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Title

Infestation rate studies

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INTRODUCTION

An attempt was made to relate infestation rates to various factors, such as, the location of samples on Lake Winnipeg, the year the sampling was carried out, the age of the fish taken, and water levels on Lake Winnipeg. This was done in order to see if any of these factors had any bearing on the infestation rates.

Data were obtained from the provincial government lake surveys, from records in the office of Mr. H. V. Dempsey, Chief Supervisor, and from data collected by Dr. W. A. Kennedy on Lake Winnipeg in 1948 and 1949.

AN ANALYSIS OF INFESTATION RATES FOR 7 LOCATIONS AND 6 YEARS ON LAKE WINNIPEG

To determine if there were significant changes in infestation rates on Lake Winnipeg by years or by locations, an analysis of variance was performed on the data shown in Table 1 below. This table gives the infestation rates in cysts per hundred pounds of whitefish for the years 1944-1949 at George Island, Berens River, Spider Island, Sandy Island, Warrens Landing, Big Black River. The data in Table 1 is also shown graphically in Figure 1.

Table 1.

Location	Year 1944	1945	1946	1947	1948	1949
George Island	38	16	40	12	20	23
Berens River	21	7	18	14	22	15
Spider Island	52	17	17	25	44	49
Sandy Island	37	36	33	10	21	42
Warrens Landing	54	13	12	13	55	46
Big Black River	30	37	39	19	62	72
Lake Winnipeg (overall)	43	19	28	18	38	40

The analysis of variance of Table 1 is presented below in Table 11.

Table 11.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Between years	5	3343	669	4.37^{**}
Between locations	5	2473	495	3.24^{*}
Error	25	3837	153	
Total	35	9653		

$F^{**} = 3.86$
$F^{*} = 2.60$

The infestation rates differ significantly by years at the 1 per cent level. The infestation rates do not differ significantly for the years 1945, 1946 and 1947 but these years differ

significantly from the infestation rates for 1944, 1948 and 1949.

The infestation rates differ significantly by location at the 5 per cent level. The rates of infestation at Berens River are consistently low. Infestation rates at Spider Island, Sandy Island and Warrens Landing do not differ significantly from one another. The sampling done at these points seems to indicate that the fish come from the same population as far as infestation rates are concerned. On the other hand, Big Black River has higher rates of infestation over the years and differs significantly from the other locations. It would follow that since the infestation rates differ by location it would not be possible for data from one part of the lake to represent the whole lake.

The data collected in 1948 and 1949 were pinpointed as to where the fish were taken. Previous to that the fish examined at Warren's Landing may have come from points as far as 100 miles away. In view of this an analysis of variance was performed on the rates of infestation for 7 locations for 1948 and 1949. (An additional location was included.) The analysis is shown in Table 111 below.

Table 111.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Between years	1	37	37	0.70
Between locations	6	3527	588	11.09††
Error	6	316	53	
Total	13	3880		

$F_{\dagger\dagger} = 8.47$

This analysis indicates that infestation rates differ significantly between the 7 locations at the 1 per cent level. Since the infestation rates for Lake Winnipeg in 1948 and 1949 were 38 and 40 cysts per hundred pounds respectively, they do not differ significantly.

Since the infestation rates are based partly on the weight of the samples, the average weight of the fish may change from year to year and thus affect the infestation rate. In Table IV the changing average weights of the fish are shown year by year with other factors for Lake Winnipeg.

Table 1V.

Year	Sample size	I. R.	Cysts/fish	Average weight (pounds)
1944	985	38.50	0.9706	2,5224
1945	800	19.00	0.5063	2.6638
1946	695	27.50	0.7698	2.8106
1947	823	17.65	0.4423	2.5045
1948	1189	38.37	1.0706	2.7898
1949	670	39.96	0.9716	2.4314

The changing average weights have not affected the infestation rate sufficiently to account for the marked differences in infestation rates from year to year. For example, in 1947 with an infestation rate of 17.65 cysts per hundred pounds the average

weight of 2.5045 pounds differed little from the average weight of 2.4314 pounds in 1949 with an infestation rate of 39.96 cysts per hundred pounds. The factor that has caused the marked differences in the infestation rates is the changing effect of cysts per fish which will be dealt with in a separate study below. It is to be noted that the sample size is large enough to establish the infestation rate for a given year with an accuracy of ±4 cysts per hundred pounds.

AN ANALYSIS OF INFESTATION RATES BY AGES AND LOCATIONS ON LAKE WINNIPEG, 1948 SURVEY

The infestation rates for Lake Winnipeg whitefish by locations and age groups are given below in Table V. These figures are from the 1948 lake survey. The ages from 14 and over are grouped together.

Table V

Locations	9	10	11	12	13	14 and over
George Island	26	29	12	14	17	11
Shoal point	34	61	59	42	59	10
Berens River	59	22	19	21	29	32
Spider Island	24	46	52	37	16	46
Sandy Island	8	24	22	28	10	14
Warren's Landing	53	56	64	58	13	51
Big Black River	73	70	41	68	30	105
Selkirk Island	36	43	34	21	32	34

An analysis of variance on the above data yields the following results.

Table VI

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Between ages	5	1,443	289	1.16
Between locations	7	10,450	1493	6.00
Error	35	8,706	249	
Total	47	20,599		

$F_{.05} = 2.49$

$F_{.01} = 3.21$

On the basis of the above data rates of infestation do not vary significantly from age to age. This may be due to the fact that the ages do not cover a very wide range. It will be noted that there are no fish in the small age groups (2, 3, 4, 5, year olds) in the commercial catch from which the fish for the above survey were obtained.

The analysis also shows what was found previously, that infestation rates differ significantly by locations. Here the differences are highly significant.

AN ANALYSIS OF CYST PER FISH BY AGE GROUPS AND LOCATIONS ON LAKE WINNIPEG 1948 SURVEY

The data from the Lake Winnipeg survey of 1948 were analysed for cysts per fish by age groups and locations. The

data had been collected at the following 8 locations: George Island, Shoal Point, Berens River, Spider Island, Sandy Island, Warren's Landing, Big Black River and Selkirk Island. The ages were grouped as follows: 9, 10, 11, 12, 13, 14 years and over. None of the fish under 9 years of age were used as their numbers were too small to permit a statistical investigation. The age groups of 14 years and over were combined to give a group whose size permitted a statistical analysis.

Since the distribution of cysts per fish is a skew distribution, a transformation must be employed to permit an analysis of variance on the data. The transformation used here was log (C+1) where C is the number of cysts. Then the final means and standard deviations are in transformed units and not the original cysts per fish.

The analysis of variance is given below in Table VII. This was done by means of the theory of disproportionate subclass numbers with interaction present (Snedecor, 1946).

Table VII

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Between ages	5	.6976	.1395	2.28*
Between locations	7	4.1040	.5863	9.58**
Age X location	35	3.7800	.1080	1.76**
Error	1110	67.92	.0612	
Total	1157			

The above analysis indicates that cysts per fish for the given ages differ significantly at the 5 per cent level of significance. The average number of cysts per fish (in transformed variates) for the given age groups with their 95 per cent fiducial limits are shown below in Table VIII.

Table VIII

Age	Mean	95 per cent fiducial limits
99	.19	±.05
10	.23	±.02
11	.22	±.03
12	.25)	±.03)
13	.20) .26	±.05) ±.05
14 and over	.32)	±.06)

An examination of Table VIII will show that the earlier age groups differ significantly from the 14-year-olds and over. Dr. Miller is of the opinion that the ages from 12 years and older should be grouped together. When that is done the average numbers of cysts per fish shows an increase from the 9-year-olds to the 12-year-olds and over. The slight drop from .23 to .22 from the 10 to the 11-year-olds could be attributed to sampling fluctuations If earlier ages had been available, no doubt the increase in cysts per fish would have been noticeable from the earlier ages to the older groups.

In the analysis of variance of Table VII the cysts per fish by locations differ significantly at the 1 per cent level. In Table IX below the 8 locations with their averages are shown.

Table IX

Location	Average cyst per fish (transformed variate)	95 per cent fiducial limits
George Island	.13	±.04
Shoal Point	.21	±.04
Berens River	.20	±.04
Spider Island	.26	±.04
Sandy Island	.13	±.04
Warren's Landing	.32	±.04
Big Black River	.36	±.04
Selkirk Island	.22	±.04

The above table relects similar significant differences as were found under the study of infestation rates by locations (p. 2). Places which are close to one another: George Island, Berens River and Sandy Island do not differ significantly in cysts per fish. Warren's Landing and Spider Island do not differ significantly nor do Spider Island and Shoal Point. Big Black River is very high and differs significantly from Shoal Point, Sandy Island, Berens River and Selkirk Island.

In Table VII, the interaction term of age X location is significant at the 1 per cent level. This indicates that certain age groups have a different average of cysts per fish because of

the location. This may arise from the fact that the immediate physical environment of some of the locations permits more mixing of the jackfish and whitefish in certain years.

AN ANALYSIS OF CYSTS PER FISH BY LOCATIONS ON LAKE WINNIPEG, 1949 SURVEY

The data collected in the 1948 Lake Winnipeg survey were analysed for cysts per fish by 7 locations: Berens River, George Island, Sandy Island, Big Black River, Spider Island, Warren's Landing and Selkirk Island. The analysis of variance for these data is given below in Table X.

Table X

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Between locations	6	3.3833	.5639	9.33**
Within locations	663	40.0977	.0605	
Total	669			

** = 2.84

This again shows similar results to the 1948 data, namely, that cysts per fish differ significantly from one location to another. The average number of cysts per fish (in transformed variates) for the 7 locations is given below in Table XI.

Table XI

Location	Average number of cysts per fish	95 per cent fiducial limits
Berens River	.09	±.05
George Island	.13	±.05
Sandy Island	.27	±.05
Big Black River	.31	±.05
Spider Island	.22	±.05
Warren's Landing	.23	±.05
Selkirk Island	.23	±.05

Big Black River still has a high cysts per fish count and Berens River is again low. It is of interest to note that points as close together as Sandy Island and George Island differ significantly in their cyst per fish count.

A comparison of Table XI with Table IX will show that the average number of cysts per fish by locations in 1948 changed only slightly in 1949. The average number of cysts per fish rose for Sandy Island and dropped for Warren's Landing and Berens River. At all these points there were no significant changes.

DISTANCES BETWEEN LOCATIONS ON LAKE WINNIPEG OVER WHICH A SAMPLE IS VALID

During the years 1948 and 1949, the places where the samples were taken for the surveys were pinpointed to the nearest mile. Previous to these years, boats landing at Big Black River

may ahve taken their fish at Berens River or boats landing at George Island may have taken their fish near Sandy Island.

The data in Tables VIII and IX were used to determine distances between locations on Lake Winnipeg over which a sample is valid. Since it was impossible to obtain valid estimates of whitefish population in the areas where the samples were pinpointed, statistical formulae involving population numbers could not be used and another method was used.

By this method the distances between adjacent locations which did not differ significantly in cysts per fish were measured. The distances are not the same each year since the pinpointing around any one location will change from year to year depending on where the fish are taken. For 1948 the distances and locations of interest to this study are given below in Table XII.

Table XII

Location	Miles
Warren's Landing to Spider Island	12
Spider Island to Shoal Point	17
Sandy Island to George Island	13
George Island to Berens River	44

From the above table it would seem that 44 miles would be a distance over which samples of size 100 fish would be valid (this being the sample size which is used at each location on Lake Winnipeg). However, Shoal Point differed significantly from

Big Balck River in cysts per fish and the distance between these points is 12 miles. Thus considering all the locations, the distance over which the samples would be valid is less than 12 miles.

On examination of Table IX it is found that Warren's Landing does not differ significantly in cysts per fish from Spider Island over a distance of 9 miles, while in Table XI Sandy Island differs significantly in 1949 from George Island over a distance of 15 miles.

On the basis of the data from these two years it would appear that locations 9 miles apart could be sampled as one area or the sample from one location would adequately represent the other. But points differing by 12 miles in some areas of Lake Winnipeg represent different populations of whitefish with respect to cysts per fish.

INFESTATION RATES AND CYSTS PER FISH RELATED TO LAKE WINNIPEG WATER LEVELS

Data on the levels of Lake Winnipeg were obtained from the Water Resources Branch of the Department of Mines and Natural Resources, Province of Manitoba. From these the average lake levels for the last 3 weeks in May and the first week in June were obtained (this being the time when the whitefish could feed on infested Cyclops). The maximum lake levels were also obtained for the years 1944-1949. These are shown below in Table XIII together with other related data.

Table XIII.

Year	Height May-June (ft.)	Maximum height (ft.)	I. R.	Cyst per fish
1944	711.7	712.9	38.50	.97
1945	713.4	713.8	19.00	.51
1946	713.3	713.4	27.50	.77
1947	713.0	714.6	17.65	.44
1948	713.5	714.4	38.37	1.07
1949	712.5	712.5	39.96	.97

The cysts per fish and May-June heights of Lake Winnipeg are graphed for the 6 years in Figure 2. There is only a very low relationship between the two factors, possibly because the fish may eat the infested Cyclops in the May and June period but the cysts do not show up at the time the fish are examined.

When the maximum height of the lake for that year is taken and plotted against infestation rate in Figure 3 and against cysts per fish as in Figure 4, a better relationship appears. One point in the upper right hand part of Figures 3 and 4 is due to the year, 1948. No explanation can be given for this departure from the trend of the other points on the graphs. In general, the trend is that the higher the water level of Lake Winnipeg, the lower the infestation rate (or cysts per fish). A correlation coefficient of - .46 was found between maximum heights and cysts per fish. This would imply that water level would account for

22 per cent of the variation of the cysts per fish.

Dr. R. B. Miller is of the opinion that the above relationship is due to the fact that when the lake level is high the jackfish can spawn in the streams tributary to a lake and hence do not mix with the whitefish at that time, resulting in lower infestation rates. When the lake levels are low there is more mixing of jackfish and whitefish resulting in increased infestation rates.

CYSTS PER FISH AND CONSECUTIVE DAYS FISHING IN THE SAME LOCALITY

The purpose of this study was to determine if the cysts per fish or infestation rates varied from day to day in fish which were caught in the same locality on consecutive days of fishing. When the dates are not consecutive, storms arose but the fish were lifted as soon as conditions permitted.

Four separate collections of whitefish data were made by Dr. W. A. Kennedy for this study. The dates for the series are as follows:

1. Aug. 16 and Aug. 22, 1948 at Big Black River
2. June 17-19, 1949 at Big Black River
3. July 25-30, 1949 at Big Black River
4. Aug. 25-29, 1949 at Black Island

(All locations on Lake Winnipeg).

In the analysis of the data the logarithmic transformation was used to permit the use of the analysis of variance. The data in Table XIV below were collected 20 miles west of Big Black

River on August 16 and August 22, 1948. A storm arose on August 17 and the nets could not be lifted until August 22.

Table XIV

Number of cysts	Aug. 16	Aug. 22
0	7	13
1	2	5
2	0	6
3	1	1
4	0	0
5	0	1
6	0	0
7	0	0
8	1	0
Total fish	11	26
Cysts per fish	1.1818	.9615
Average weight pounds	1.8518	2.3003
I. R.	63.81 cysts/cwt.	41.80 cysts/cwt.

The analysis of variance in this data is shown in Table XV.

Table XV

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Between dates	1	.0058	.0058	.07
Within dates	35	2.8197	.0806	
Total ($F^{\#} = 250$)	36	2.8255		

Since the F value is not significant, it is unlikely that means of the two groups, 1.1818 and .9615 cysts per fish come from different populations of fish as far as cysts per fish are concerned. The fact that the second group has a much higher infestation rate is mostly explained by the lower average weight of the fish in that group.

On June 17, 18 and 19 of 1949, Dr. Kennedy collected the data shown in Table XVI 5 miles west of Big Black River.

Table XVI

Number of cysts	June 17	June 18	June 19
0	11	7	8
1	5	2	3
2	4	0	1
3	1	0	0
4	1	0	0
Total fish	22	9	13
Cysts per fish	.9091	.2222	.6923
Average weight pounds	2.1591	1.9514	2.1774
I. R.	42.11	11.39	31.79

The analysis of variance of the above tale is shown in Table XVII below.

Table XVII

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Between dates	2	.1400	.0700	1.43
Within dates	41	2.0006	.0488	
Total ($F^{*} = 3.22$)	43	2.1406		

Since the above F value for variation between dates in cysts per fish is not significant, the fish caught on the three dates would seem to have come from the same population as far as cysts per fish are concerned.

On July 24-30, 1949, Dr. Kennedy collected 74 whitefish 13 miles west of Big Black River. Their cysts count is given below in Table XVIII.

Table XVIII

Number of cysts	July 24	July 27	July 28	July 29	July 30
0	9	19	5	4	1
1	3	9	2	2	3
2		1	3	3	1
3			4		1
4			2		
5			0		
6			0		
7			1		
8			1		
Total fish	12	29	18	9	6
Cysts per fish	.2500	.3793	1.5556	.8889	1.3333
Average weight lbs.	2.3644	2.2931	2.0731	2.1456	2.1356
I. R.	10.57	16.54	75.04	41.42	62.44

The analysis of variance for the above data in Table XVIII is shown in Table XIX below.

Table XIX

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Between dates	4	.7993	.1998	4.75***
Within dates	69	2.9050	..0421	
Total	73	3.7043		

Since the F value is significant at the 1 per cent point, it is unlikely that the cysts per fish for the given dates constitute random samples from the same homogeneous population. The 95 per cent fiducial limits for the mean cyst count (in transformed variates) are given below for the five dates.

July 24	.0695 ± .1180
July 27	.1099 ± .0745
July 28	.3244 ± .0964
July 29	.2259 ± .1363
July 30	.3304 ± .1669

July 24 and 27 differ significantly from July 28 and July 30. On the assumption that the data on July 24 and 27 are homogeneous and that of July 28 to July 30 are also homogeneous another analysis of variance was run on the new data and is shown below in Table XX.

Table XX

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F
Between dates	1	.4078	.4078	9.14***
Within dates	72	3.2132	.0446	
Total	73	3.6210		

This would indicate that as far as cysts per fish are concerned, two different populations of fish were caught on the two dates.

From August 25 to August 29, 1949, Dr. Kennedy collected 43 whitefish 2 miles S. E. of the S. W. corner of Black Island. The data are given below in Table XXI.

Table XXI

Number of cysts	Aug. 25	Aug. 26	Aug. 28	Aug. 29
0	4	2	16	6
1	4	1	2	4
2	1	0	2	
3		1		
Total fish	9	4	20	10
Average weight pounds	2.2014	1.8593	2.3750	2.4438
Cysts per fish	.6667	1.000	.3000	.4000
I. R.	30.28	53.78	12.63	16.37

The analysis of variance of the above data is shown below in Table XXII.

Table XXII

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Between dates	3	.0898	.0299	.91
Within dates	39	1.2879	.0330	
Total ($F^{\dagger} = 2.84$)	42	1.3777		

Since the F value is not significant at the 5 per cent point, there is no reason for assuming that the 43 whitefish caught on the above dates differ as far as cysts per fish are concerned.

The data shown in Tables XIV, XVI, XVIII and XXI represent 2, 3, 5 and 4 consecutive days fishing respectively, and of these the data in Table XVIII showed significant differences in cysts per fish. It may be that at least 5 consecutive days fishing may have to be done before any significant changes occur in cysts per fish. It may take around 5 days for 1 group to move out and another group of fish move in having a different infestation rate from the first group. It is also possible for it to take that long for a second group to move in on these grounds and mix sufficiently with the first group to change the infestation rate.

AN ANALYSIS OF CYSTS PER FISH FOR VARIOUS DEPTHS

The 44 whitefish caught at Big Black River on June 17, 18 and 19, 1949, were also classified as to the depth at which they were caught. Table XXIII records the cysts per fish for the depths in fathoms. This was done to determine if there were any significant differences in cysts per fish for fish caught at, say 5 fathoms, from those caught at, say 8 fathoms. It was found in the analysis of Table XVII that the cysts per fish did not vary day by day at this location on June 17, 18 and 19, so the data can then be grouped together regardless of days as is done in Table XXIII.

Table XXIII

Cysts per fish	5	6	7	8
0	11	4	2	9
1	5	0	1	4
2	1	0	1	3
3		0	1	0
4		1	0	1
Totals	17	5	5	17
Cysts per fish	.4118	.8000	1.2000	.5882
Average weight pounds	1.9338	2.3000	1.9625	2.2169
I. R.	21.29	34.78	61.15	26.53

The analysis of variance of Table XXIII is given below in Table XXIV. As usual the variables were transformed by the logarithmic transformation before analysing.

Table XXIV

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Between fathoms	3	.1207	.0402	0.80
Within fathoms	40	2.0199	.0505	
Totals	43	2.1406		

Since the F value is not significant there is no indication that the fish caught at different depths differ in cysts per fish. The high value noted in Table XXIII for a depth of 7 fathoms is not indicative of a trend at that depth but is merely due to the low size of the sample (5 fish).

SUFFICIENT SAMPLE SIZES FOR LAKE WINNIPEG SURVEY AT BIG BLACK RIVER

Figure 5 gives the size of a sample to be selected in the area of Big Black River based on the results of 44 fish caught there from June 17 to June 19. (See Table XVI of this report.)

The chart is to be used in the following manner. If we wish to be within 6 cysts per hundred pounds of the true infestation rate at Big Black River, then we read upward from 6 until

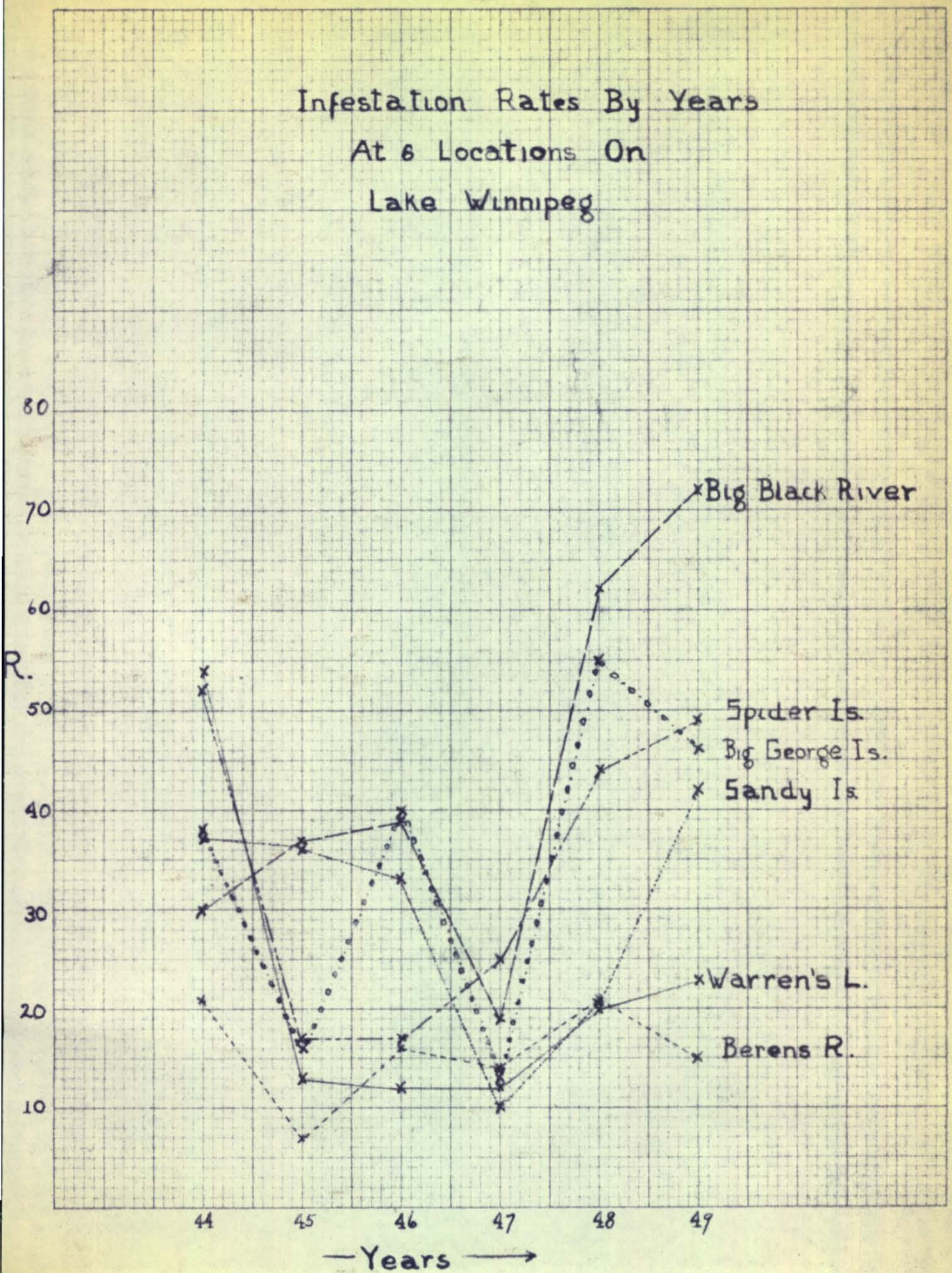
we hit the curved line and then the size of the sample is read as 250 fish.

When this chart is used for this work we shall be right 95 per cent of the time.

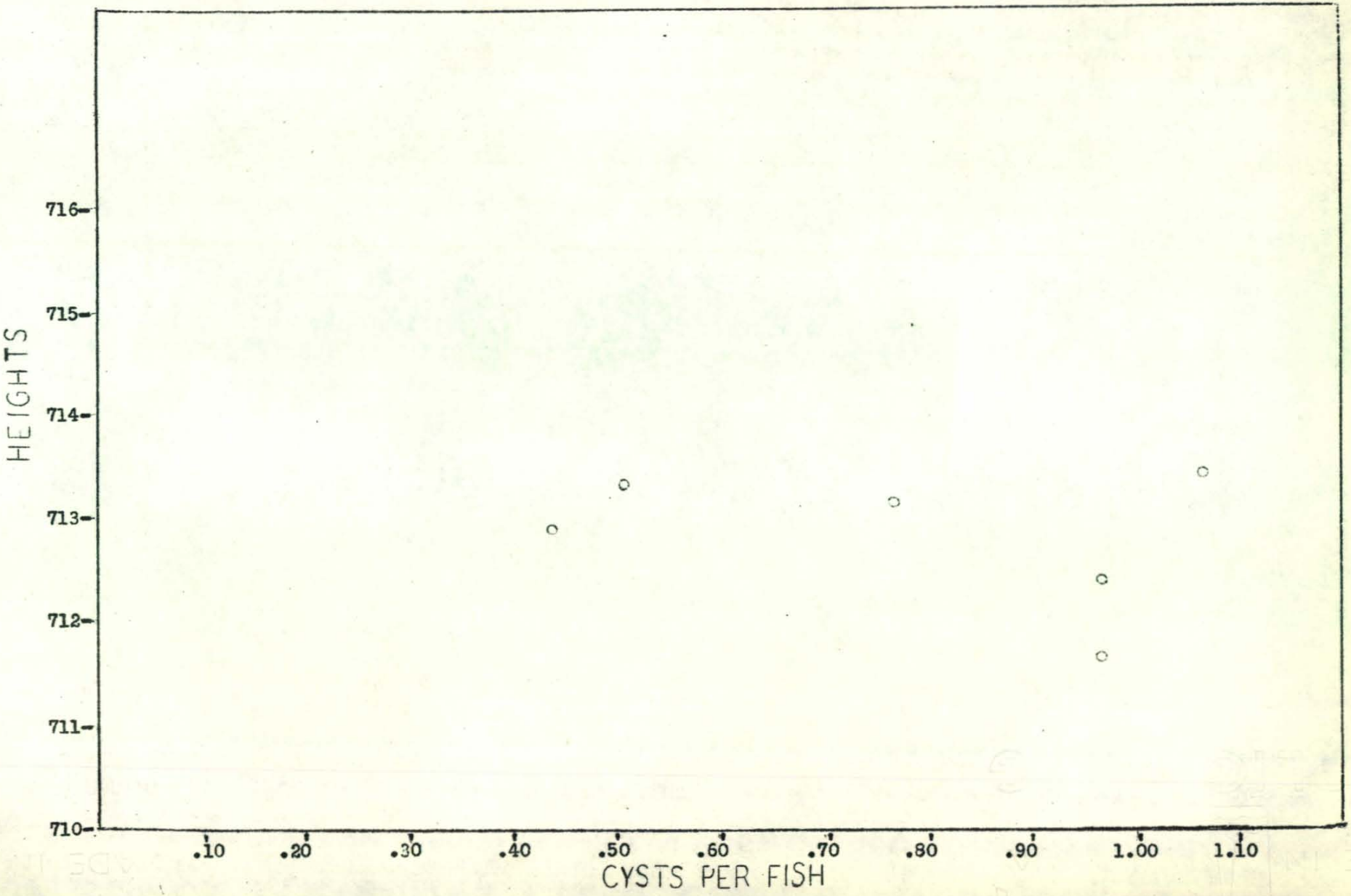
REFERENCES

1. Snedecor, G. W. Statistical Methods, 1946. Iowa State College press, Ames Iowa.

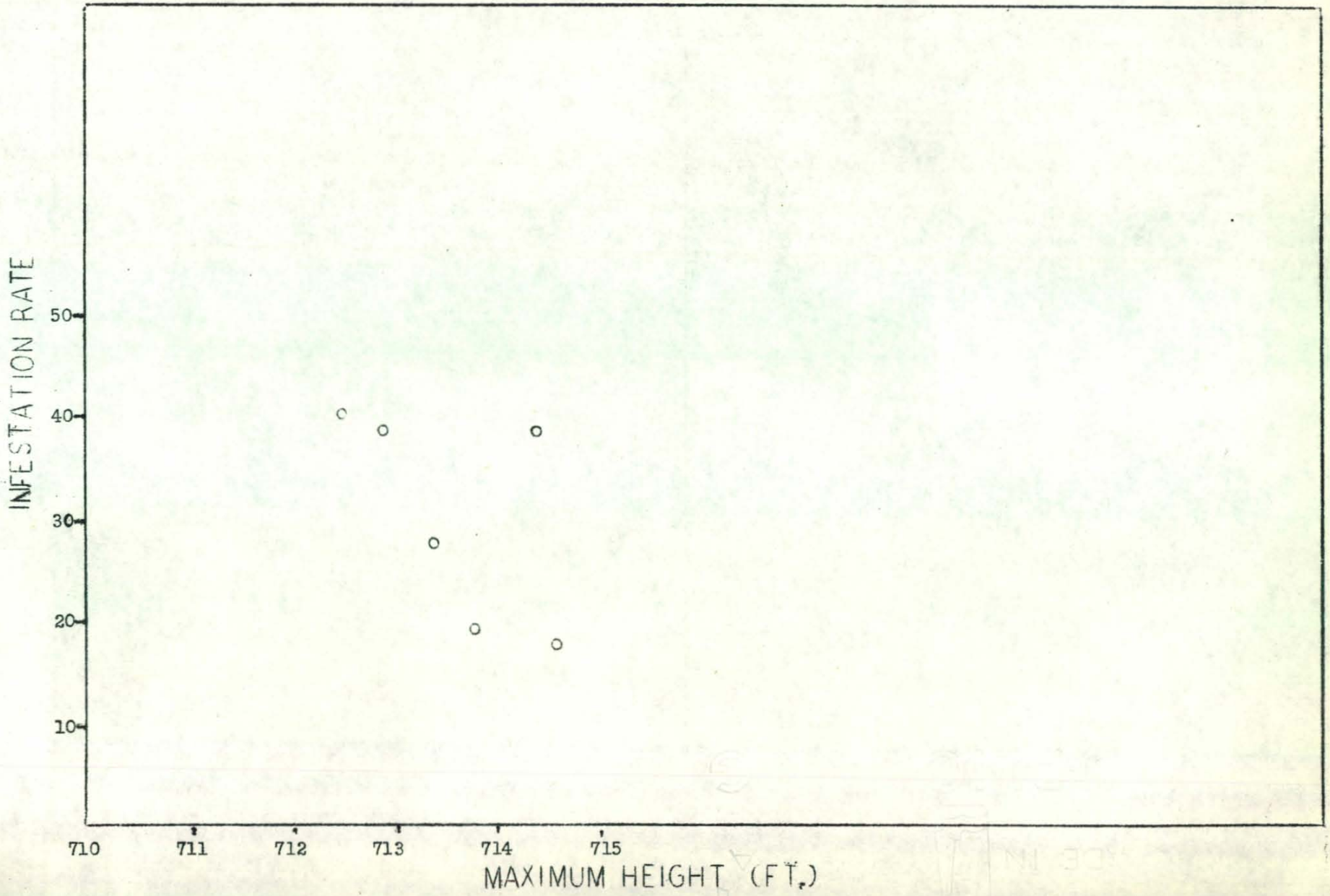
FIGURE 1


Infestation Rates By Years
At 6 Locations On
Lake Winnipeg
80
70
60
R.
50
40
30
20
10
Big Black River
Spider Is.
Big George Is.
Sandy Is.
Warren's L.
Berens R.
44
45
46
47
48
49
Years

MAY - JUNE HEIGHTS AND CYSTS PER FISH FIGURE 2

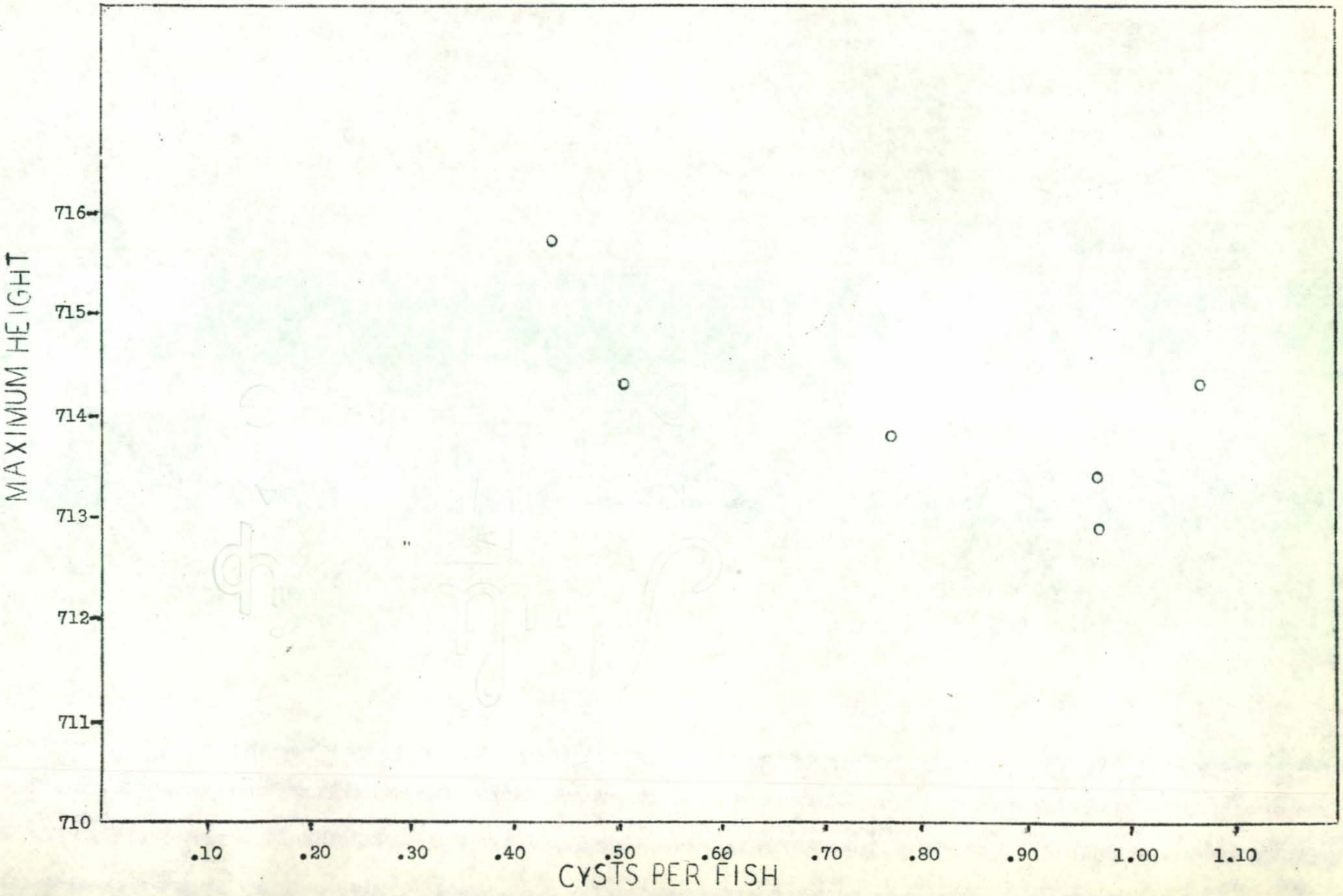


MAXIMUM HEIGHT AND INFESTATION RATE FIGURE 3



CYSTS PER FISH AND MAXIMUM HEIGHT

FIGURE 4



SIZE OF SAMPLE WITH 95% CONFIDENCE AT BIG BLACK RIVER FIGURE 5