June level of 3 droughts in 10 years and is fairly uniform throughout the state.

In September, Figure 11, page 20, the average continues to be 3 droughts in 10 years with the areas around Ludington, Manistee, Mackinaw City, and Alma rising to 4 in 10 years. The remainder of the state is quite uniform.

3. Droughts of 3 to 4 weeks in May, Figure 12, page 21, averaged slightly over 1 in 10 years throughout the state. Areas around Petoskey and between Bay City and East Tawas were higher than the average with 2 in 10 years, while the extreme southwest was low with 1 drought in 20 years.

In June, Figure 13, page 21, the average increased to slightly under 2 droughts in 10 years with the area around West Branch having 3 in 10 years and the area around Hillsdale, Jackson, and Adrian having 1 in 10 years.

The July average, Figure 14, page 22, was very similar to June with slightly under 2 droughts in 10 years. The only extreme variance was centered around Petoskey where no droughts of this duration have been recorded.

The month of August, Figure 15, page 22, revealed an average of slightly greater than 2 in 10 years. Above average areas of 3 droughts in 10 years are centered around Cadillac and Saginaw while the East Lansing area is low with 1 drought in 10 years.

In September, Figure 16, page 23, the average dropped to less than 1 drought in 10 years. The high area this month is around Ann Arbor with 2 droughts in 10 years and the low around Cadillac with no droughts occurring.

4. In the 4 to 5 week droughts, the average for May, Figure 17, page 23, is 1 drought every 33 years. The above average area extends across the northern part of the state between Petoskey and Alpena. The average here is 1 in 15 years. Directly north of this area, around Mackinaw City and a strip running southeast from Manistee to Flint, no droughts of 28 to 35 days duration occurred.

In June, Figure 18, page 24, the average for the state increased to 1 in 14 years. The areas between Cadillac and Mackinaw and around Saginaw

Flint and Bay City should expect about 1 each 10 years, while Detroit had none in 51 years.

In July, Figure 19, page 24, the state average was 1 in 15 years with highs of 1 in 10 years around Grand Haven, Manistee, Alpena, and Hillsdale. Areas around Saginaw and Ann Arbor have never experienced these droughts.

In August, Figure 20, page 25, the droughts have occurred on the average of 1 each 12½ years over the state. The central area of Michigan between Alma and Grayling has had these periods about once in 8 years, while in the Hillsdale area, it has been closer to once in 25 years.

The September average, Figure 21, page 25, drops down again to 1 in 33 years. Isolated high areas of 1 in 20 years are found around East Lansing, Port Huron and West Branch. An extreme high of 1 in 12½ years is found southeast of Traverse City. The areas around Alma, Allegan and Battle Creek, however, have experienced none of these droughts.

5. The state average for droughts lasting 5 weeks or longer during May is 1 in 50 years. The average was uniform throughout the central area from Manistee and Ludington across the state to Bay City and Saginaw. The south central area up to East Lansing was entirely free of these droughts

as was the area between Onaway and Alpena. The region between Petoskey and East Tawas, on the other hand, has experienced these severe periods about once every 20 to 25 years as shown in Figure 22, page 26.

The average for June, Figure 23, page 26, rises slightly to once in 25 years. The drought free areas during this month are located around Coldwater and Onaway, while frequencies of once in 12 years are found around Port Huron and Grand Haven.

In July, Figure 24, page 27, the average rises again to 1 in 17 years. Higher frequencies of once in 10 years have occurred along a strip running south from Petoskey down to Grand Haven. The area around Onaway has had none of these droughts.

In August, Figure 25, page 27, the droughts occur most frequently averaging once every 12½ years. Higher frequencies of 1 in 10 years are found along the west side between Ludington and St. Joseph. Lower frequencies of 1 in 20 years are located in a narrow strip running diagonally across the state from Traverse City down to Detroit.

In September, Figure 26, page 28, the frequency drops again to 1 drought in 33 years. During this month, the eastern half of the state averages slightly higher or about once every 20 to 25 years. The west side of the state is lower and averages

about 1 drought every 50 years. No droughts have occurred around Manistee and West Branch.

CONCLUSION

In looking over the data it would appear that no definite pattern exists over the entire state. That is, it cannot be said that droughts are more prevalent in the southern half than in the northern half. Nor can it be said that the severe droughts will affect the eastern half more than the western. The maps do clearly show us, however, that short droughts occur more frequently in May and September than in the other three months. They also show that August is the most dangerous month for droughts lasting three weeks or longer.

Fig. 1 Map of weather stations used in this project.

Fig. 2

MAY

7 to 14 Day Droughts

Fig. 3

JUNE

7 to 14 Day Droughts

Fig. 4

JULY

7 to 14 Day Droughts

Fig. 5

AUGUST

7 to 14 Day Droughts

Fig. 6

SEPTEMBER
7 to 14 Day Droughts

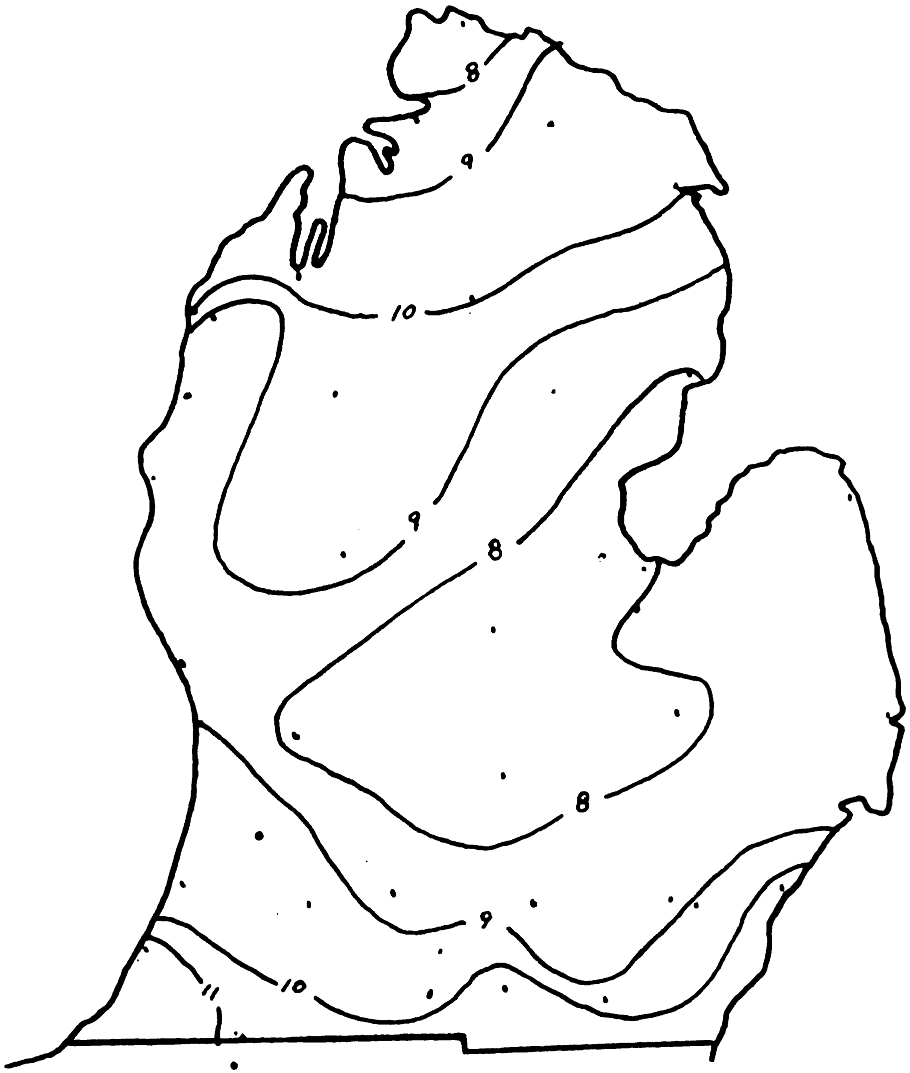


Fig. 7

MAY
14 to 21 Day Droughts

Fig. 8

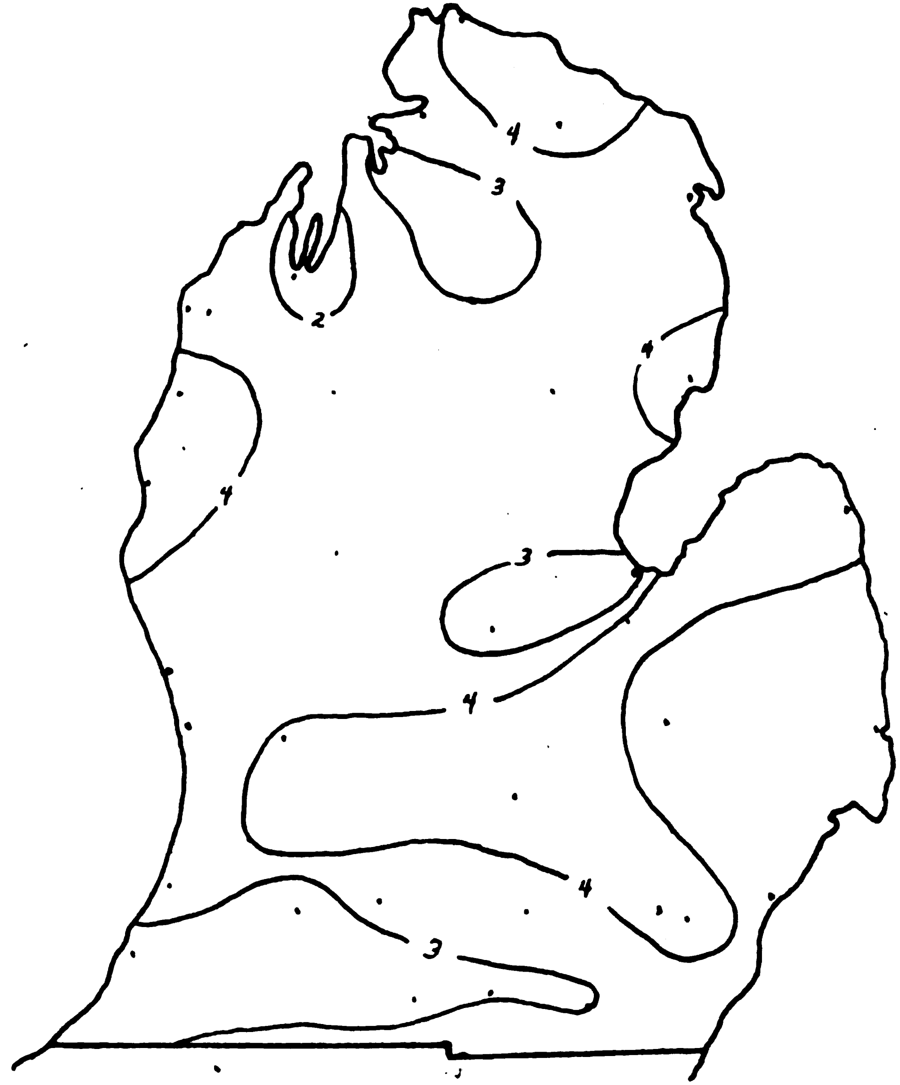
JUNE

14 to 21 Day Droughts

Fig. 9

JULY

14 to 21 Day Droughts



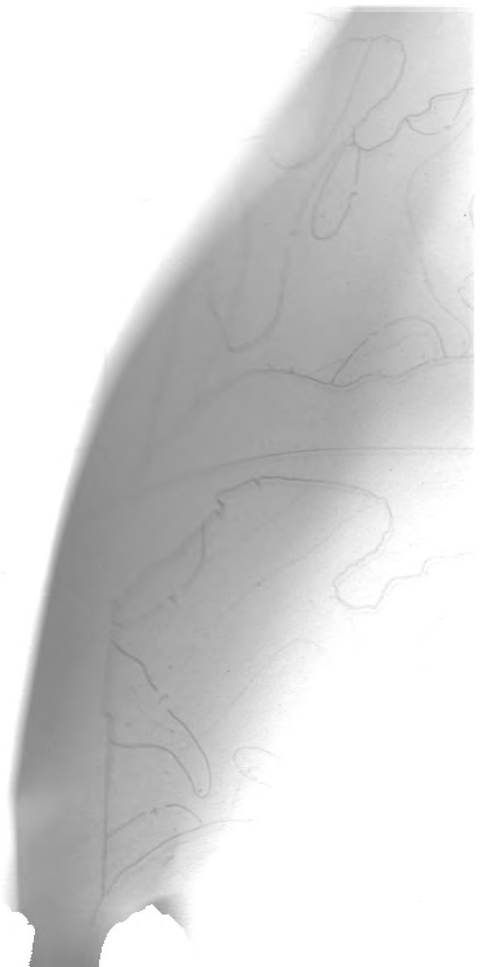


Fig. 10

AUGUST

14 to 21 Day Droughts

Fig. 11

SEPTEMBER

14 to 21 Day Droughts

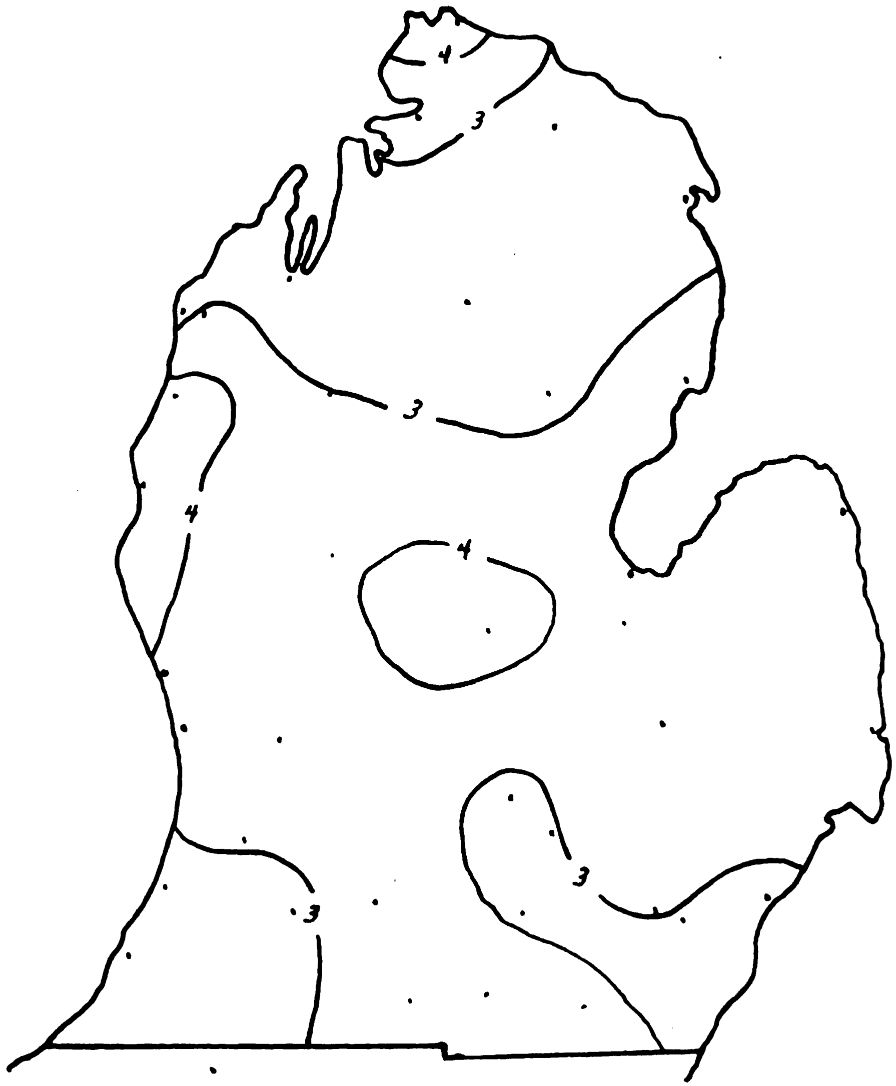


Fig. 10

AUGUST
14 to 21 Day Droughts

Fig. 11

SEPTEMBER
14 to 21 Day Droughts

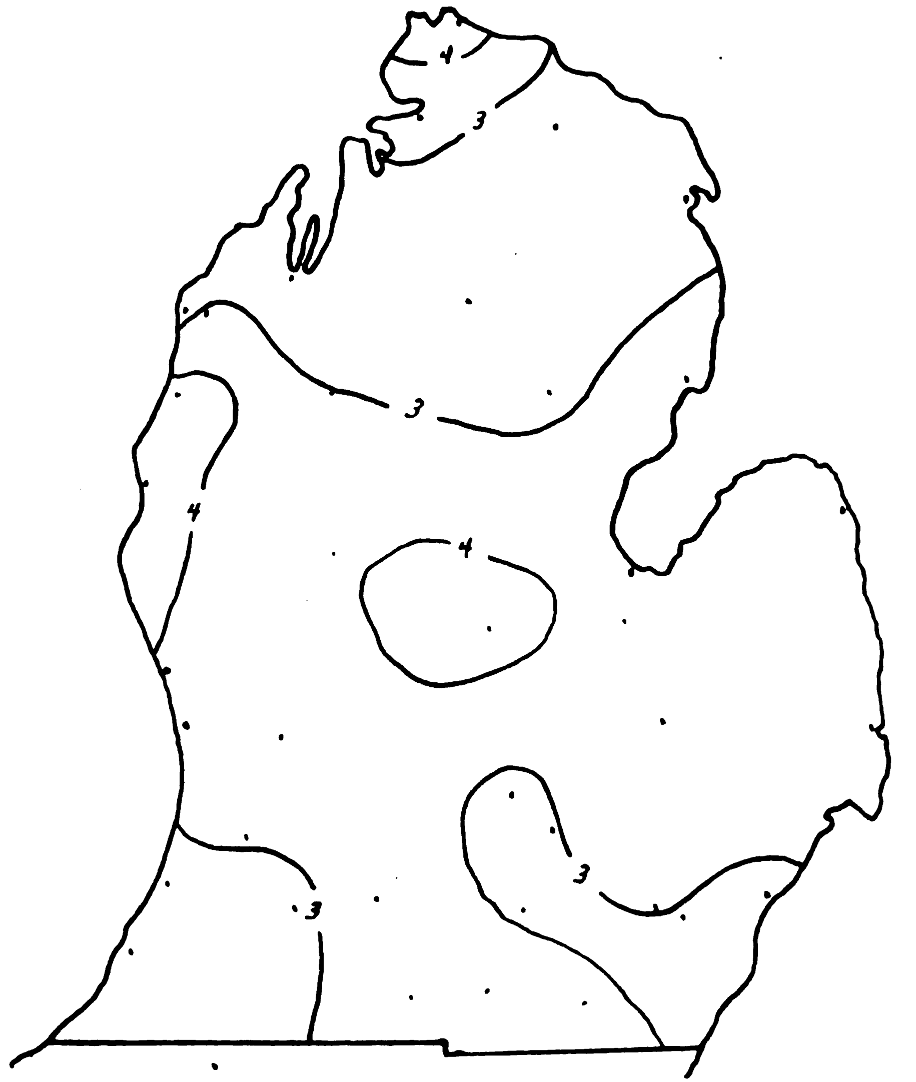


Fig. 12

MAY

21 to 28 Day Droughts

Fig. 13

JUNE

21 to 28 Day Droughts

Fig. 14

JULY

21 to 28 Day Droughts

Fig. 15

AUGUST

21 to 28 Day Droughts

Fig. 8

JUNE

14 to 21 Day Droughts

Fig. 9

JULY

14 to 21 Day Droughts

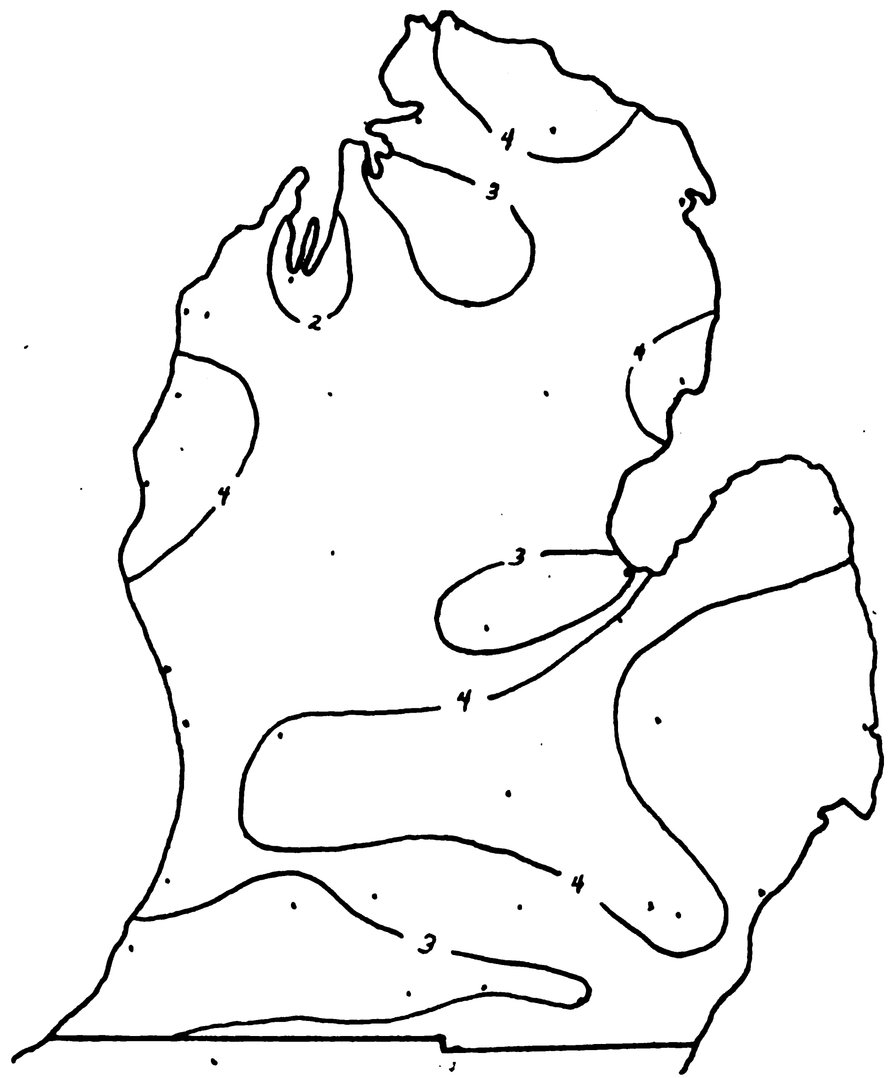


Fig. 10

AUGUST

14 to 21 Day Droughts

Fig. 11

SEPTEMBER

14 to 21 Day Droughts

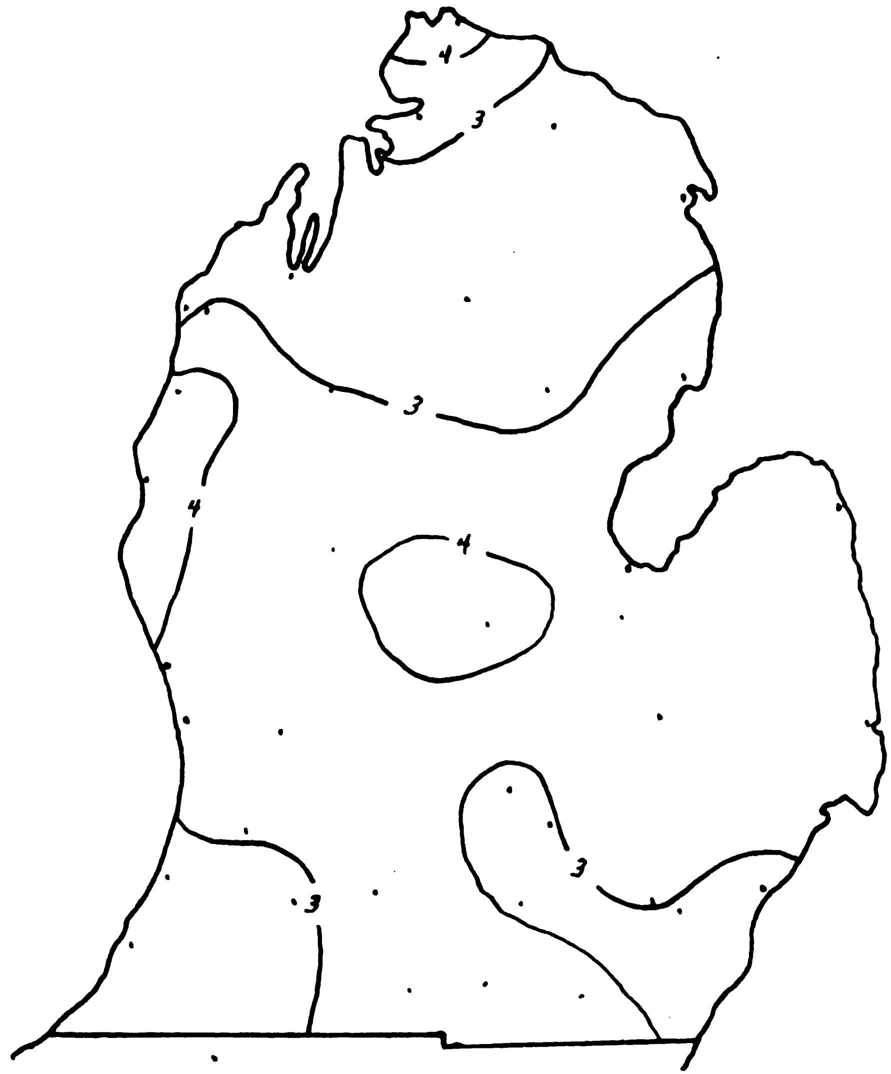


Fig. 12

MAY

21 to 28 Day Droughts

Fig. 13

JUNE

21 to 28 Day Droughts

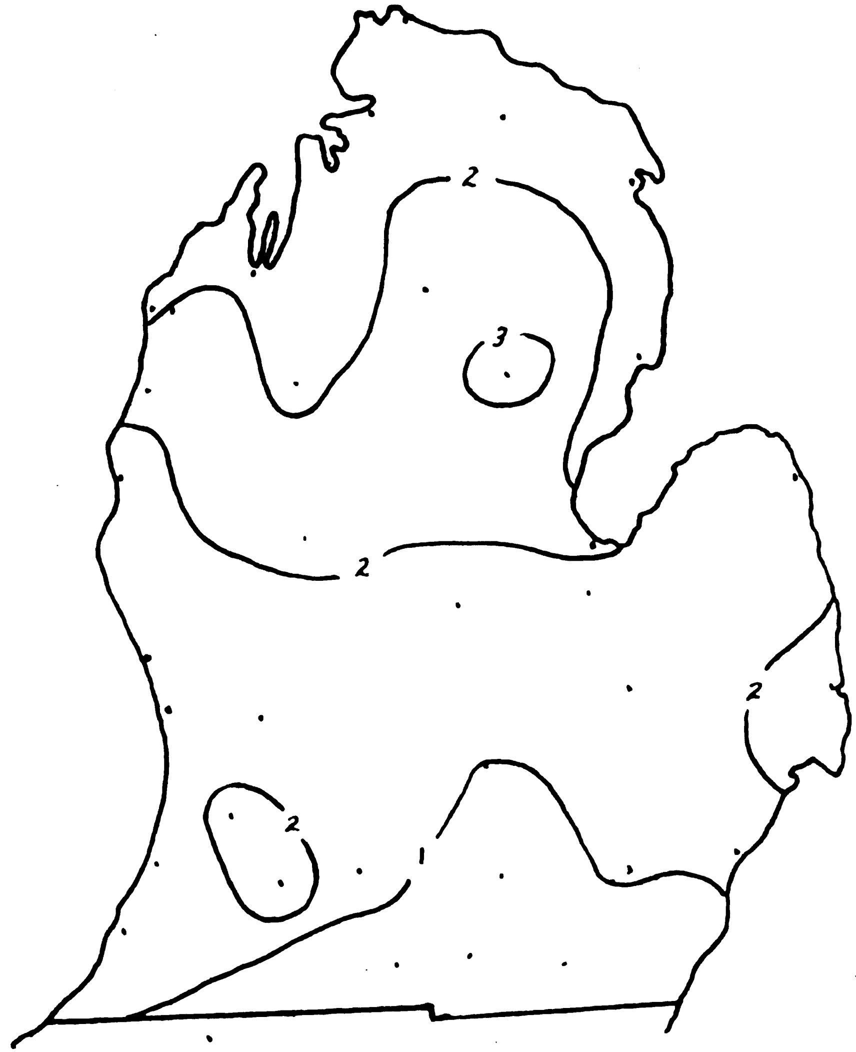


Fig. 14

JULY

21 to 28 Day Droughts

Fig. 15

AUGUST

21 to 28 Day Droughts

Fig. 16

SEPTEMBER
21 to 28 Day Droughts

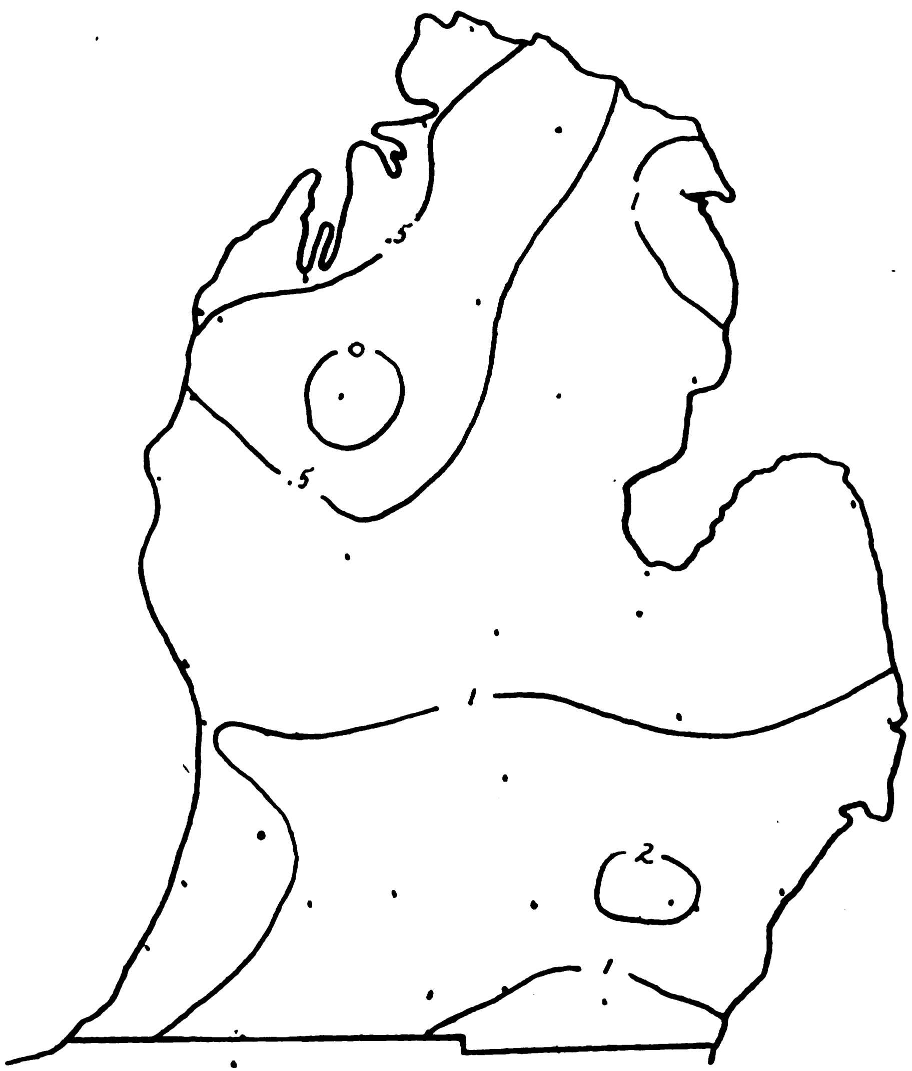


Fig. 17

MAY
28 to 35 Day Droughts

Fig. 18

JUNE

28 to 35 Day Droughts

Fig. 19

JULY

28 to 35 Day Droughts

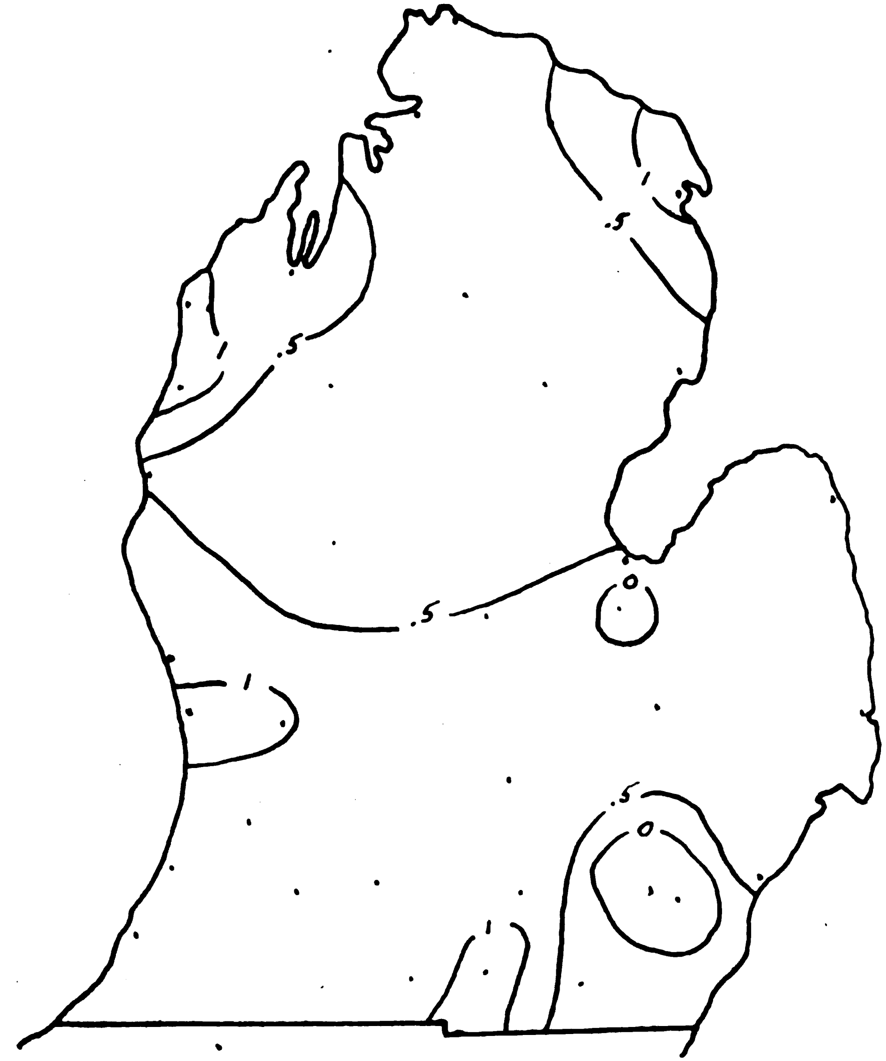


Fig. 20

AUGUST

28 to 35 Day Droughts

Fig. 21

SEPTEMBER

28 to 35 Day Droughts

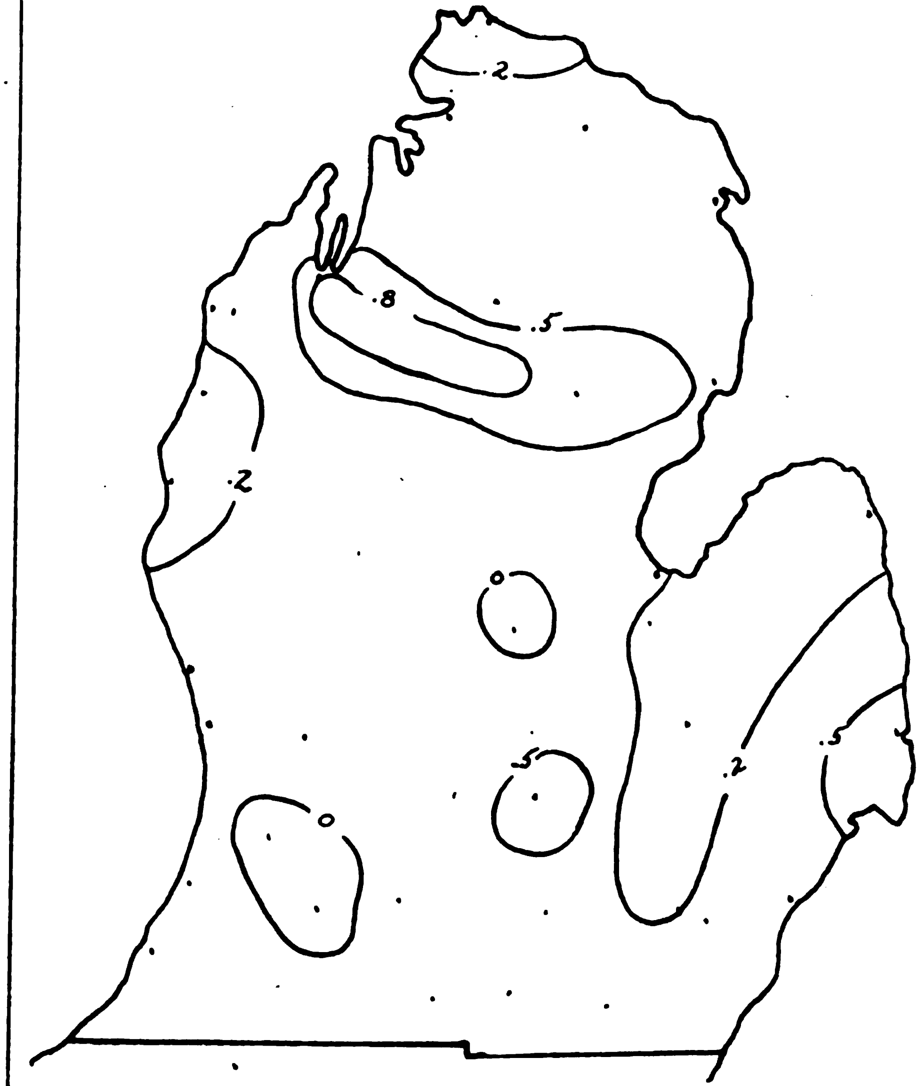


Fig. 22

MAY

35 or more Days Droughts

Fig. 23

JUNE

35 or more Days Drought

Fig. 24

JULY

35 or more Days Drought

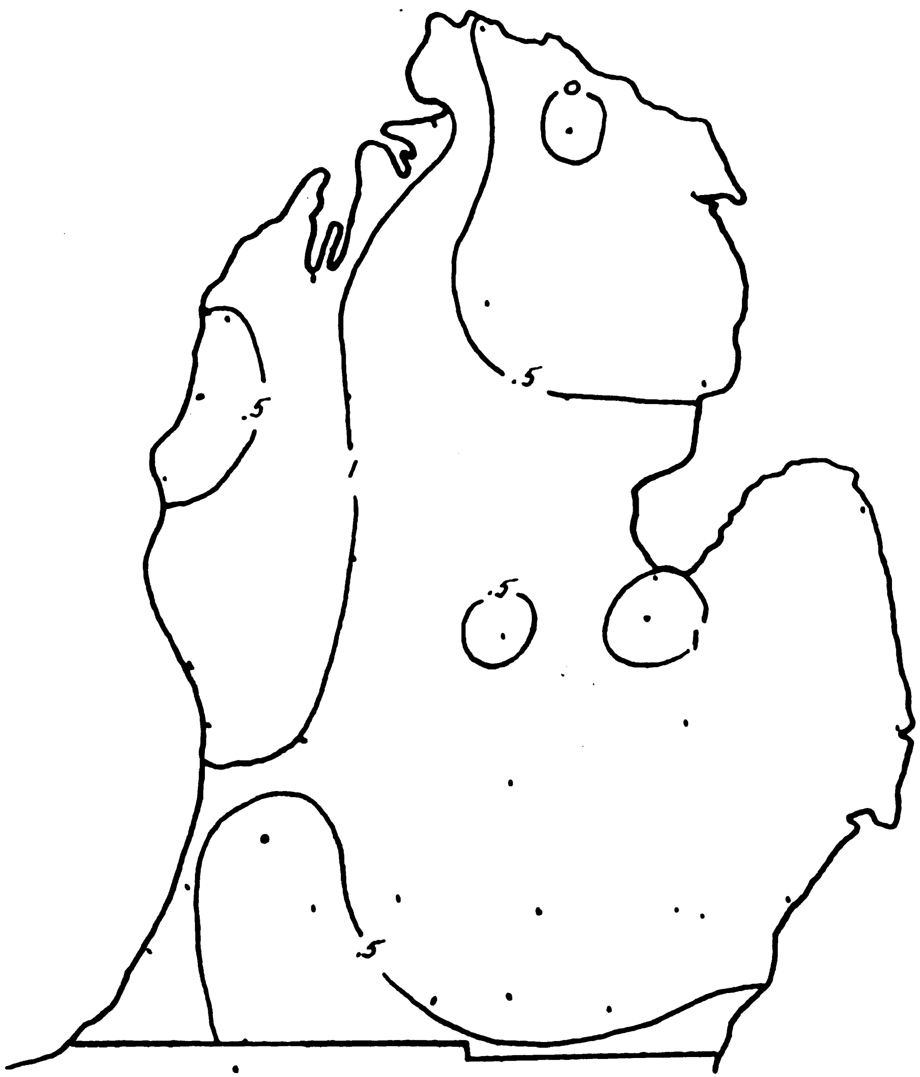


Fig. 25

AUGUST

35 or more Days Drought

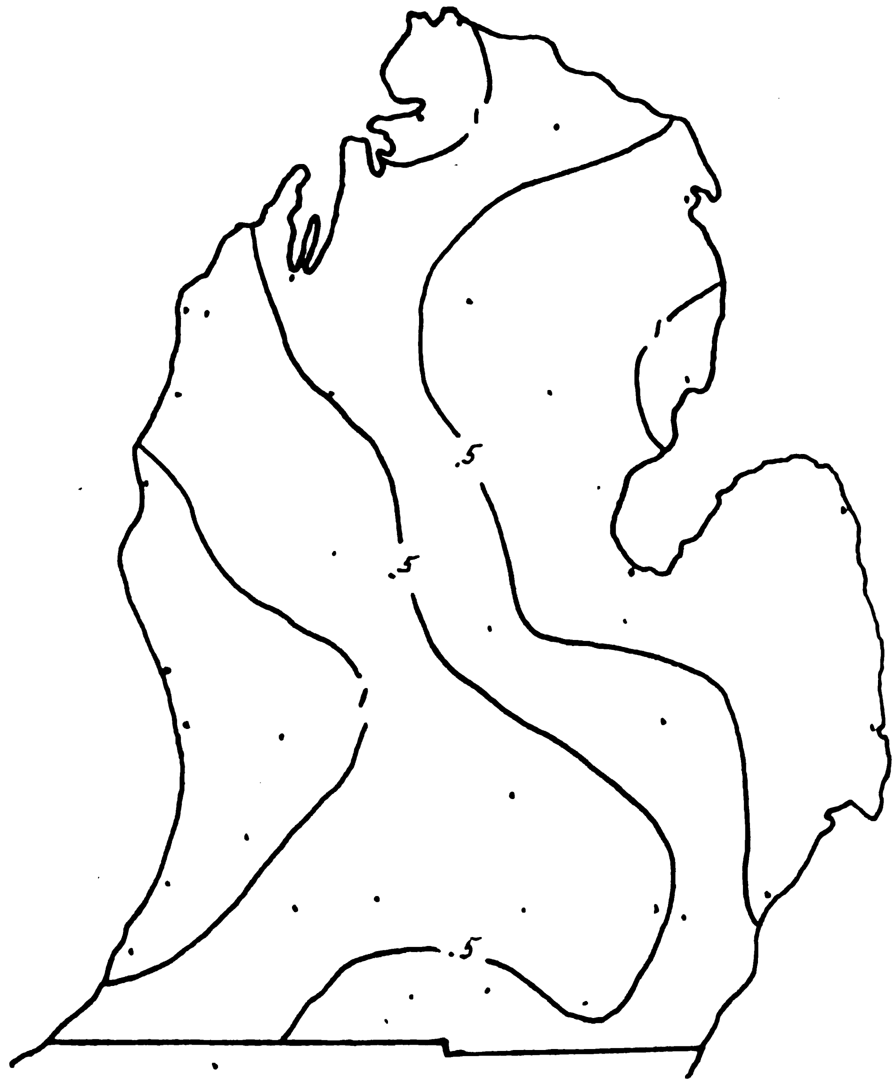


Fig. 26

SEPTEMBER

35 or more Days Drought

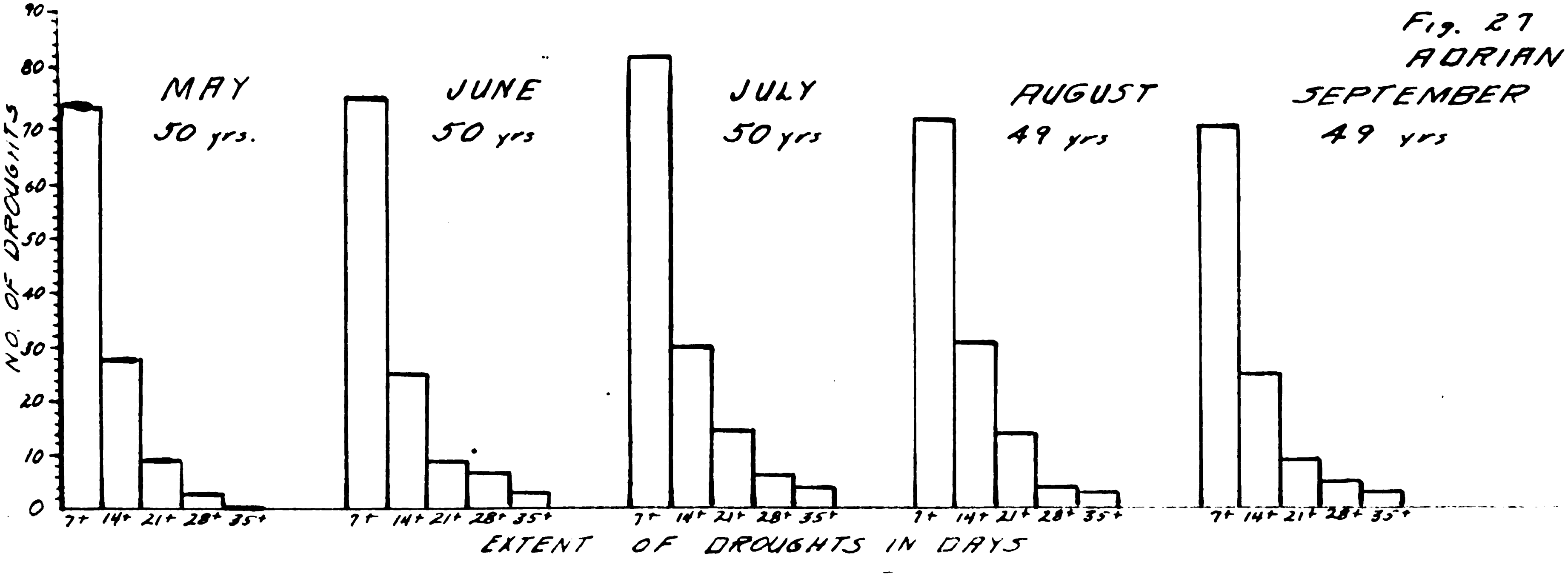


Fig. 27
ADRIAN

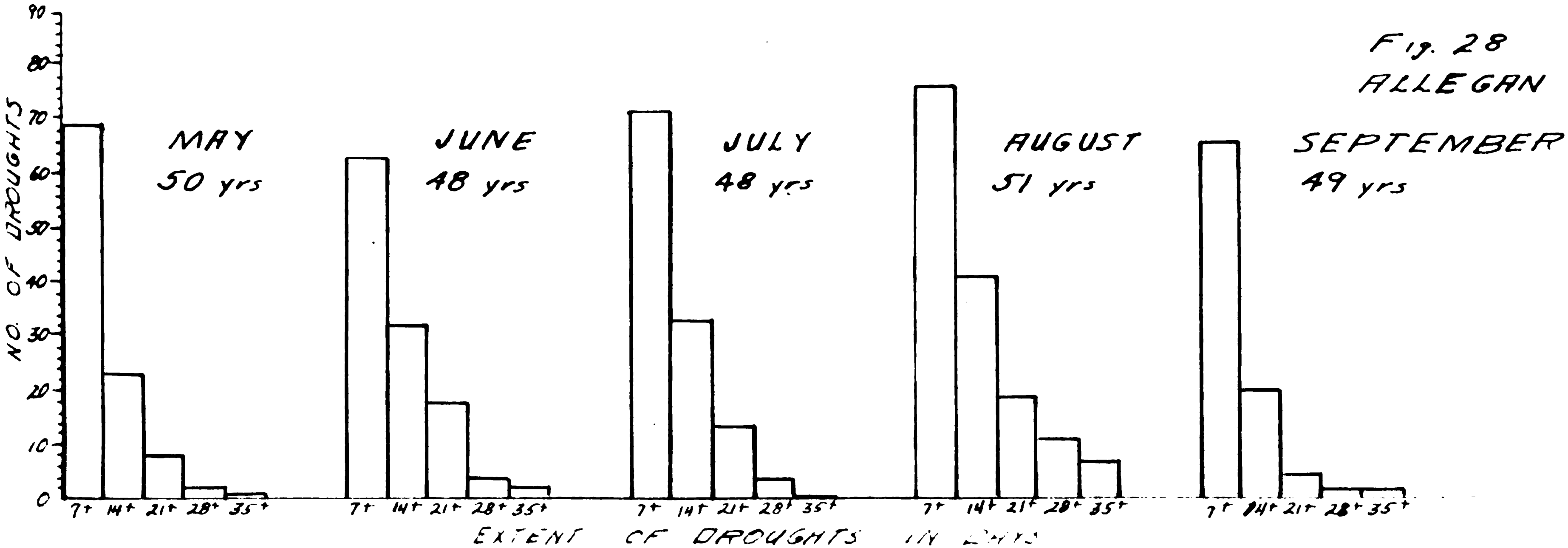


Fig. 28
ALLEGAN

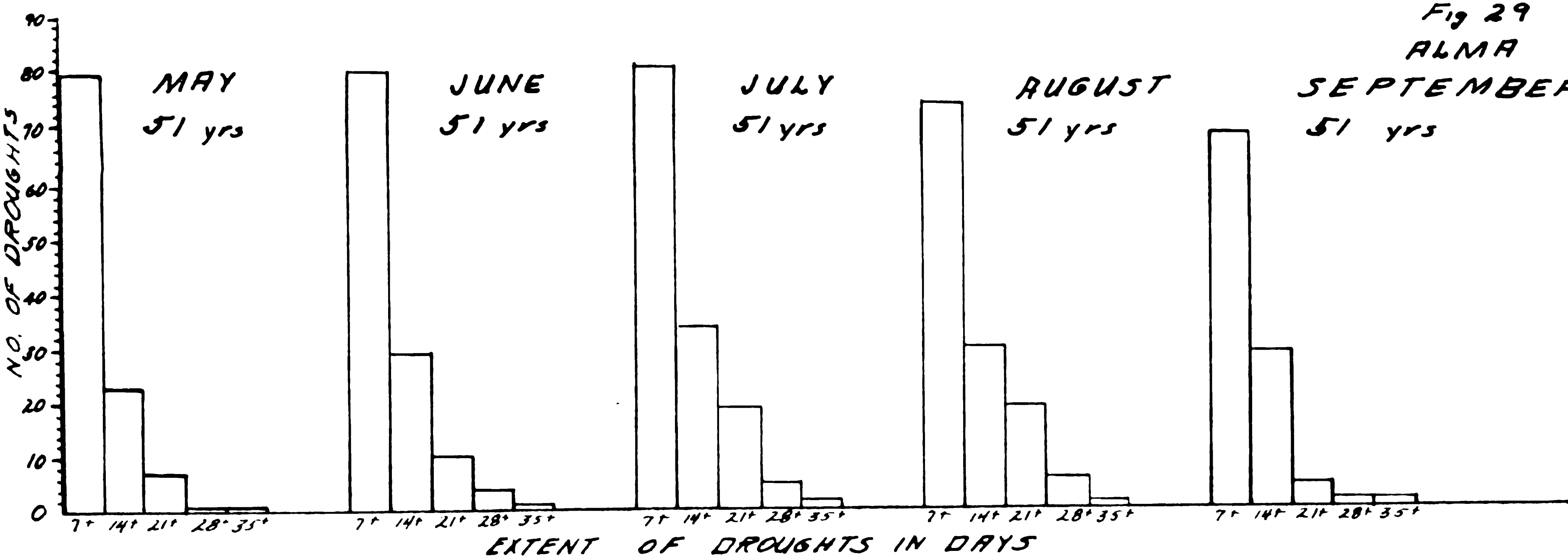


Fig 29
ALMA

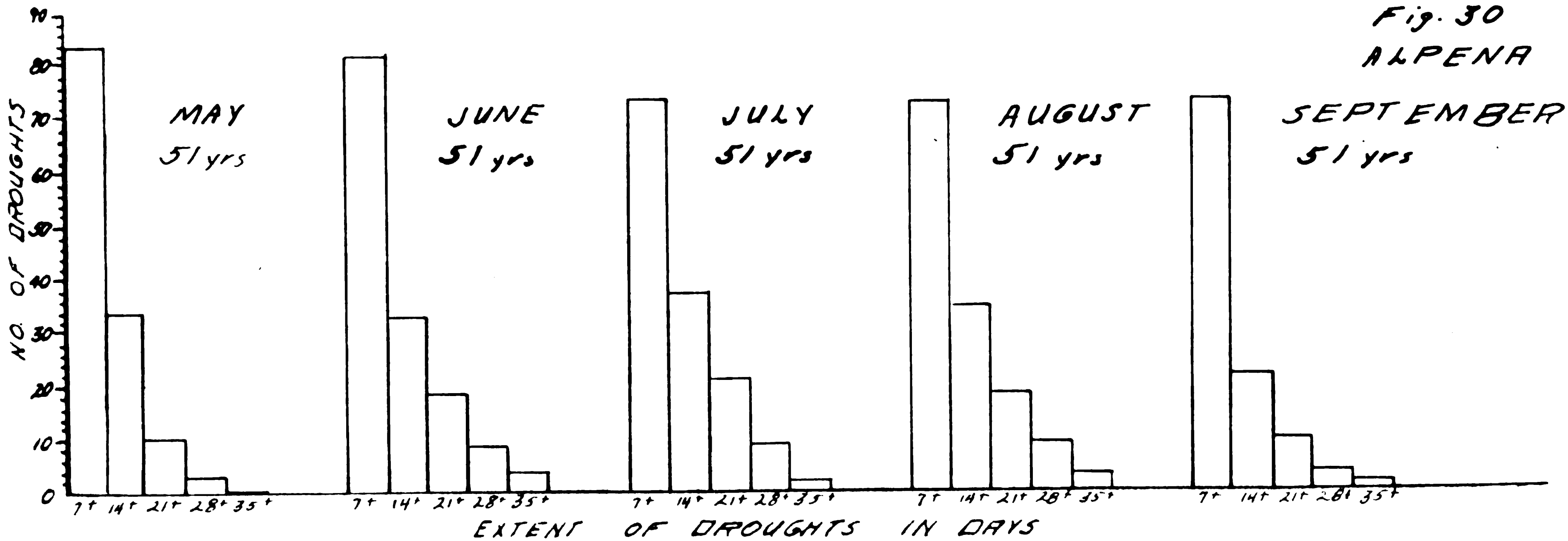


Fig. 30
ALPENA

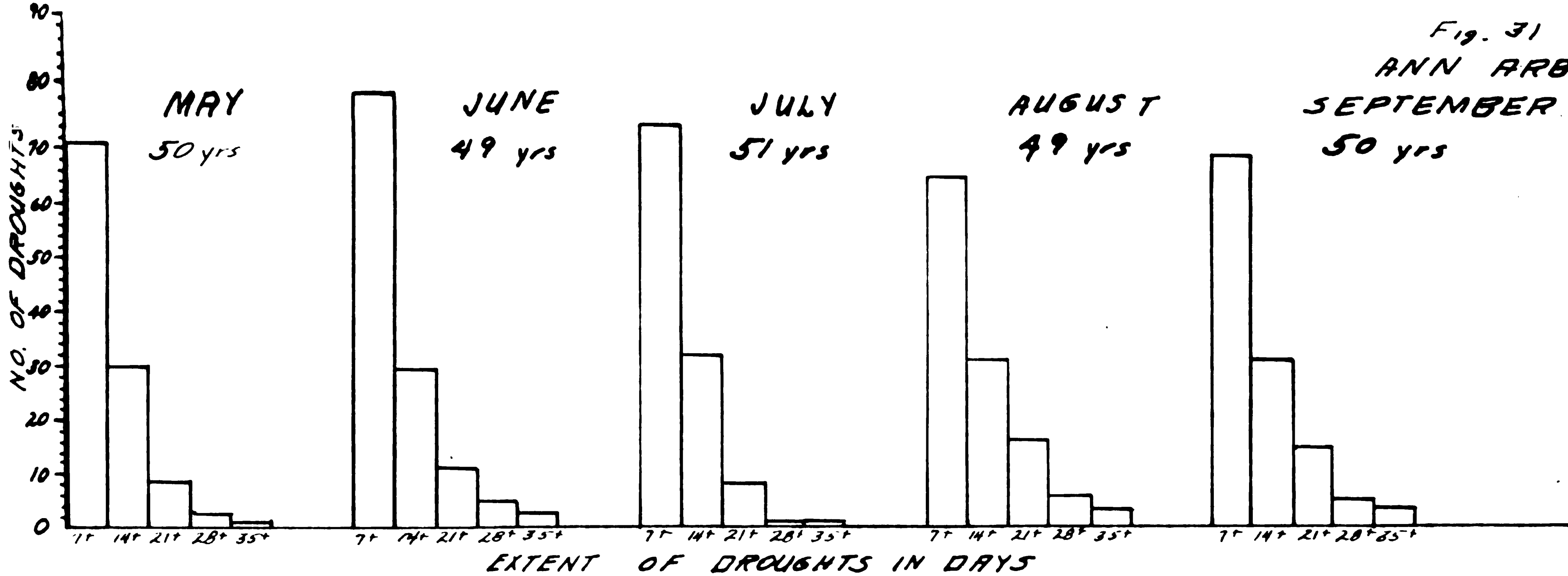


Fig. 31
ANN ARBOR

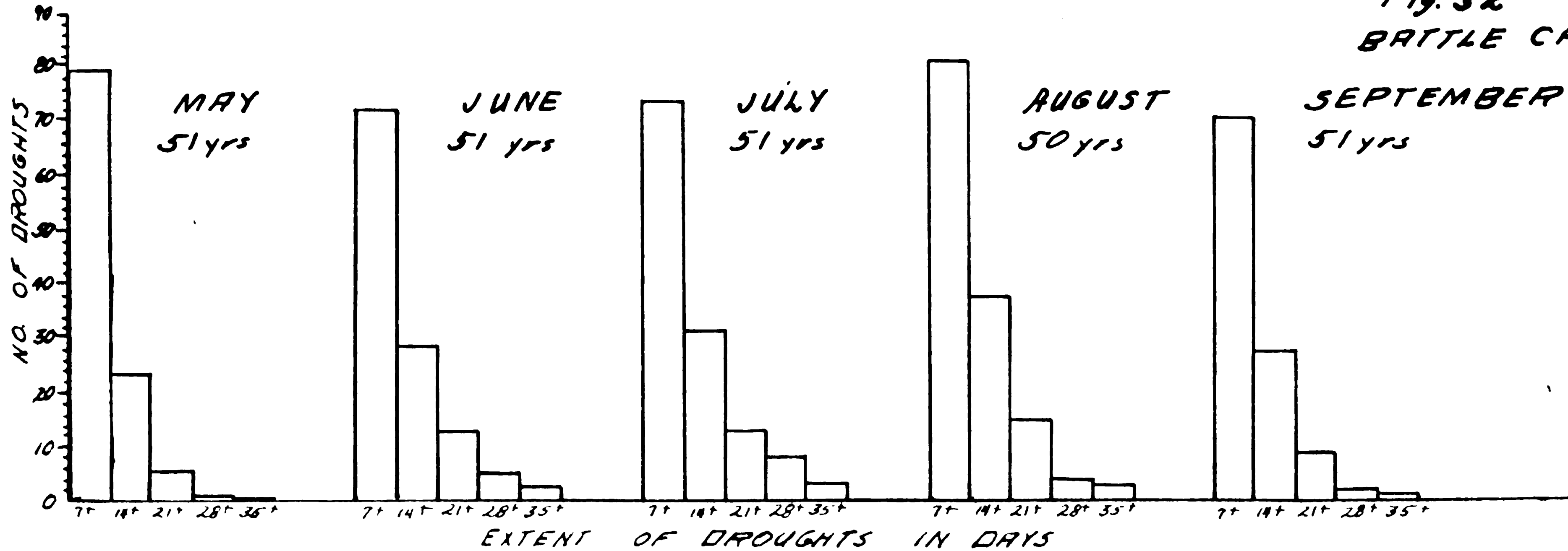


Fig. 32
BATTLE CREEK

Fig. 33
BAY CITY

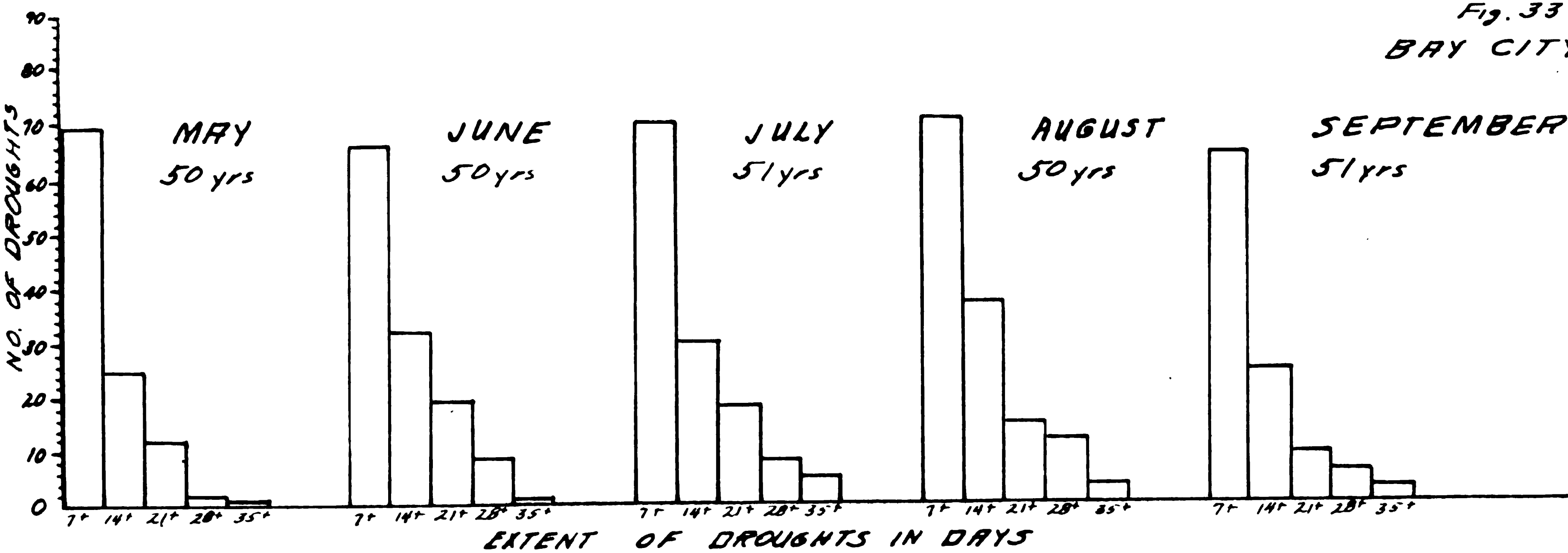
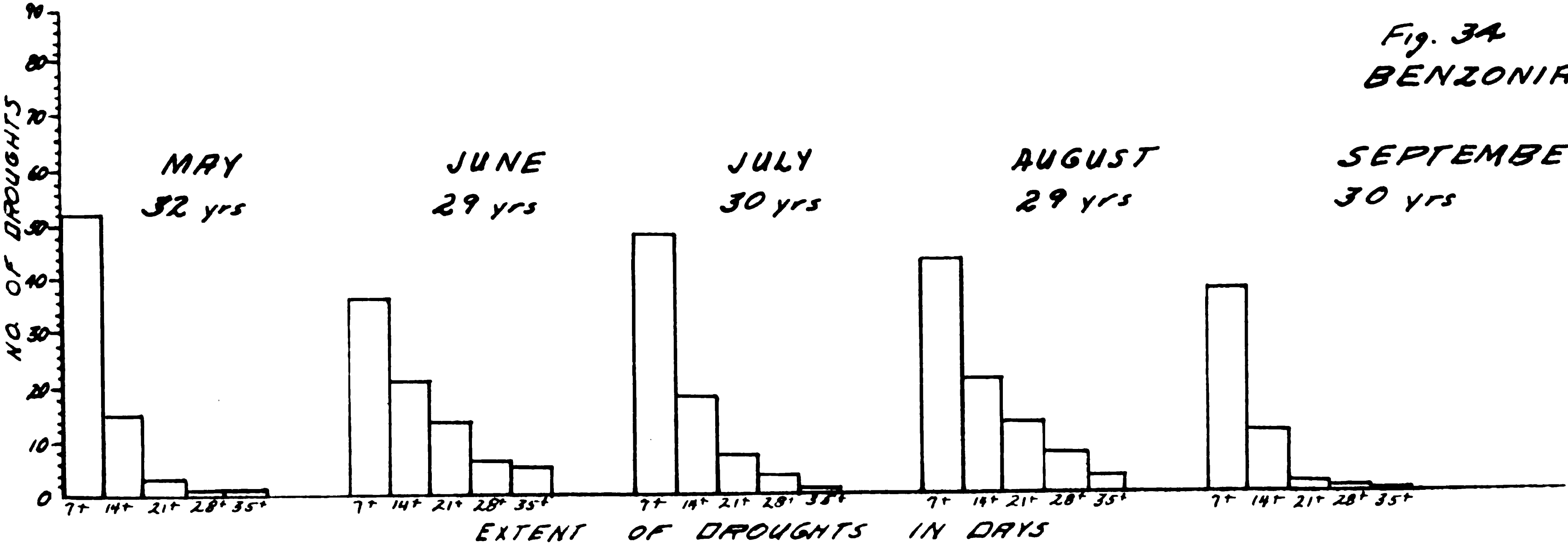


Fig. 34
BENZONIA



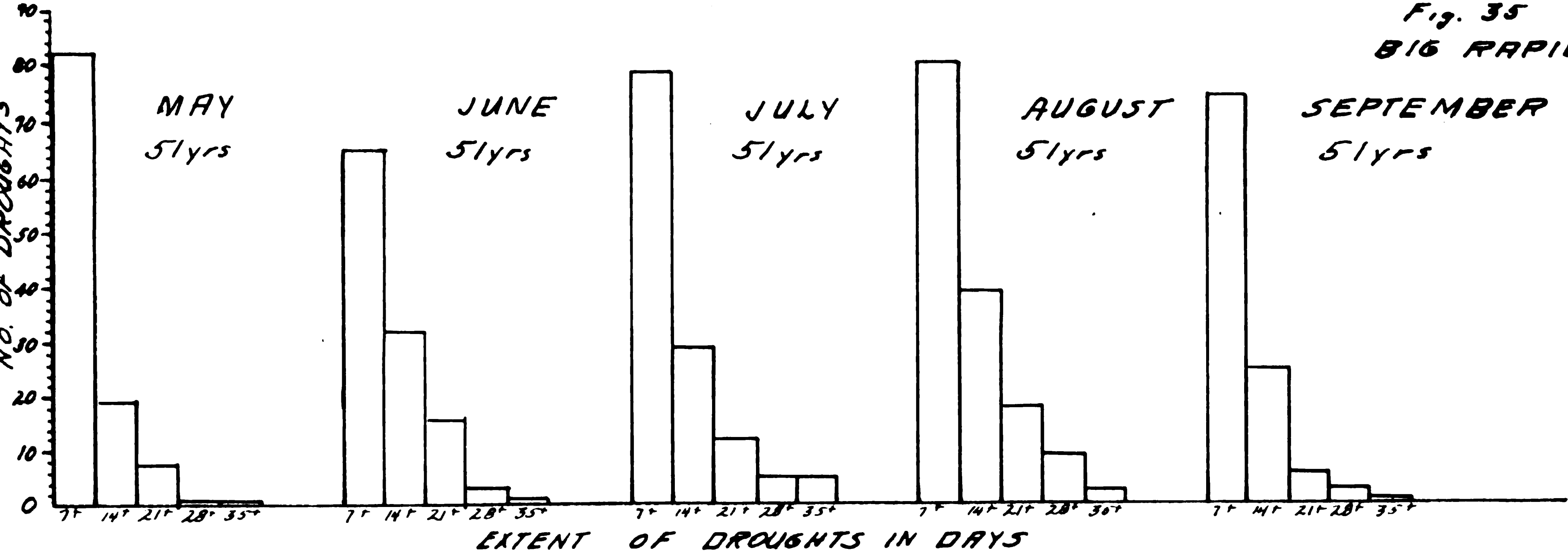


Fig. 35
BIG RAPIDS

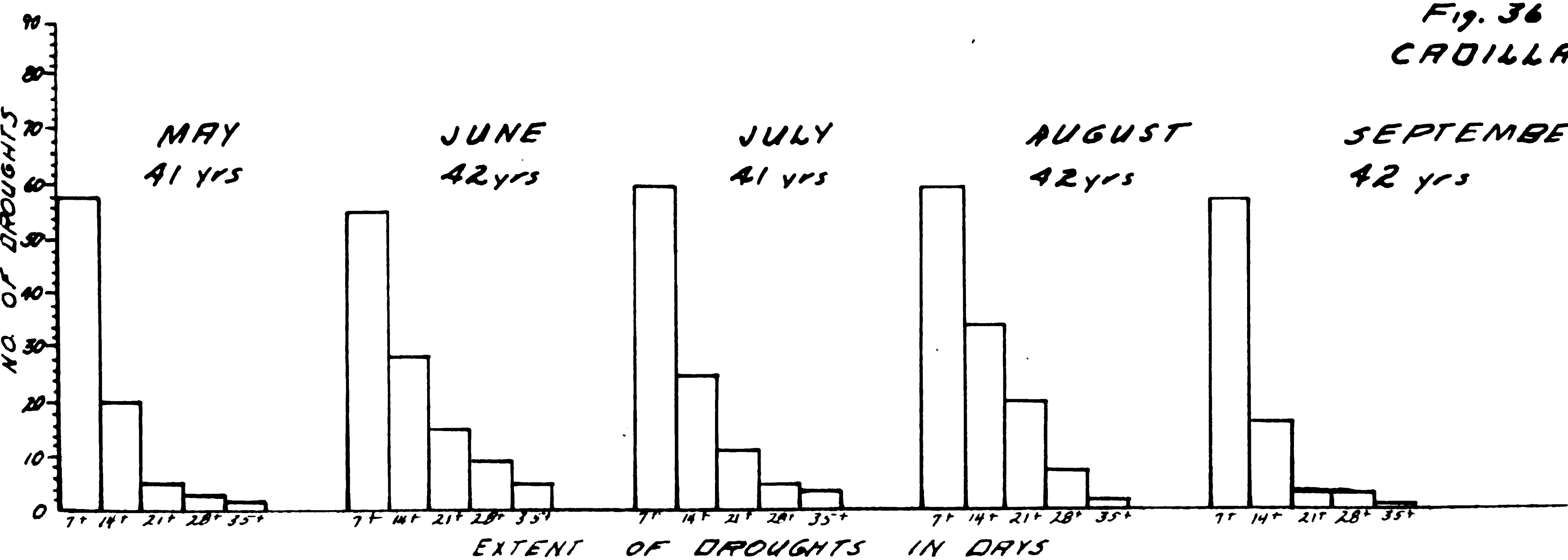


Fig. 36
CADILLAC

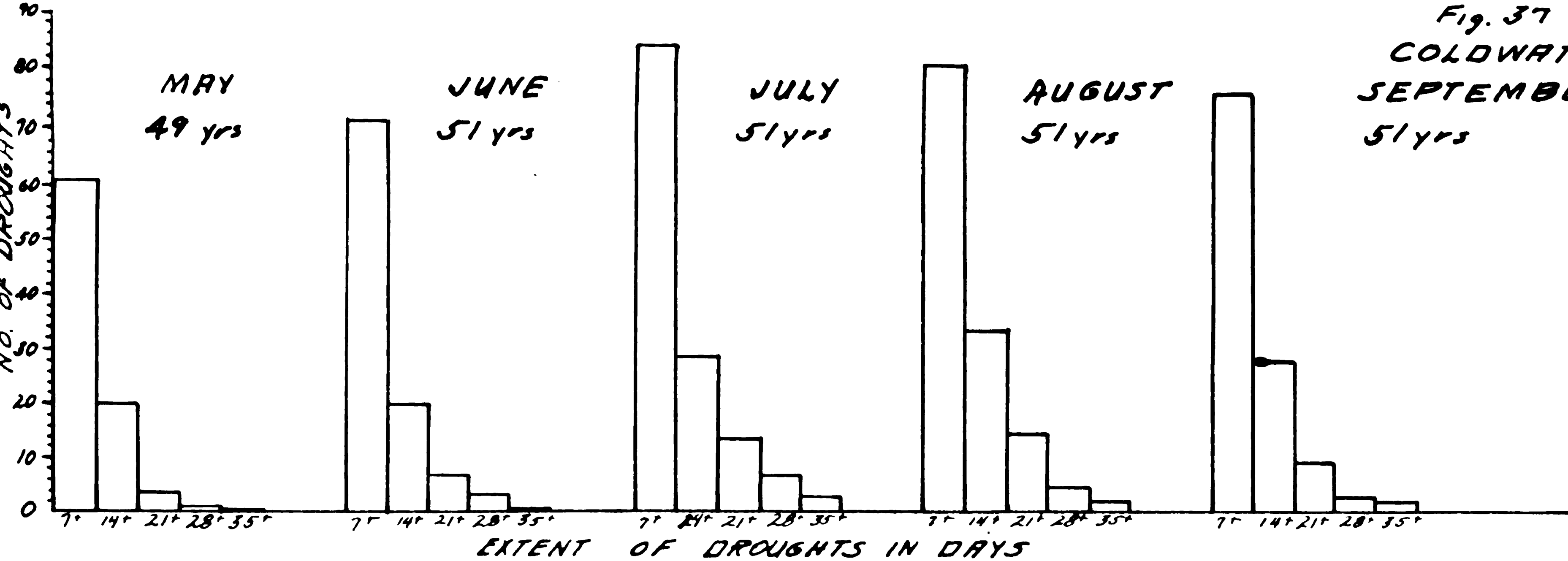


Fig. 37
COLDWATER

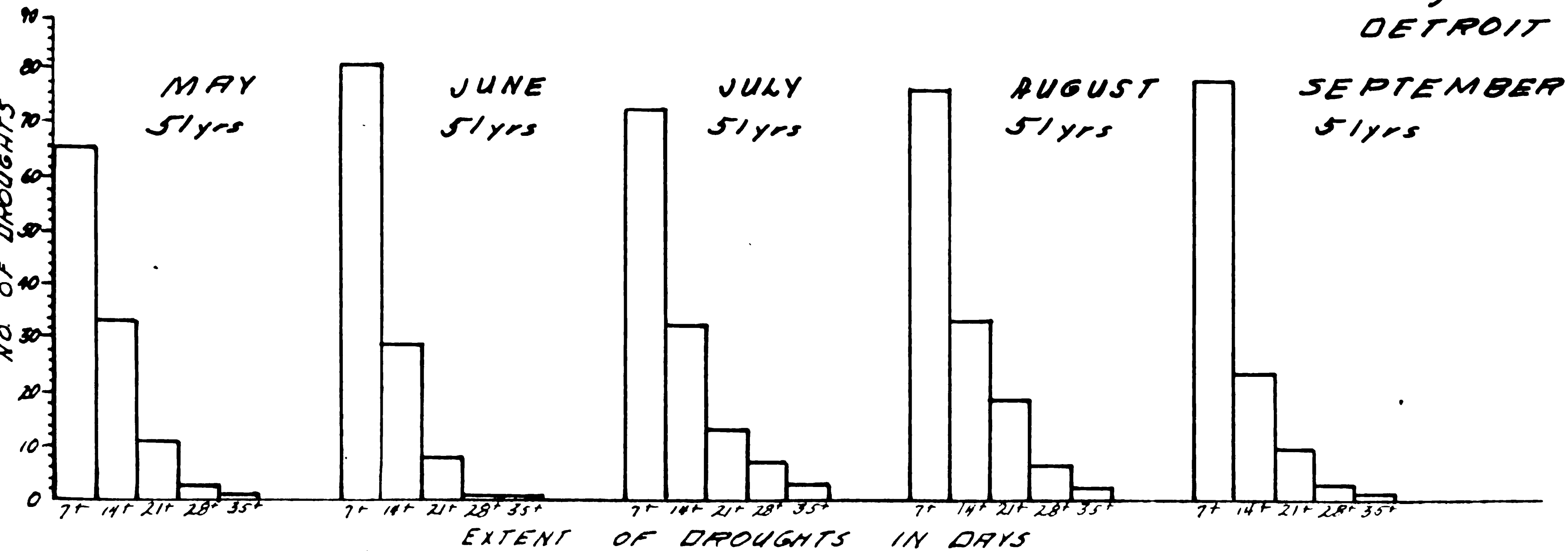


Fig. 38
DETROIT

Fig. 39
EAST TAWAS

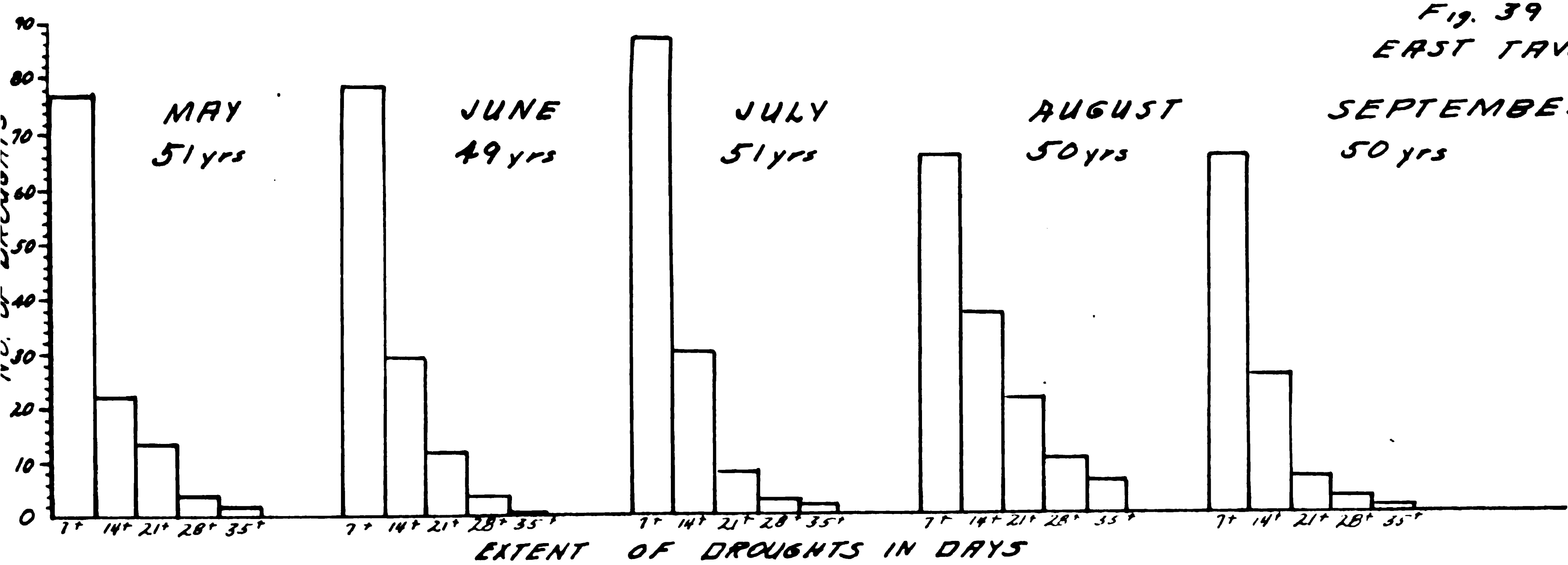
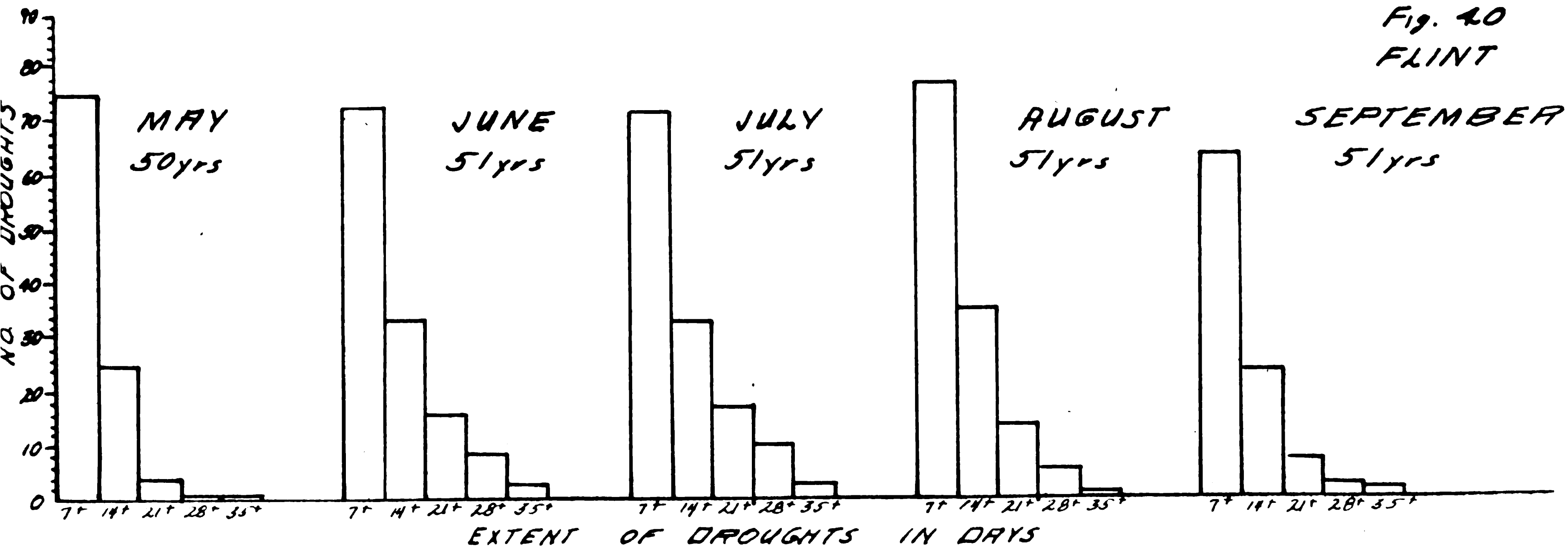


Fig. 40
FLINT



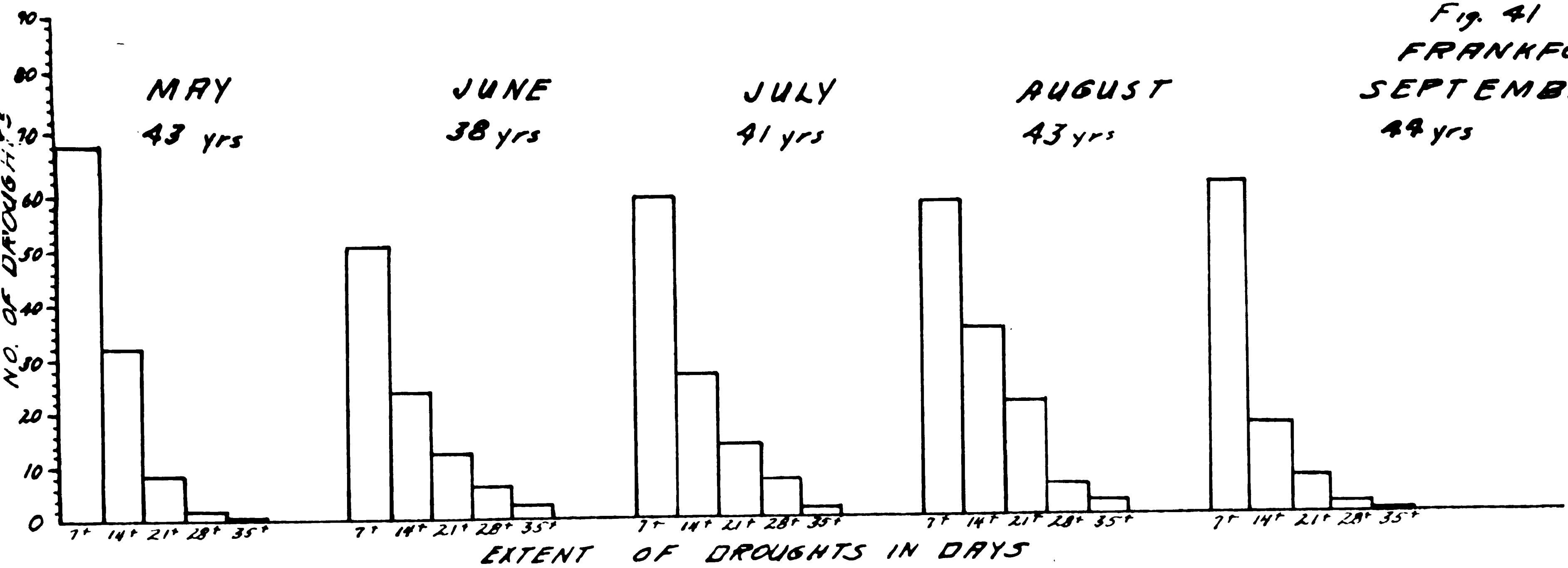


Fig. 41
FRANKFORT

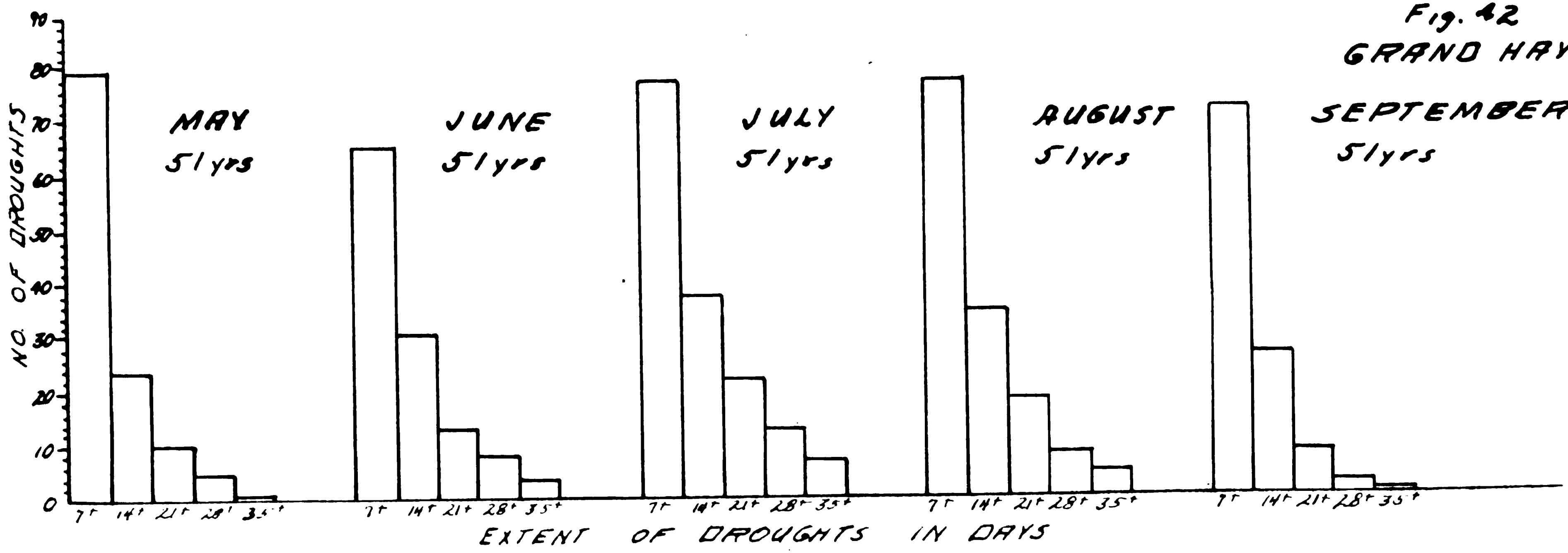


Fig. 42
GRAND HAVEN

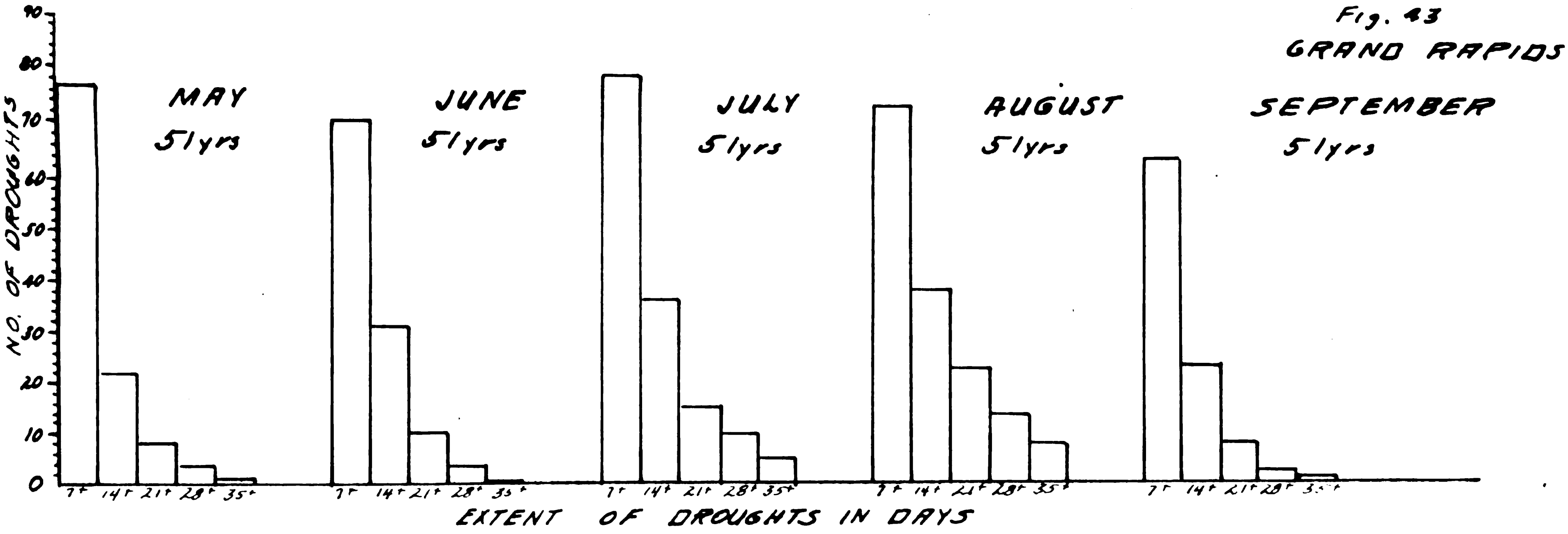


Fig. 43
GRAND RAPIDS

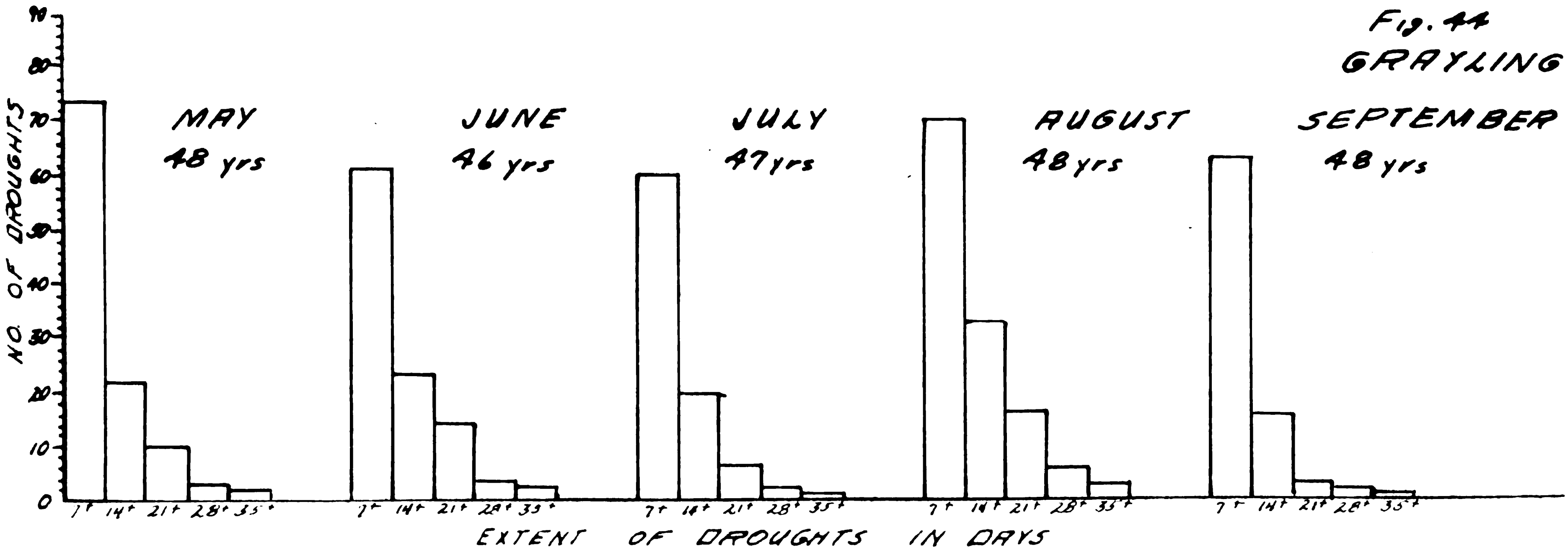


Fig. 44
GRAYLING

Fig. 45
HARBOR BEACH

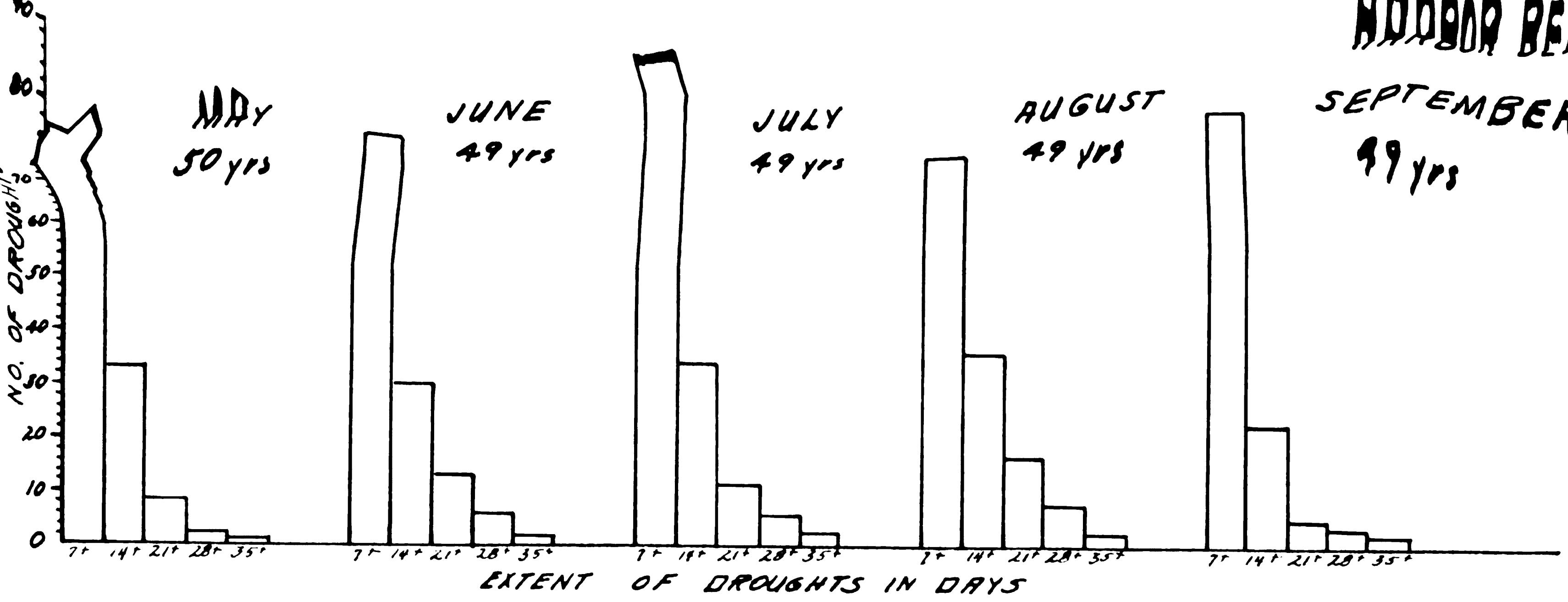


Fig. 46
HILLSDALE

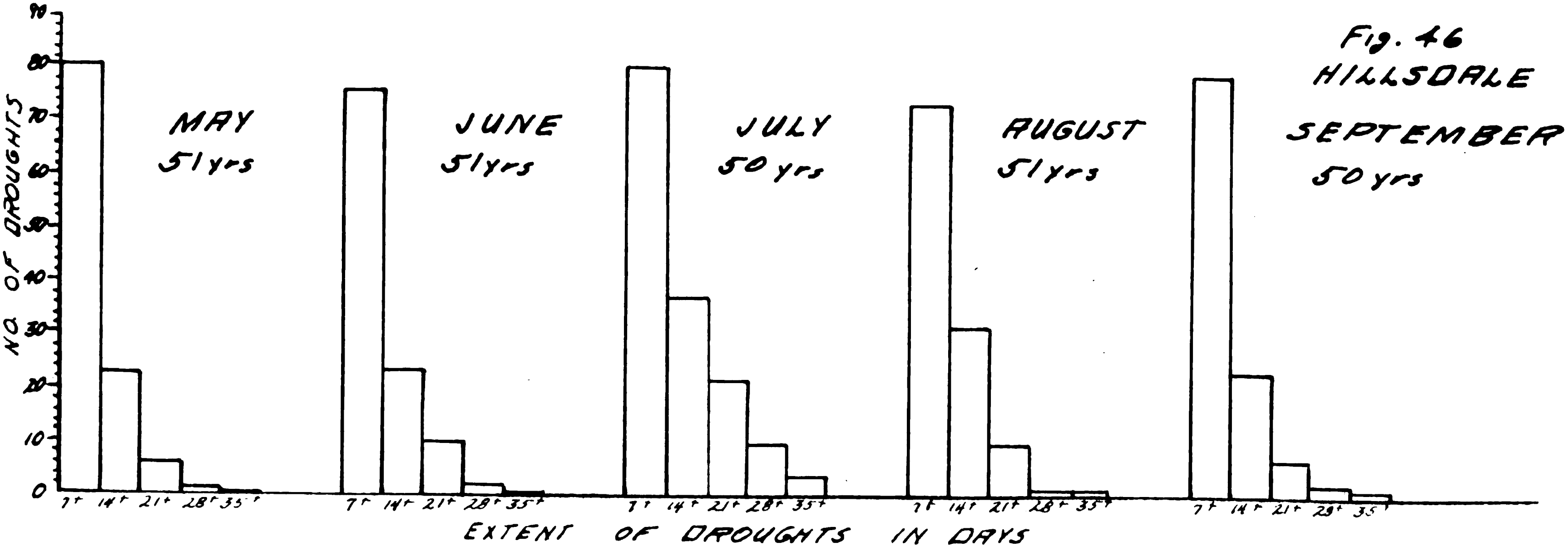


Fig. 47
JACKSON

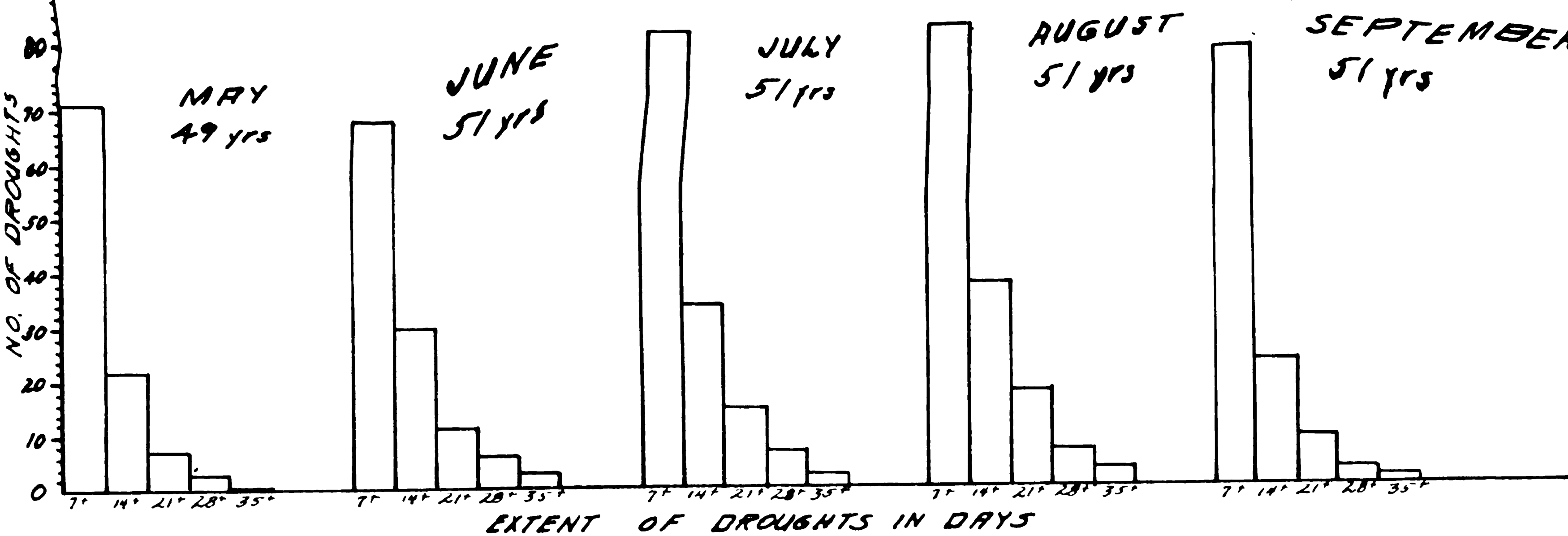


Fig 48
KALAMAZOO

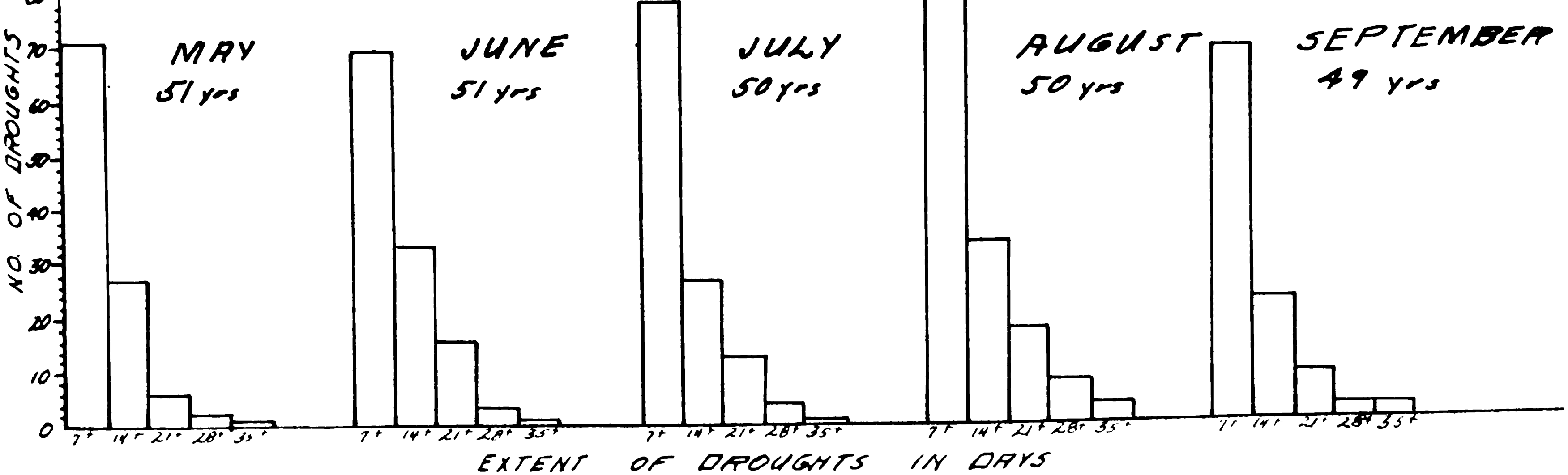


Fig. 49
LANSING, EAST

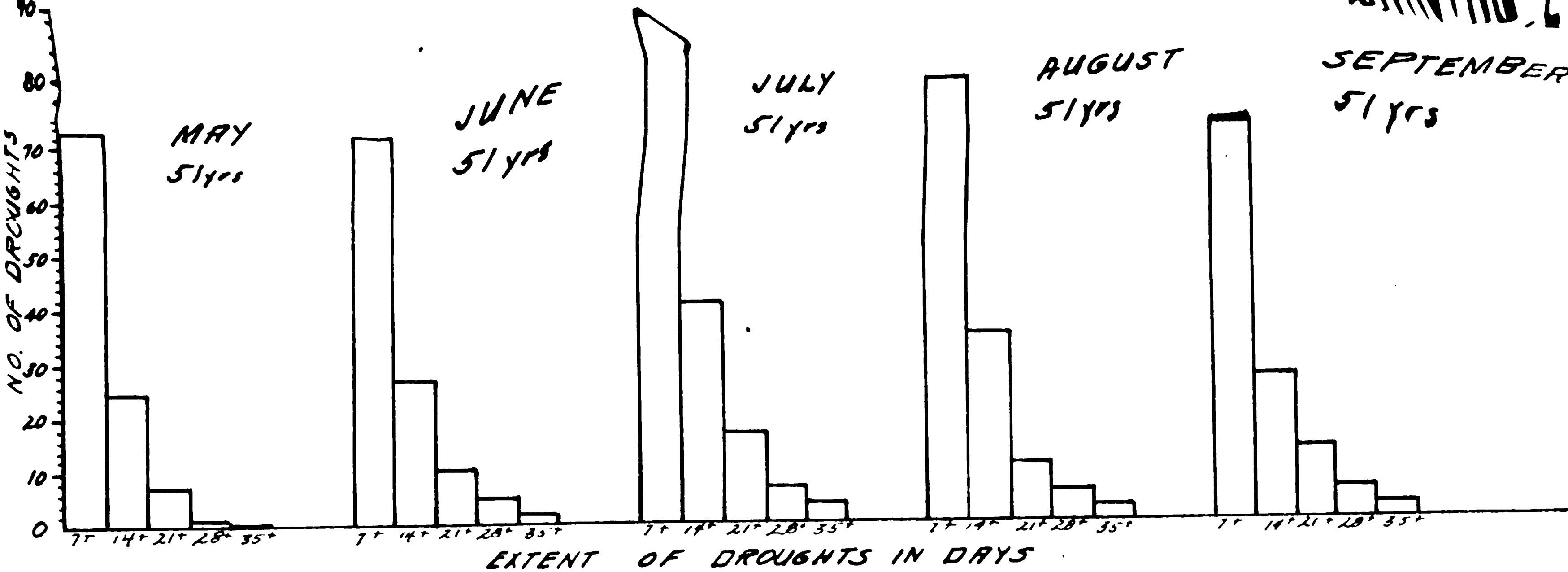
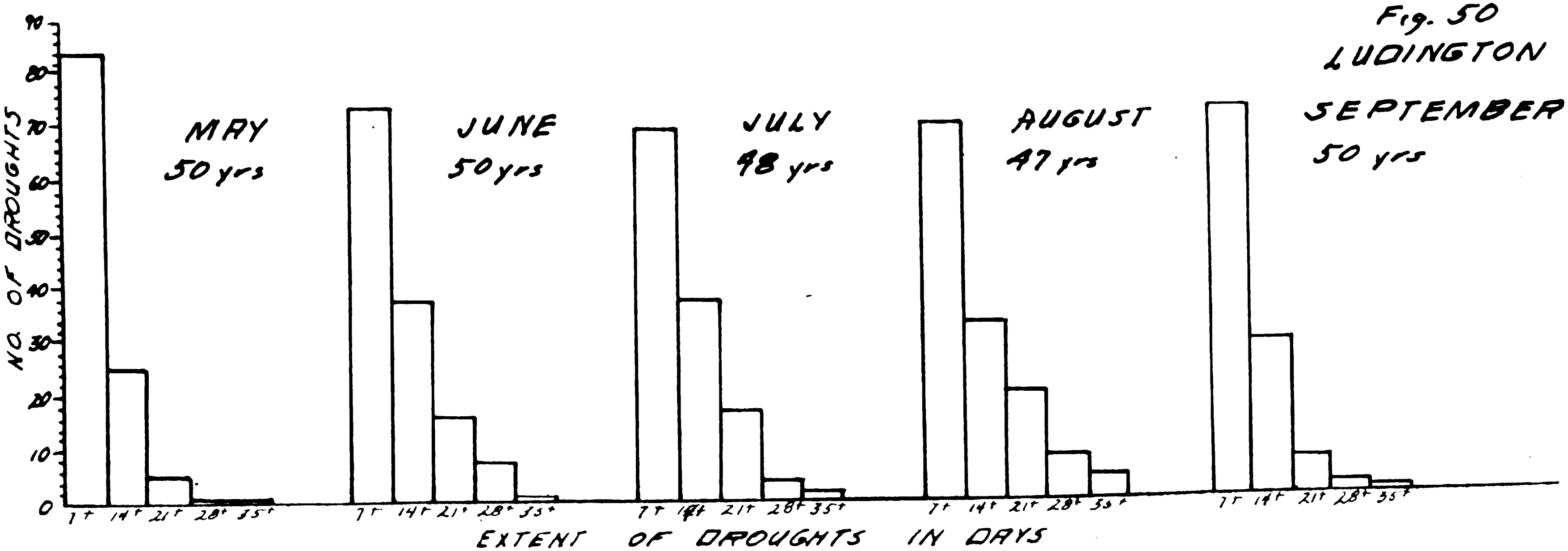


Fig. 50
LUDINGTON



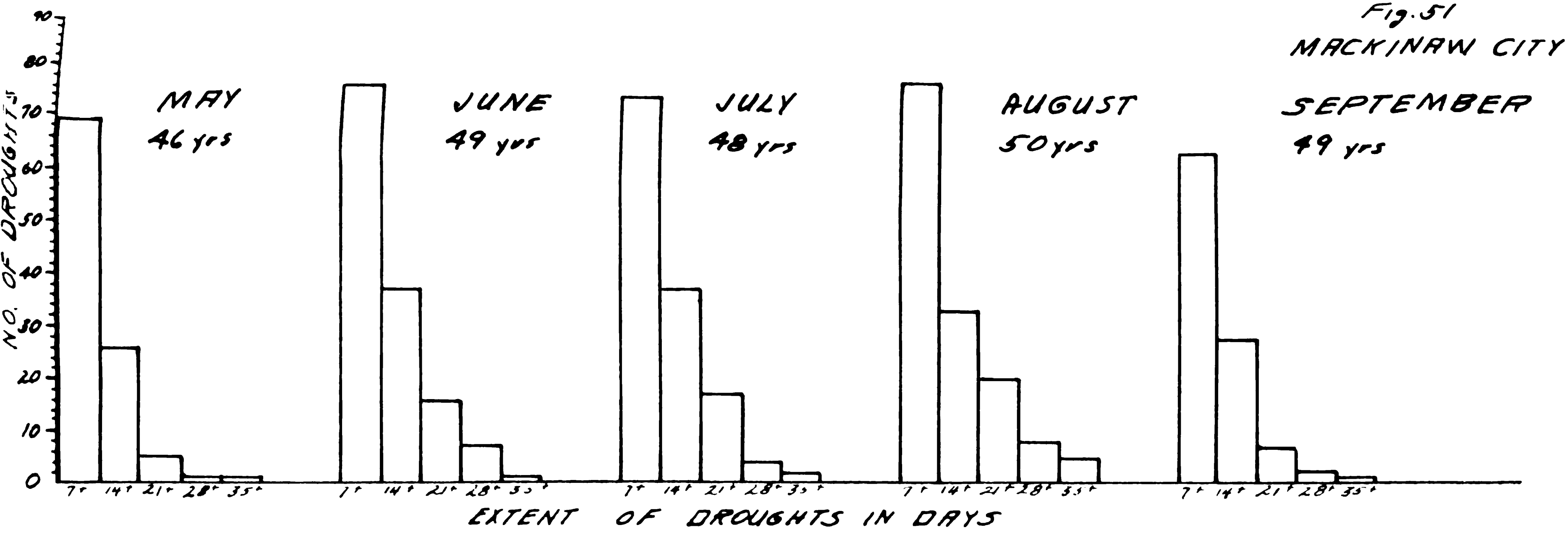


Fig. 51
MACKINAW CITY
MAY
46 yrs
JUNE
49 yrs
JULY
48 yrs
AUGUST
50 yrs
SEPTEMBER
49 yrs
NO. OF DROUGHTS
EXTENT OF DROUGHTS IN DAYS

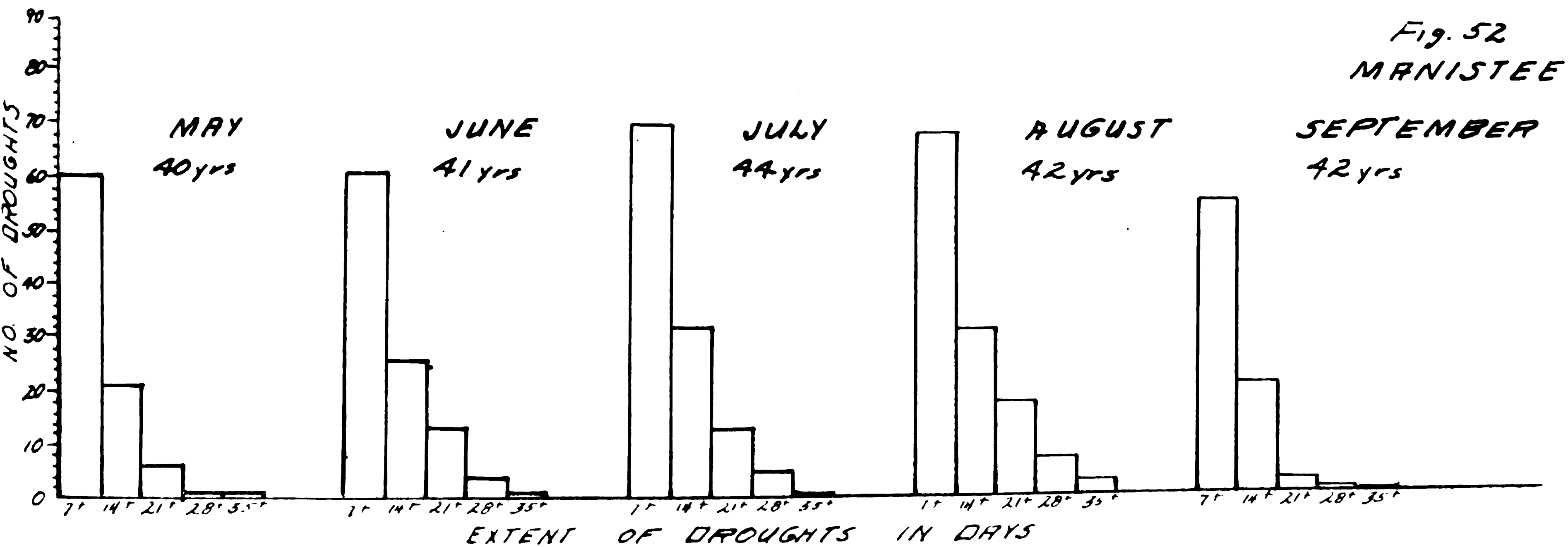


Fig. 52
MANISTEE
MAY
40 yrs
JUNE
41 yrs
JULY
44 yrs
AUGUST
42 yrs
SEPTEMBER
42 yrs
NO. OF DROUGHTS
EXTENT OF DROUGHTS IN DAYS

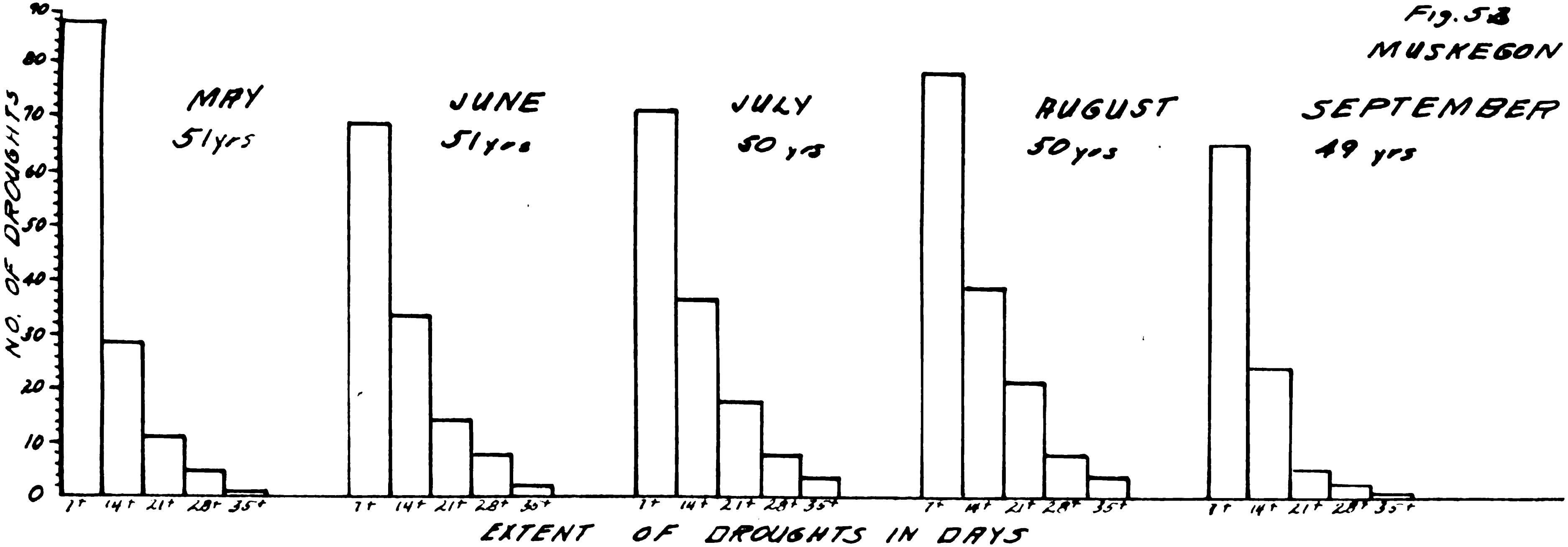


Fig. 53
MUSKEGON
MAY
51 yrs
JUNE
51 yrs
JULY
50 yrs
AUGUST
50 yrs
SEPTEMBER
49 yrs
NO. OF DROUGHTS
0
10
20
30
40
50
60
70
80
90
7+ 14+ 21+ 28+ 35+
EXTENT OF DROUGHTS IN DAYS

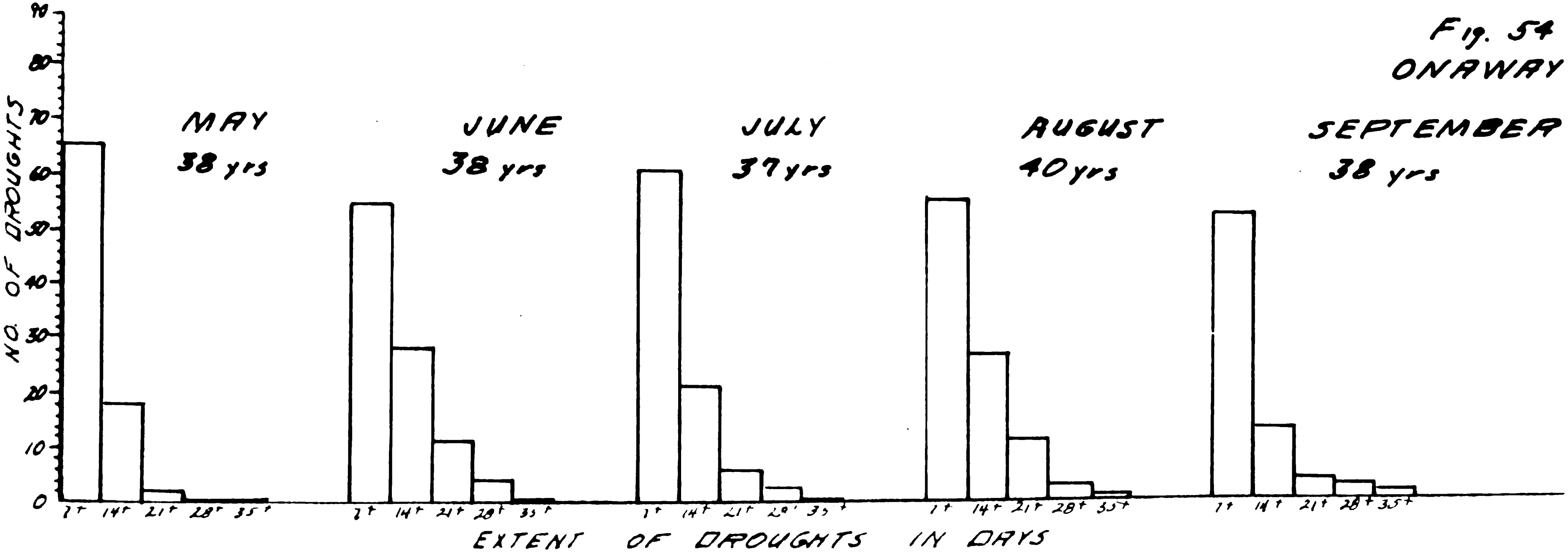
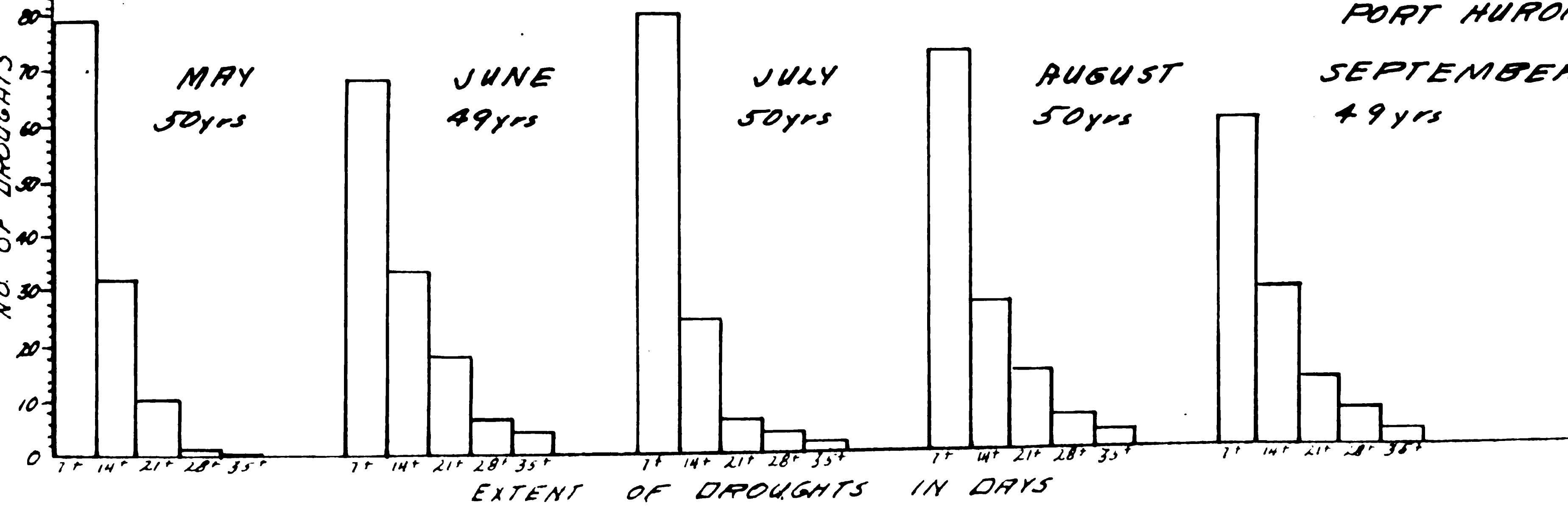


Fig. 54
ONAWAY
MAY
38 yrs
JUNE
38 yrs
JULY
37 yrs
AUGUST
40 yrs
SEPTEMBER
38 yrs
NO. OF DROUGHTS
0
10
20
30
40
50
60
70
80
90
7+ 14+ 21+ 28+ 35+
EXTENT OF DROUGHTS IN DAYS

Fig. 55
PETOSKEY

Fig. 56
PORT HURON



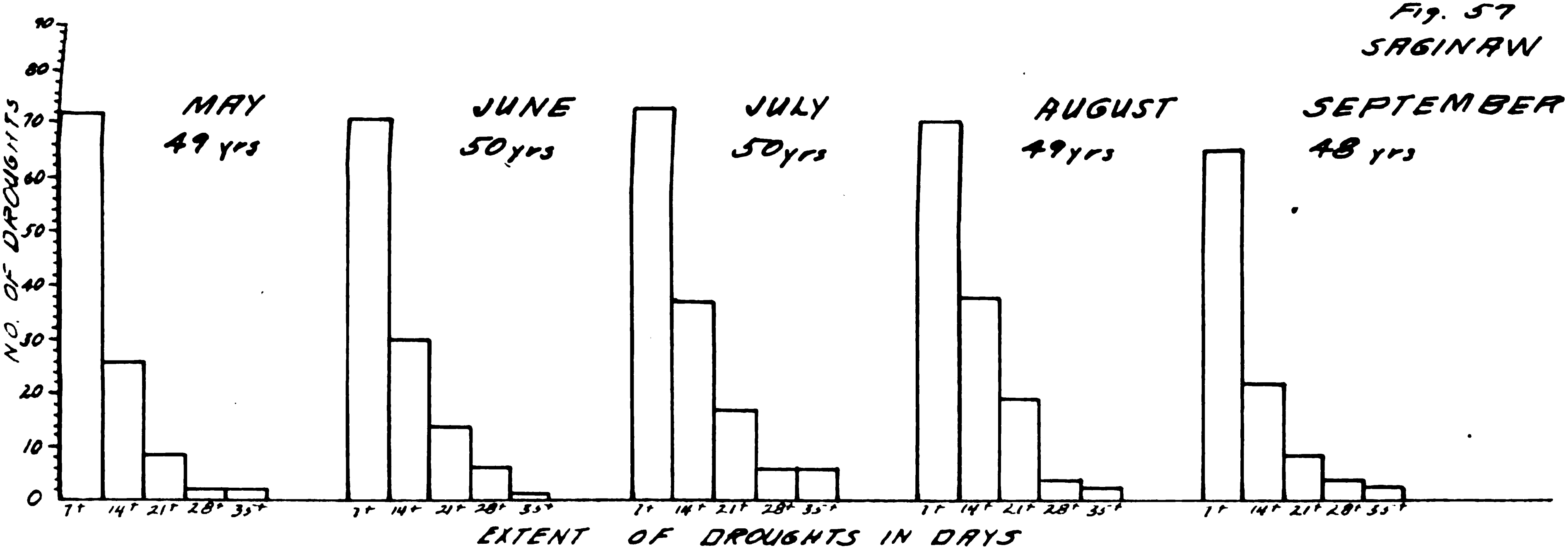


Fig. 57
SAGINAW

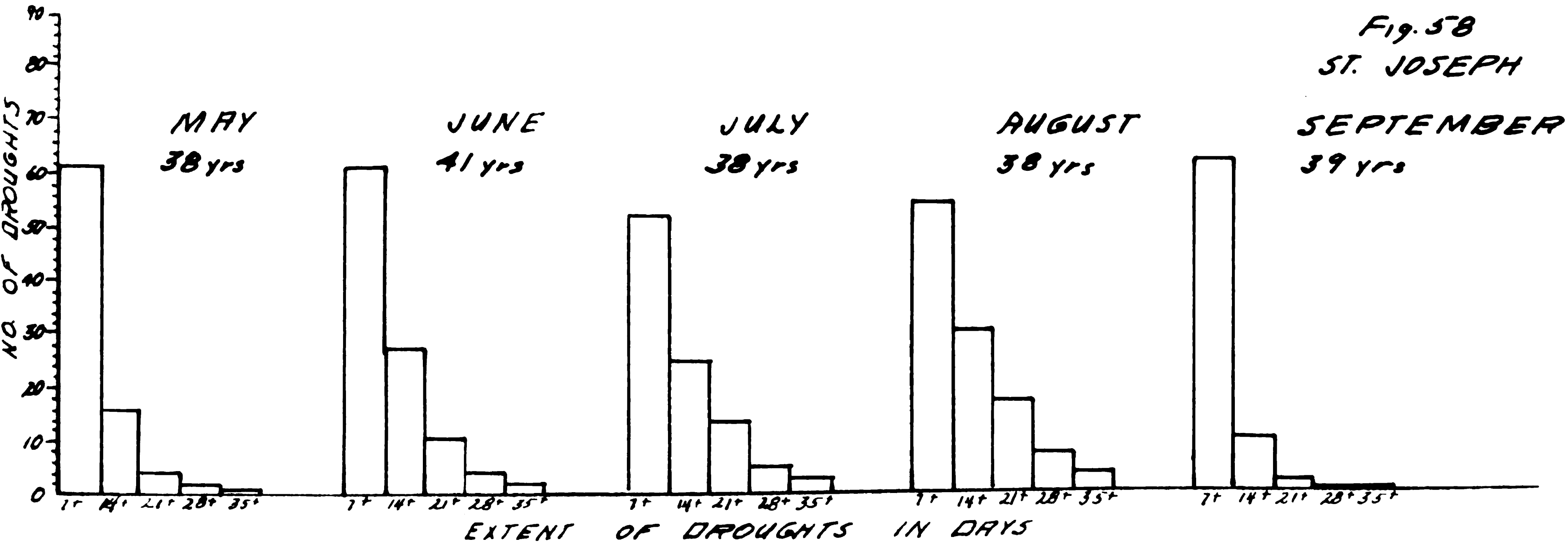


Fig. 58
ST. JOSEPH

Fig. 59

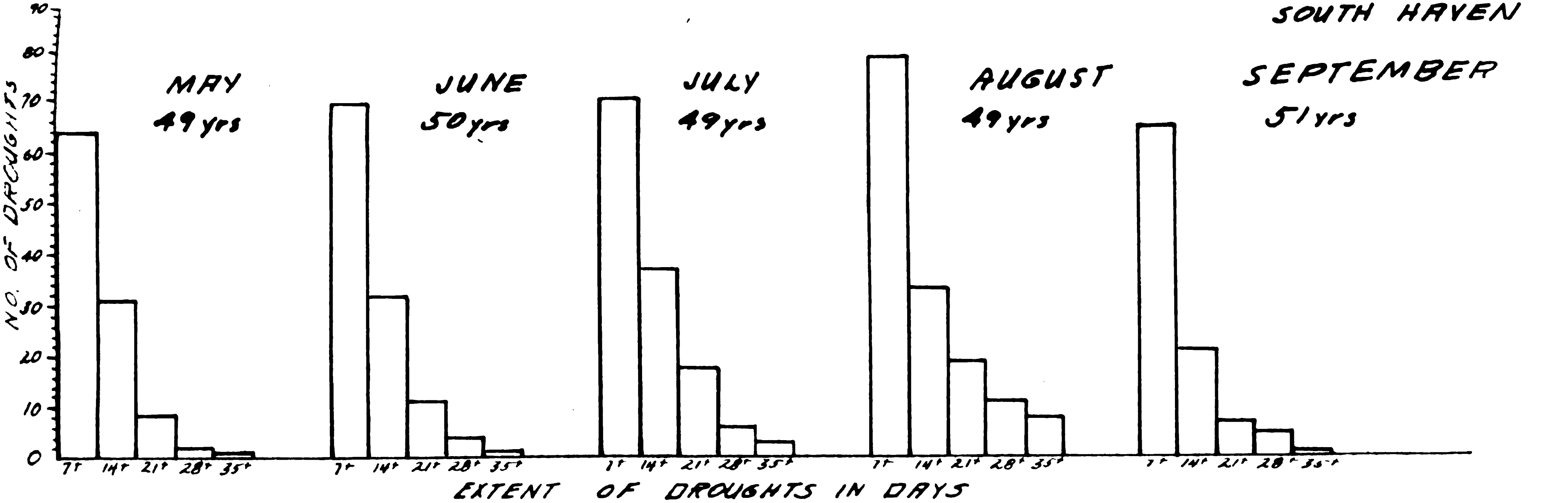
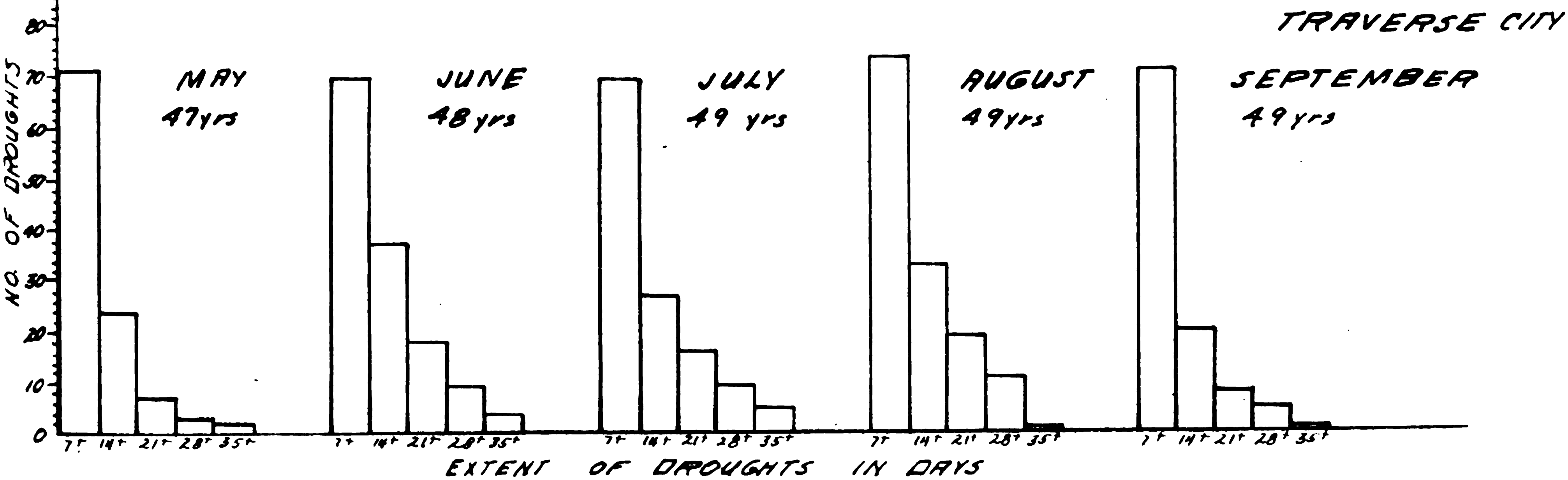

SOUTH HAVEN
MAY
49 yrs
JUNE
50 yrs
JULY
49 yrs
AUGUST
49 yrs
SEPTEMBER
51 yrs
NO. OF DROUGHTS
0
10
20
30
40
50
60
70
80
90
7+ 14+ 21+ 28+ 35+
EXTENT OF DROUGHTS IN DAYS

Fig. 60


TRAVERSE CITY
MAY
47 yrs
JUNE
48 yrs
JULY
49 yrs
AUGUST
49 yrs
SEPTEMBER
49 yrs
NO. OF DROUGHTS
0
10
20
30
40
50
60
70
80
90
7+ 14+ 21+ 28+ 35+
EXTENT OF DROUGHTS IN DAYS

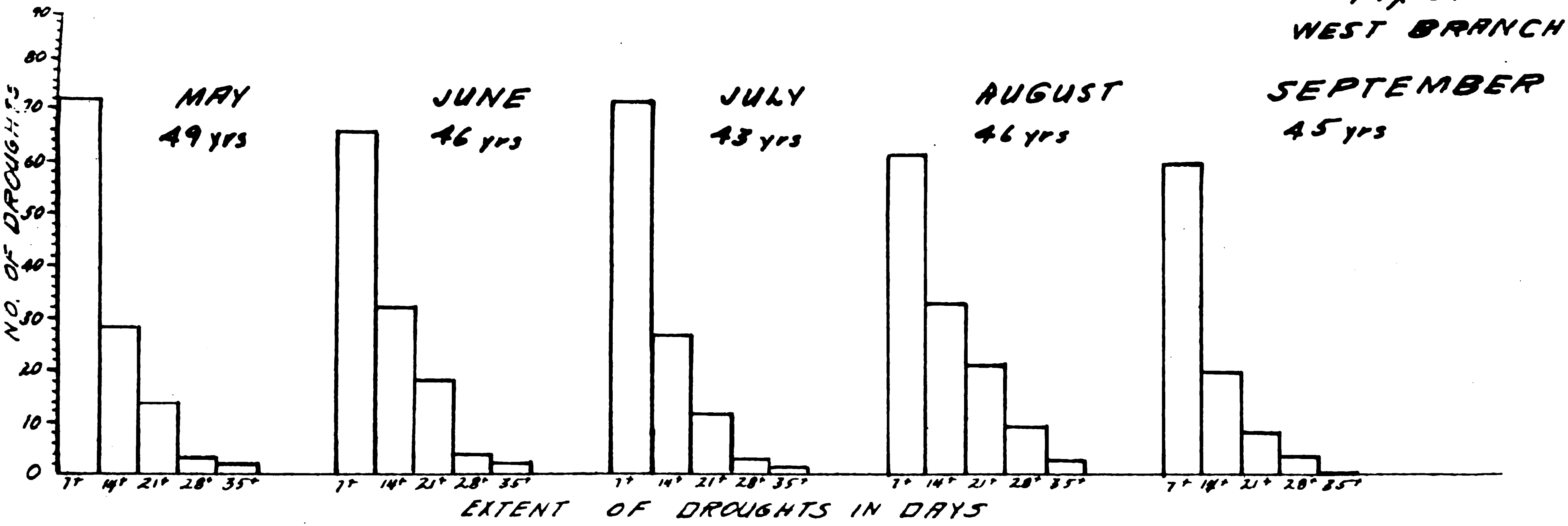


Fig 61
WEST BRANCH

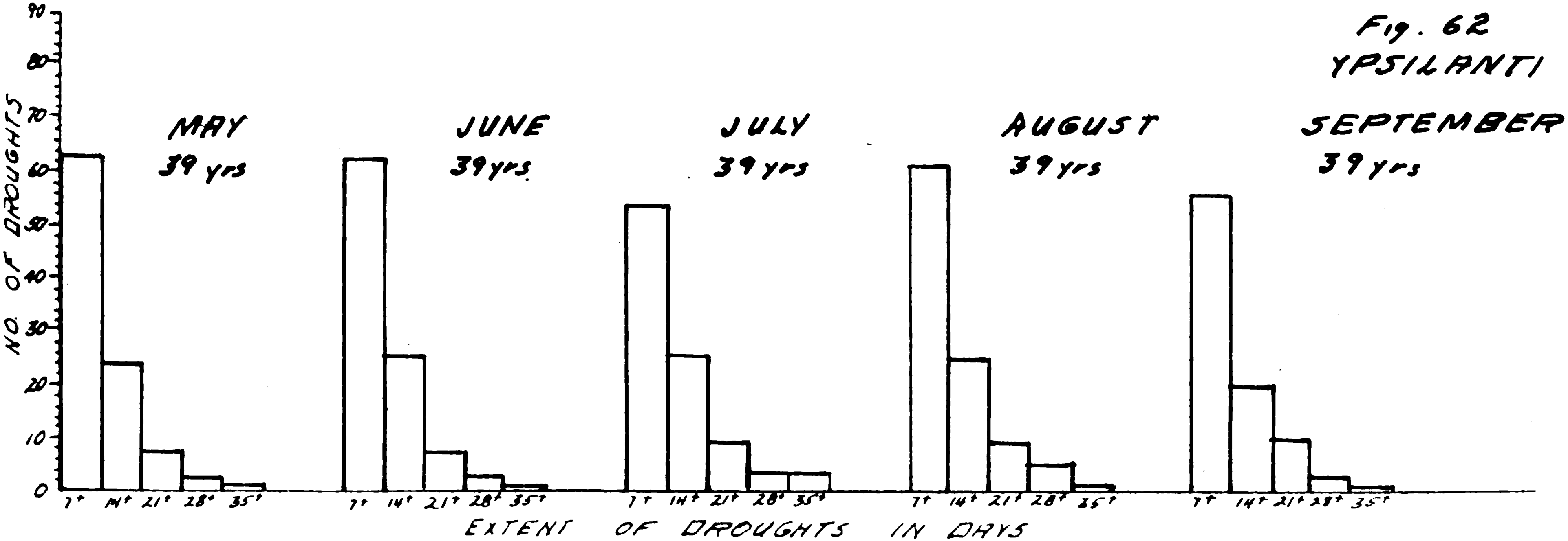
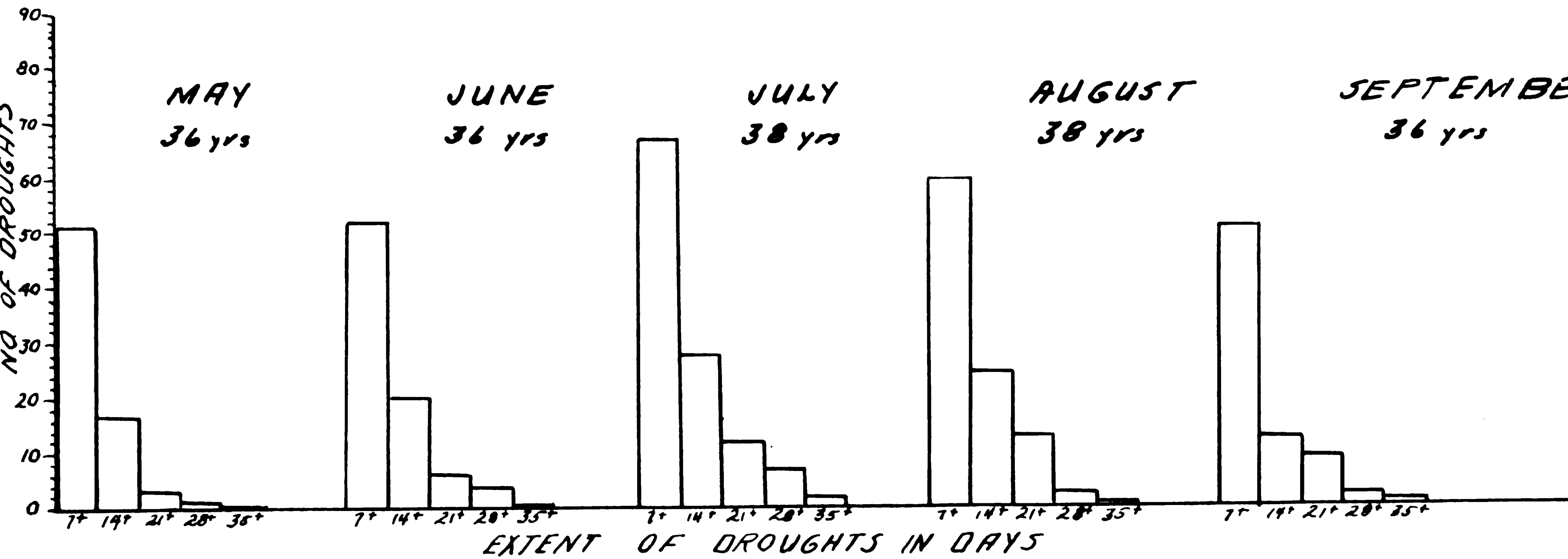


Fig. 62
YPSILANTI

Fig. 63
SOUTH BEND, IND.



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(2) Israelsen, O. W., Irrigation Principles and Practices, New York, pp. 1-5, 284-292.

(3) Millar, C. E., and Turk, L. M., Fundamentals of Soil Science, John Wiley & Sons, New York, pp. 397.

(4) Carreker, J. R., and Liddell, W. J., "Results of Irrigation Research in Georgia, Part I," Agricultural Engineering, Vol. 29, 1948, pp. 243-244.

(5) Staebner, F. E., "Determining an Index of Supplemental Irrigation and Its Application," Agricultural Engineering, Vol. 21, No. 6, 1940, pp. 215-217.

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