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TEST FISHING IN BRISTOL BAY
1960-64

By:

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ALASKA FISH & GAME

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ABSTRACT

Test fishing has been conducted in Bristol Bay since 1960. Outside test fishing is used in and beyond the commercial fishing districts during closed fishing periods to provide the managing agency with information regarding timing, pattern of entry and general magnitude of sockeye runs to Bristol Bay. Inside test fishing is conducted in the river mouths immediately above the inner fishing boundaries and is used to provide daily estimates of sockeye which have passed through the fishery and can be counted as escapement. Statistical analysis of past data indicates that a single regression line (expressing daily escapement as a function of daily inside test fishing indices) can be used for the four years of data on the Ugashik River and a single regression line can be used for the two years of Egegik data. A statistical test rejects the use of a common regression line for the five years of Kvichak inside test fishing data.

INTRODUCTION

Test fishing has been conducted in Bristol Bay by the Division of Commercial Fisheries of the Alaska Department of Fish and Game since 1960. Two different types of test fishing methods have been utilized to provide information regarding the salmon run at two different stages. A) Outside test fishing is conducted both in the commercial fishery area and farther out in the bay to obtain information regarding time and pattern of entry of sockeye (Oncorhynchus nerka) into the fishing districts. This also provides some estimate of the abundance of salmon in the bay. This information, in combination with other information such as predicted returns, desired escapement goals, previous commercial catch, estimated escapement, etc., provides the management biologist with a basis for opening, closing or extending the commercial fishing periods. In the past, outside test fishing has been conducted only during the closed fishing periods, as it is felt that when the fishing fleet is operating, it provides sufficient information regarding abundance and stage of the run. B) Inside test fishing is conducted inside the mouths of the rivers and is used to provide a measure of abundance of the salmon which have already passed through the commercial fishery and are migrating up the rivers to spawn. Although counting towers situated at the heads of the rivers provide daily escapement counts, the migration rates from the commercial fishing districts to the counting towers may vary from 2-14 days depending on the size of the run, the river, etc., and hence some more immediate estimate of escapement is required for managing the fishery.

Both the outside and inside test fishing have proved to be valuable fishery management aids in Bristol Bay during the past fishing season.

METHODS

A) Outside Test Fishing

Commercial fishing districts, test fishing areas and counting tower locations in Bristol Bay in 1964 are shown in Figure 1. Outside test fishing was also conducted during the 1962-63 seasons in the Naknek-Kvichak district, however, it was first initiated in the Egegik and Nushagak districts in 1964. Each of the test fishing districts is divided into subsections for test fishing purposes. Maps of the Naknek-Kvichak, Egegik and Nushagak test fishing areas showing the subsections are given in Figure 2, 3 and 4 respectively.

Test fishing is conducted from commercial 32-foot gill netting boats operated by commercial fishermen. Each test boat carries one or two observers from the Alaska Department of Fish and Game. The department personnel direct the test fishing operations with regard to fishing area, time fished, etc. The boats are equipped with short wave radios which are used to transmit test fishing operations with regard to fishing area, time fished, etc. The boats are equipped with short wave radios which are used to transmit test fishing data to the King Salmon or Dillingham management offices. When possible, this data is radioed in immediately after each drift is completed, however atmospheric conditions prevent this at times. The value of the outside test fishing data to management is increased according to the rapidity with which it can be transmitted to the management office. This is especially true during the peak of the season which may last only several days.

Fishing gear consists of 50-150 fathoms of standard commercial gillnet of 5-3/8 inch stretch mesh. An attempt was made to standardize gear at 100 fathoms, however, during periods of very heavy salmon concentration, catches became too large resulting in a decrease of further test fishing time (as the boat had to deliver the fish to the cannery) and mobility of the test boat. In the larger Naknek-Kvichak district especially, mobility is an important factor. Therefore, when large numbers of fish were present, the gear was restricted to 50 fathoms to limit the catches. Similarly, during periods of light concentrations of sockeye, 150 fathoms of gear was used as this allowed better fishing patterns for the net as well as allowing more fishing area to be covered.

Generally, fishing time per drift was set at 30 minutes, however, during periods of heavy concentration of fish, the fishing time, as well as the fishing gear, was decreased in an attempt to limit the total catches. When few salmon were present, the nets were fished for longer periods of time, allowing the tide to carry the boat and net across the larger part of a subsection.

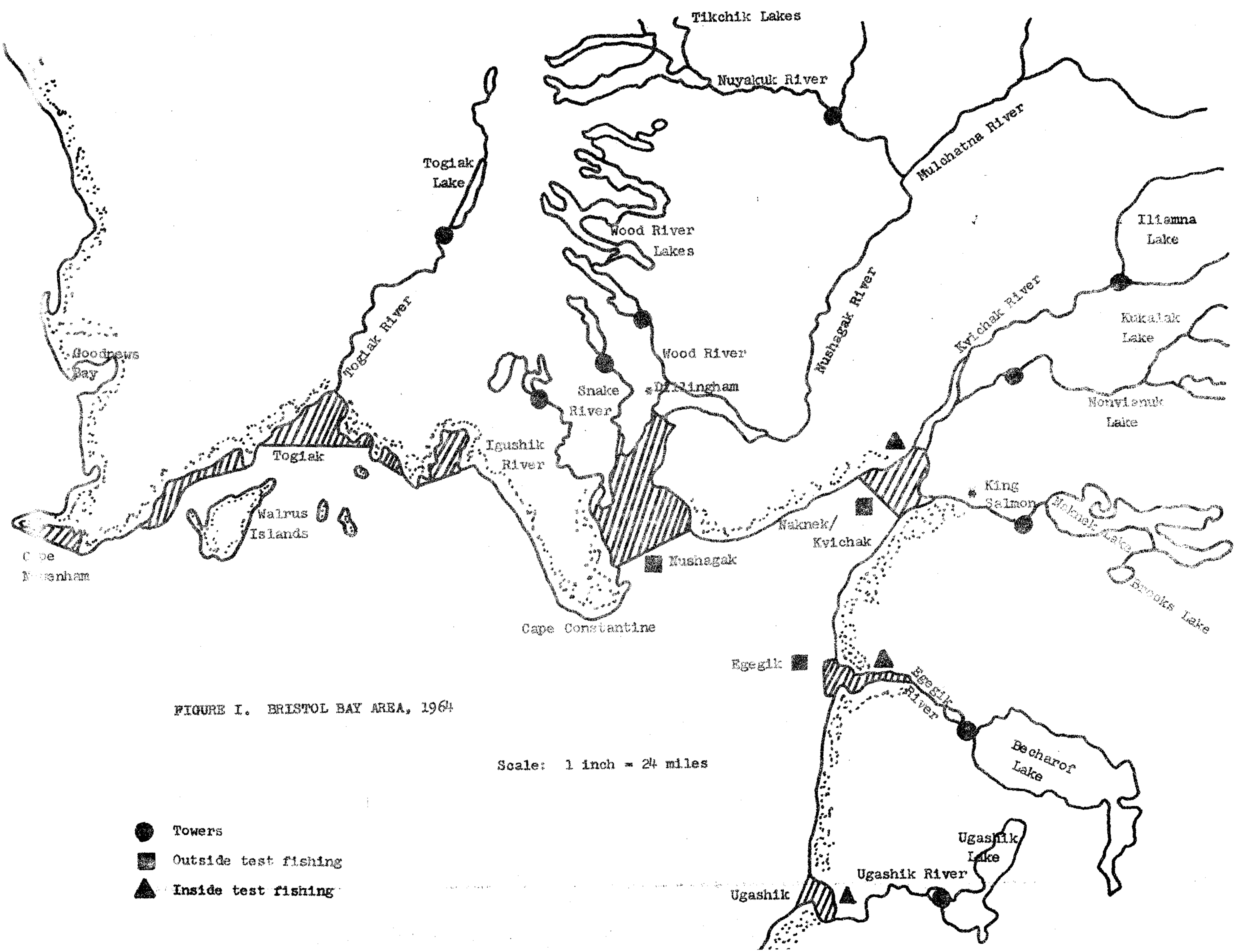


FIGURE I. BRISTOL BAY AREA, 1964

Scale: 1 inch = 24 miles

FIGURE 2. OUTSIDE TEST FISHING AREA

NAKNEK-KVICHAK, 1965

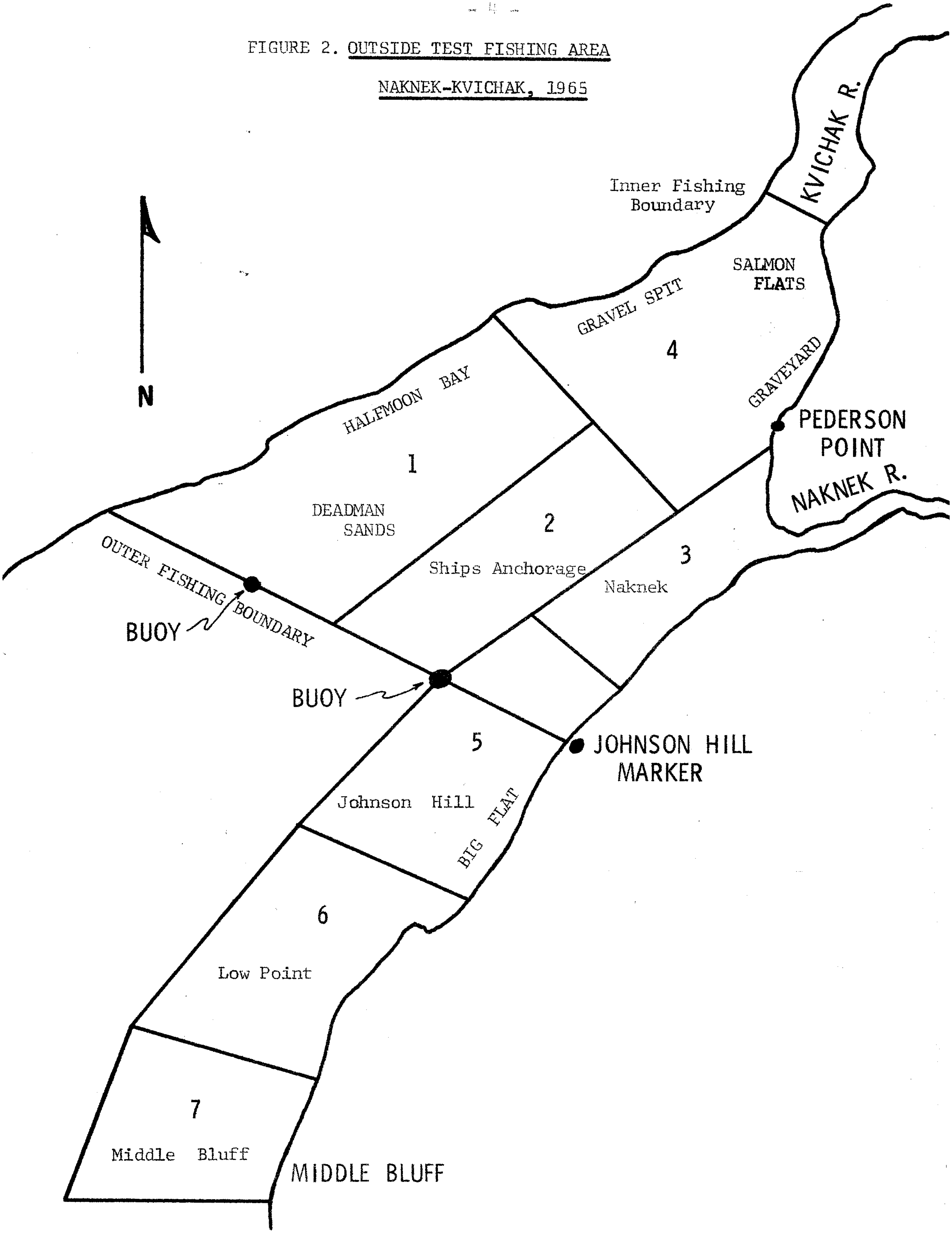
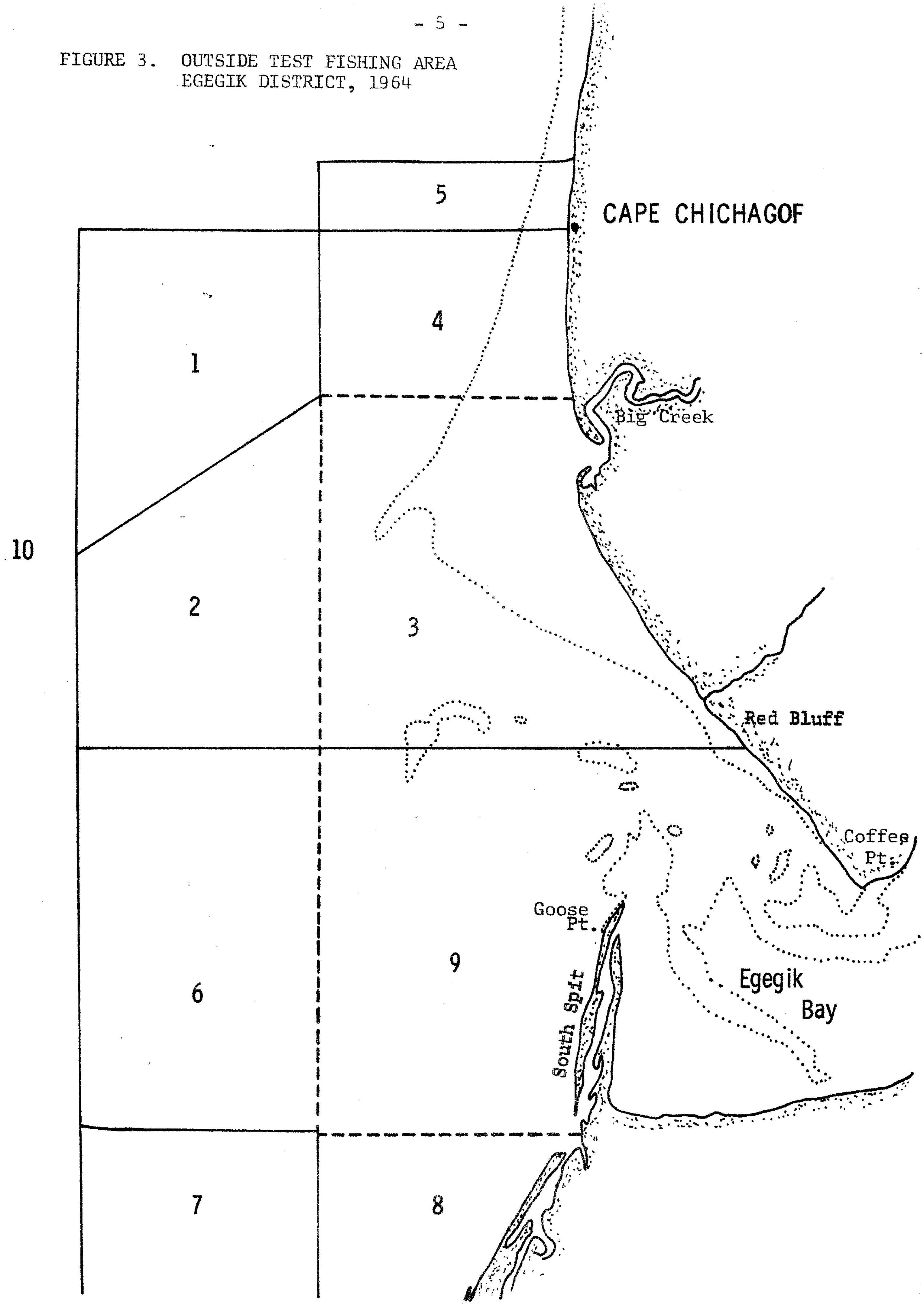


FIGURE 3. OUTSIDE TEST FISHING AREA
EGEGIK DISTRICT, 1964



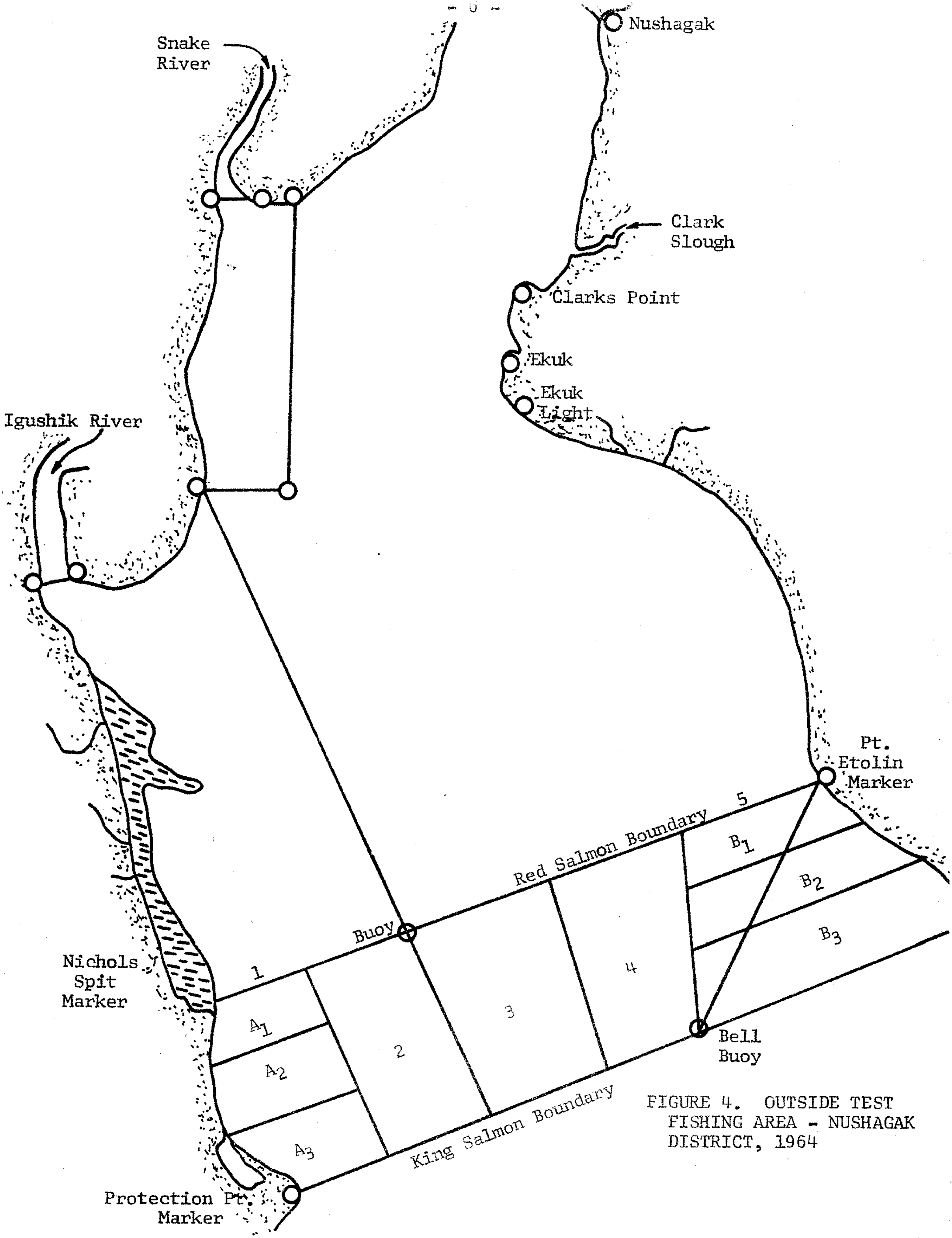


FIGURE 4. OUTSIDE TEST FISHING AREA - NUSHAGAK DISTRICT, 1964

Special fishing patterns were developed in each of the districts depending on the entry pattern of the sockeye into the district. For example, in the Naknek-Kvichak district, the test boat would generally leave the mouth of the Naknek River, move down to Johnson Hill, then to Low Point and finally to Middle Bluff, making drifts as it moved down the bay. As in the past, Middle Bluff proved to be a milling area in 1964, therefore after an attempt was made to determine whether the fish were actually moving up the coast toward the rivers, the test boat would then move across to the west side of the bay, fishing the Halfmoon Bay, Gravel Spit, Salmon Flats, Graveyard and finally the Naknek River area. At this time, the test boat would either make another circuit or wait for a period of time before it began fishing again.

In addition to the standard test fishing procedures, other studies are conducted from the outside test boats. In 1964 smaller mesh net was used at times in the Naknek-Kvichak section to determine whether a large portion of the run was small 2-ocean fish which were passing through the standard 5-3/8 inch net. In the outside Egegik district in 1964, scales were collected from fish taken in each subsection. These scales are presently being studied in an attempt to determine what percent of the sockeye passing through the Egegik district are actually bound for the Naknek-Kvichak system.

B) Inside Test Fishing

Locations of the inside test fishing sites are also shown in Figure 1. The inside test fishing program was first initiated on the Kvichak River in 1960. The following year, in 1961, it was extended to the Ugashik River and in 1962 the Egegik River was included in the program.

The methods employed in inside test fishing differ somewhat from the outside test fishing methods. As mentioned in the introduction, inside test fishing is conducted in the mouths of the above rivers, directly above the commercial fishery inner boundaries. At this point, the sockeye have already passed through the commercial fishery and can be counted as escapement. (Although several small subsistence fisheries operate on the rivers between the commercial fishery districts and the counting towers, it is felt that the effect of these subsistence fisheries does not warrant further adjustment of the test fishing indices).

In an attempt to standardize the inside test boat catches both within a given year and between different years, a single restricted fishing area is designated for each of the three rivers. Thus, for a given river, each individual drift is made in approximately the same place. Commercial Bristol Bay gillnetters, operated by two Department personnel per boat, are used for the inside test fishing. Fishing gear is standardized at 50 fathoms of 5-3/8 inch stretch mesh gillnet. Although fishing time per drift is theoretically standardized at 30 minutes, the actual fishing time may be shorter during periods of heavy concentration of sockeye, or longer if complications occur when the net is being pulled into the boat. However, total fishing time is usually in the range of 15-45 minutes.

As the migratory pattern of the Bristol Bay sockeye moving into the river mouths is usually dependent on the tidal conditions, test fishing is conducted during approximately the same stage of the tide every day. This allows two periods of test fishing per day with one or two drifts made per period, hence 2-4 drifts are obtained each day. The total data per day is combined to form a single daily test fishing index for each river. The inside test fishing data is transmitted after each fishing period to the King Salmon management office via short wave radios installed in the fishing boats or from the more powerful cannery radios when necessary.

RESULTS AND ANALYSIS

In order to arrive at a quantitative measure of the fishing success of the test boats, a test fishing index was defined as follows:

$$\text{Index} = \frac{1000 \times (\text{Number of Salmon Caught})}{(\text{No. of Fathoms of Gear}) \times (\text{Minutes Fished})} \quad (1)$$

Thus the index is expressed in terms of "fish per thousand fathom minutes". Multiplying the catch by 1000 merely adjusts the index to a more reasonable magnitude for computational purposes. A mean fishing time for the center of the net is given by the formula:

$$T_{mean} = T_2 + 1/2\ (T_1 + T_3) \quad (2)$$

where

T_1 = time required to let the net out,

T_2 = time the entire net is fished,

T_3 = time required to pull the net,

with time being expressed in minutes.

Outside test fishing data is converted to a test fishing index for each drift. These indices generally vary from 0 to 200 fish per thousand fathom minutes. At present, no additional analysis of the outside test fishing indices has been attempted. The primary use of these indices is to provide the management biologist with a general idea of 1) abundance of sockeye in or near the commercial fishery districts; this consists of both concentration of fish in a single area as well as size or extent of the schools of fish, 2) areas in which the fish are encountered, and 3) possible movement of sockeye through the districts and toward the rivers. No attempt is made to quantitatively estimate the number of sockeye in a commercial fishery district at a given time from the outside test fishing indices.

The remaining part of this section will deal with analysis of the past inside test fishing data and references to test fishing will be understood to refer to inside test fishing unless stated otherwise.

Whereas a test fishing index is associated with each drift made by the outside test boats, the total inside test fishing data for a single day is grouped, i.e. the total daily catch and total minutes fished are used in Equation (1) to obtain a daily index for each river. Note that since fishing gear for inside test fishing is constant at 50 fathoms, Equation (1) reduces to

$$\text{Index} = 20 \times \frac{(\text{No. of Salmon Caught})}{\text{No. of Minutes Fished}} \qquad (3)$$

Past inside test fishing indices by day for the Kvichak, Egegik and Ugashik Rivers are given in Tables 1, 2 and 3 respectively. In addition the daily indices and daily escapement counts made at the counting towers are graphed in Figures I-1 to I-11. These figures appear in the index. Indices for days not fished (due to boat trouble, etc.) were obtained by determining the geometric mean of the indices of the previous and following days. Although an inside test boat operated in the Egegik River in 1962, the fishing was basically exploratory (for determination of fishing site, etc.) and frequent failure of fishing equipment prevented obtaining consistent daily indices.

In order to relate the inside test fishing indices to the daily escapement counts, some allowance must be made for the migration rate of the salmon between the fishing site and the counting tower. On the basis of past data, it is apparent that fish in different stages of the run have different migration rates. This is especially true of the Ugashik River stock where the sockeye from the early part of the run migrate up the river to a lagoon below the counting tower and remain there for a number of days before moving into the lake. However, it appears that fish from the peak, and especially from the latter part of the run, either spend less time in the lagoon or move directly through the lagoon and into the lake. Although these seasonal differences in migration rates do occur, it is felt that the advantages in stratifying the data according to early, peak and late runs is offset by the disadvantage of small sample sizes thus incurred. Therefore, an average seasonal migration rate for each river in a given year is obtained in the following manner.

Let r_i = the linear correlation coefficient between the daily fishing indices (independent variable) and the daily tower counts (dependent variable) assuming a migration rate of i days.

Then the average seasonal migration rate is the positive integer R such that

$$r_R = \underset{i = 0,\dots,n}{\text{Maximum}}\ r_i$$

where n is large enough to assure that the true seasonal average R lies between 0 and n. Figures 5, 6 and 7 show the different values of r associated with different migration rates for each year of test fishing on the Kvichak, Egegik and Ugashik Rivers respectively. In almost every case, the correlation coefficient r increases steadily to a maximum value r_R (for a migration rate of R days) then decreases when larger migration rates are allowed. In all cases except two, the correlation coefficients indicate highly significant (i.e. 99% level) linear correlation between the test fishing indices and the tower counts.

TABLE 1. DAILY INSIDE TEST FISHING INDICES*

Kvichak River, 1960-64

Date	1960	1961	1962	1963	1964
6/22					1.0
23					1.1
24		0.2		1.0	1.0
25		7.5	94.9	0.7	2.6
26		9.0	10.9	0	2.0
27	0.1	30.1	9.6	0	61.4
28	3.2	4.5	1.2	120.3	3.4
29	2.7	1.1	223.9	69.0	15.5
30	125.3	4.6	185.5	25.3	0
7/1	128.3	0.5	17.2	177.7	4.6
2	131.5	48.5	151.5	33.9	2.1
3	31.9	31.3	182.5	90.9	0
4	94.4	13.5	205.9	123.2	28.3
5	58.8	5.5	330.0	204.7	189.5
6	63.3	2.6	68.9	144.7	256.6
7	97.0	1.7	70.3	284.1	277.9
8	218.9	2.1	9.4	19.3	36.3
9	368.7	3.5	2.4	125.1	19.3
10	133.7	11.6	1.9	127.1	101.7
11	49.1	54.4	2.1	41.3	41.9
12	136.0	8.5	4.8	47.1	57.1
13	14.3	13.4	3.3	58.0	25.9
14	9.2	3.4	2.6	36.7	40.7
15	17.8	0.9	20.0	49.3	8.5
16	20.1	5.6	0.6	23.5	20.0
17	10.8	1.6	1.6	36.0	16.4
18	4.2	0.6	1.2	28.7	
19	1.0	0.6			
20	0.5	3.4			
21	0	0.6			
22	0.9	0.8			
Averages	66.2	9.4	66.8	74.7	46.7
No. of days fished	26	29	24	25	26

* Index is expressed in fish per thousand fathom minutes.

TABLE 2. DAILY INSIDE TEST FISHING INDICES*

Egegik River, 1963-64

Date	Year 1963	1964
6/22		1.2
23		0.4
24		8.2
25		6.5
26	35.9	1.9
27	16.0	10.7 1/
28	7.3	60.7
29	83.2	30.8
30	177.6	1.3
7/1	112.9	28.0
2	161.8	20.0
3	234.9	0.7
4	79.7	16.8
5	98.9	147.5
6	27.8	376.2
7	44.8	42.0
8	28.3	6.4
9	30.4	10.0
10	7.9	5.2
11	60.7	24.9
12	62.1	35.7
13	8.9	40.6
14	3.3	1.5
15	2.9	1.3
16	4.1	1.1 1/
17	2.4 1/	
18	1.4	
Averages	56.2	35.2
No. of days fished	23	25

* Index is expressed in fish per thousand fathom minutes.

1/ No test fishing indices were obtained for these days. Hence the geometric mean of the indices of the preceding and following days was used.

TABLE 3. DAILY INSIDE TEST FISHING INDICES*

Ugashik River, 1961-64

Date	1961	1962	1963	1964
6/22				6.9
23				2.6
24				6.1
25		6.3		8.8
26		14.1 1/	8.8	6.8
27		31.7	5.6	20.5
28		32.9	27.9	29.6
29		58.7	32.0	67.2
30	67.9	112.4	34.2	38.9
7/1	14.2	129.6	40.6	76.9
2	29.4 1/	241.1	40.5	145.2
3	47.2	213.3	96.9	69.0
4	75.9	188.4	190.8	242.1
5	28.8	149.4	150.9	433.8
6	56.7	158.6	78.1	437.3
7	51.4	176.3	136.4	242.2
8	87.6	252.4	107.0	225.2
9	140.4	170.7	87.4	131.1
10	90.9	191.0	131.6	149.8
11	169.8	143.5	99.2	166.8
12	235.4	145.2	159.2	206.6
13	307.1	79.3	114.2	136.0
14	216.1	68.5	161.2	144.2
15	195.6	77.5	29.2	119.3
16	82.3 1/	72.0	81.3	82.4
17	34.6	53.8	8.7	70.0
18	10.6	34.6	12.2 1/	60.0
19	9.4 1/	12.9	17.2	25.3
20	8.3	22.0		11.5 1/
21	11.1			5.3
22	21.4			
Averages	86.6	109.1	77.1	112.2
No. of days fished	23	26	24	30

* Index is expressed in fish per thousand fathom minutes.

1/ No test fishing indices were obtained for these days. Hence the geometric mean of the indices of the preceding and following days was used.

FIGURE 5. CORRELATION COEFFICIENTS BETWEEN ESCAPEMENT COUNTS AND TEST FISHING INDICES WITH DIFFERENT RATES OF MIGRATION ALLOWED (Kvichak River, 1960-64).

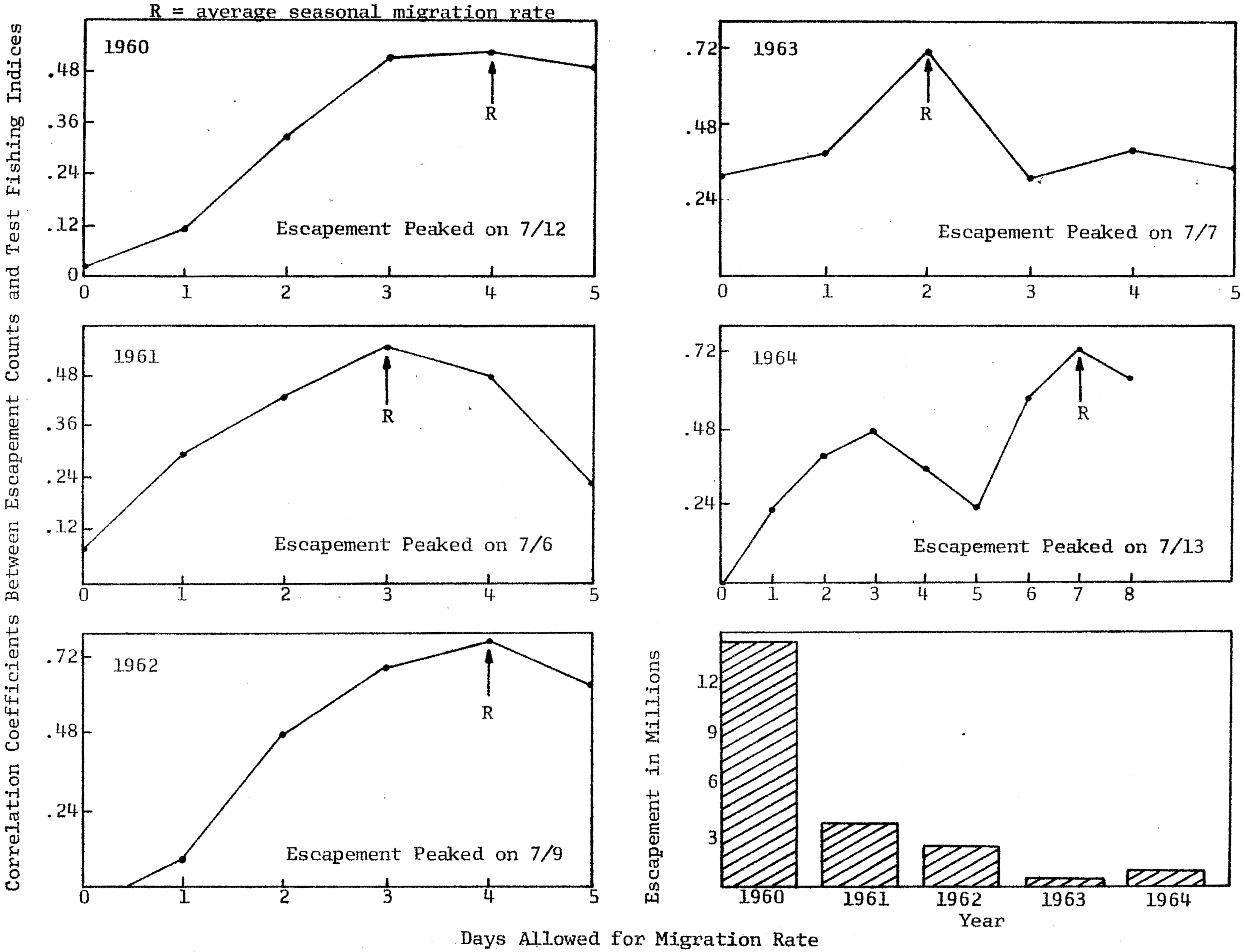
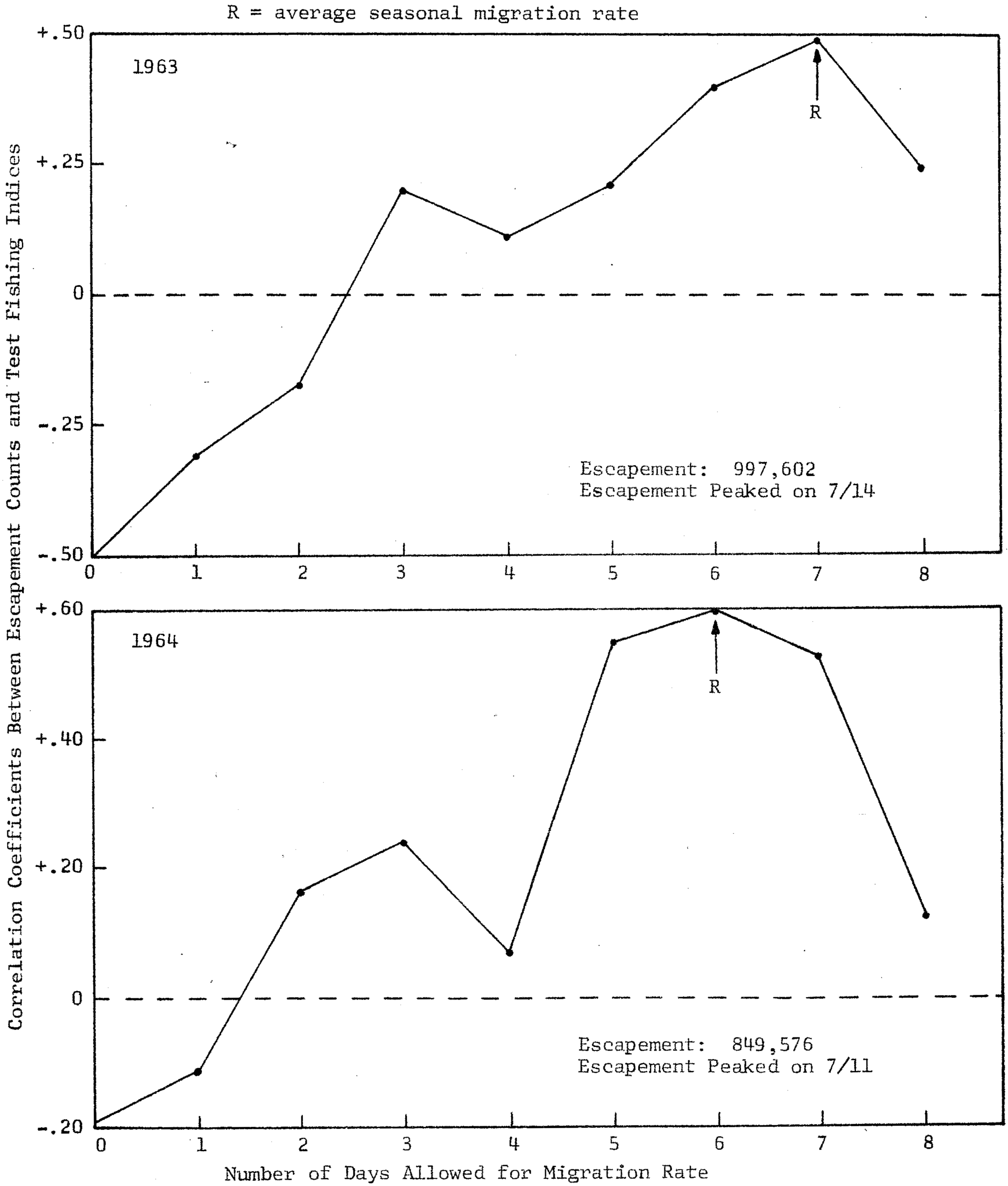
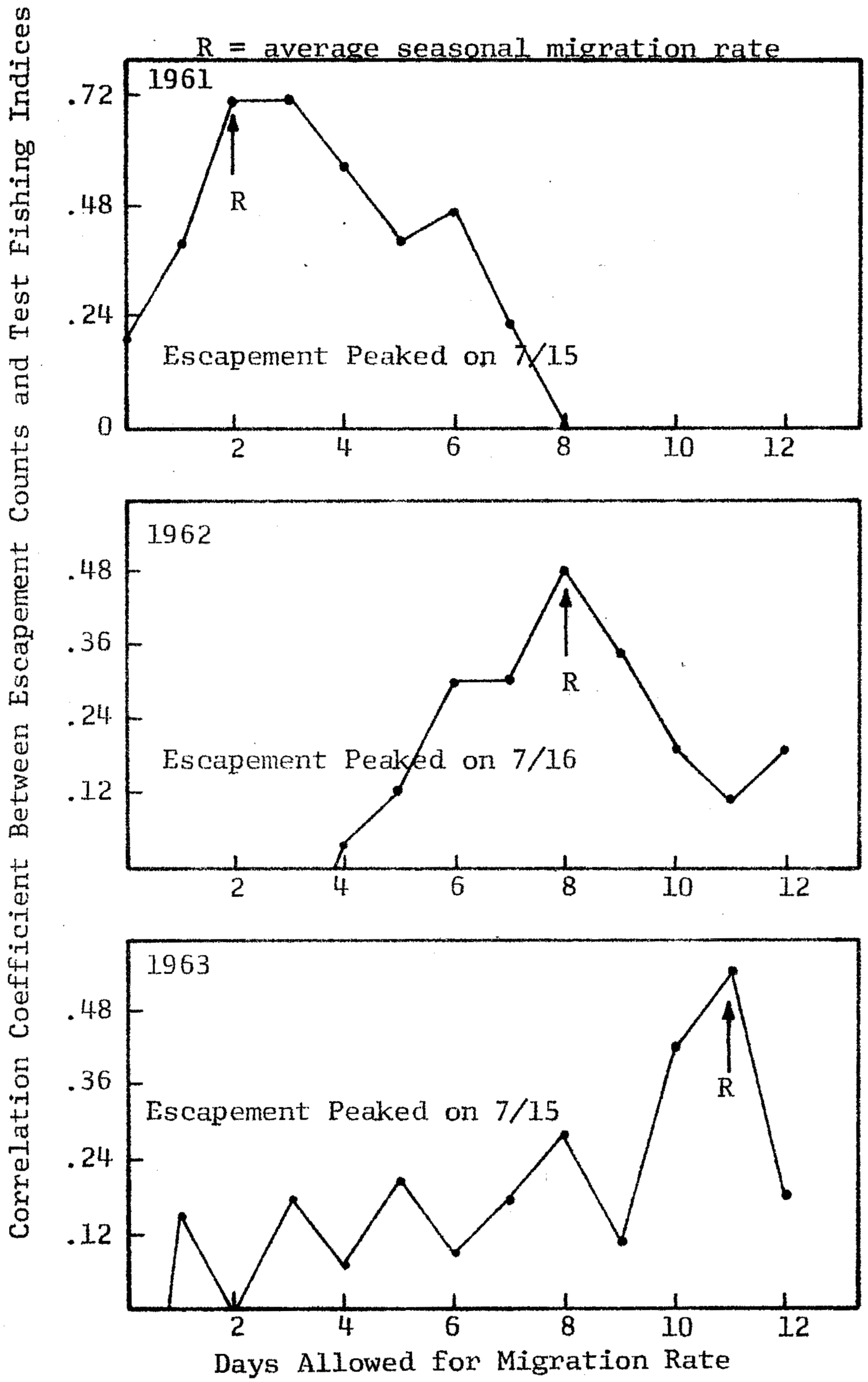


FIGURE 6. CORRELATION COEFFICIENTS BETWEEN ESCAPEMENT COUNTS AND TEST FISHING INDICES WITH DIFFERENT RATES OF MIGRATION ALLOWED
Egegik River, 1963-64





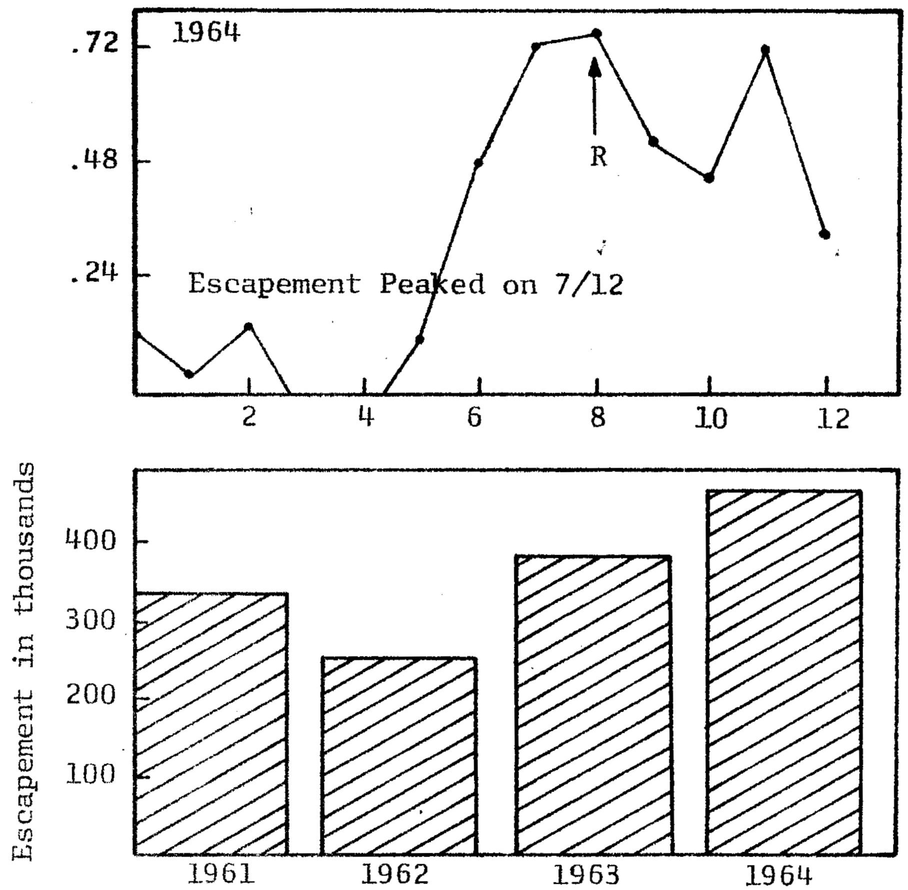


FIGURE 7. CORRELATION COEFFICIENTS BETWEEN ESCAPEMENT COUNTS AND TEST FISHING INDICES WITH DIFFERENT RATES OF MIGRATION ALLOWED (Ugashik River 1961-64).

The 1963 Egegik and 1962 Ugashik data indicate only significant (i.e. 95% level) linear correlation between the two variables.

Allowing R days (this varies between rivers and years) for the sockeye to travel from the test fishing site to the counting towers, linear regression equations are used to express the daily escapement counts as a function of the daily test fishing indices.

From Figures 5 and 7 it is apparent that average migration rates (as determined from the test fishing data) vary considerably from year to year for the Kvichak and Ugashik systems. Whereas the Kvichak migration rates vary from 2-7 days (with an average 4 day rate), the much shorter Ugashik River has indicated migration rates ranging from 2-11 days (with an average 7+ days). As mentioned above, this apparently slower migration rate for the Ugashik sockeye is due to the fact that the fish stop and congregate in the large lagoon below the lake before moving up past the counting tower. This is apparent from Index Figures I-8 to I-11 which show daily Ugashik tower counts for 1961-64. There is no apparent build-up in escapement counts prior to the period of peak counts. This also poses problems in counting the fish as the entire peak may pass the tower in one or two days.

It is interesting to note that in a pilot tagging study on the Ugashik River in 1964, Pennoyer and Seibel (1965) found an average migration rate of 9.6 days for salmon tagged during the peak of the run. This compares favorably with the 8 day migration rate indicated from the analysis of the 1964 Ugashik test fishing data.

One assumption that is not entirely supported by the test fishing data is that zero test boat catches should result in zero escapement estimates. In linear regression analysis, this assumption is equivalent to having the regression equation pass through the origin. In other words, if this assumption is satisfied, then in the equation

$$Y = a + b X \qquad (4)$$

where X = test fishing index in fish per thousand fathom minutes,
Y = estimated escapement in thousands of fish, and
a,b = parameters to be determined,

we would have a = 0. Thus Equation (4) would reduce to

$$Y = b'X$$

where b' = parameter to be determined.

Analysis of variance tables for testing the hypothesis, H_A, that a difference does exist between fitting the data with one- or two-parameter lines, are given in Index Tables I-1, I-2 and I-3 for the Kvichak, Egegik and Ugashik rivers respectively. The hypothesis was rejected for the Ugashik data and the 1962 and 1963 Kvichak data, i.e. for this date a line through the origin may be used.

In Table 4, both the general linear regression equations, and in the cases where H_A was rejected, the regression equations through the origin are given for the three rivers.

TABLE 4. REGRESSION EQUATIONS RELATING INSIDE TEST FISHING INDICES AND ESCAPEMENT COUNTS, Bristol Bay, 1960-64.

Note: In the following equations X = test fishing index in fish per thousand fathom minutes,
Y = daily tower counts in thousands of fish.

System	Year	General Regression Equation	Regression through origin where warranted	Total Escapement
Kvichak R.				
	1960	Y = 385.9 + 2.655 X		14,630,000
	1961	Y = 70.9 + 5.276 X		3,706,000
	1962	Y = 13.9 + 1.395 X	Y = 1.465 X	2,581,000
	1963	Y = 4.3 + 0.120 X	Y = 0.150 X	338,000
	1964	Y = 16.9 + 0.402 X		957,000
Ugashik R.				
	1961	Y = -1.8 + 0.194 X	Y = 0.182 X	349,000
	1962	Y = -10.2 + 0.184 X	Y = 0.117 X	255,000
	1963	Y = -13.0 + 0.375 X	Y = 0.262 X	388,000
	1964	Y = -2.8 + 0.164 X	Y = 0.152 X	473,000
	1961-1964 Data Combined		Y = 0.162 X	
Egegik R.1/				
	1963	Y = 15.9 + 0.464 X		998,000
	1964	Y = 23.6 + 0.385 X		850,000
	1963-1964 Data Combined	Y = 20.8 + 0.407 X		

1/ Although inside test fishing boats operated in the Egegik River in 1962, this was basically an exploratory study and consistent daily indices were not obtained.

Furthermore, for the Egegik and Ugashik data, the hypothesis, H_B, that a common regression line can be used for all the observations, was also tested. The analysis of covariance tables for testing H_B are given in Index Tables I-4 and I-5 for the Egegik and Ugashik data respectively. In both cases, the F-statistic used indicates an acception of H_B, i.e. a common regression line can be used for each of the systems. Therefore, the Ugashik data for 1961-64 was grouped and the 1963-64 Egegik data was grouped to determine a single regression line for each system. These equations are also given in Table 4.

H_B is obviously rejected for the Kvichak data, i.e. a common regression line should not be used to fit the grouped data.

Of the three river systems on which test fishing is conducted, the Kvichak River exhibits the greatest variations in escapement size. Since 1960, estimated escapements to the Kvichak have ranged from 338,000 to 14,630,000. For the same period, Ugashik escapements have varied from 255,000 to 2,304,000 while Egegik escapements have ranged from 702,000 to 1,799,000. (For the periods of test fishing on the Egegik and Ugashik rivers, even smaller ranges of escapements have been experienced.) Because of the very large variations in escapement to the Kvichak, it is only natural that any subsequent predictions of escapement will also exhibit appreciable variations from the true values. This is especially true when the escapements are predicted from the test fishing indices which do not reflect the same large variations as the escapements. This probably results from the fact that the daily test boat catches are actually limited by the fishing gear. This is apparent from the Kvichak test fishing data as the 1963 average daily test fishing index of 74.7 fish per thousand fathom minutes represents the highest daily average for the Kvichak. This is contrast to the fact that the 1963 escapement of 338,000 was the smallest escapement since 1960 when test fishing was initiated.

Whereas statistical tests indicate that common regression lines can be used for the Egegik and Ugashik data, the hypothesis H_B is rejected for the Kvichak data. Furthermore, H_B is rejected for the 1961 and 1962 Kvichak data which would not be expected as the escapements for these two years were of the same magnitude. It should be noted however, that the 1961 average daily fishing index of 8.5 fish per thousand fathom minutes was the lowest average yearly index, while the 1961 escapement was the second highest escapement since 1960. Although comparative escapements were also obtained for 1963 and 1964 in the Kvichak, H_B was also rejected for the data from these two years. Although we would expect differences to exist between the regression equations for years with vastly different escapement sizes, for years with escapements of the same magnitude we would expect the same regression equation to fit all of the data.

The deviations of the Kvichak data from these expected results may be due to several things. The most apparent explanations are the yearly differences in 1) test fishing methods; this includes differences in fishing area, fishing time (relative to tidal conditions) and actual methods of fishing the net, and 2) migratory patterns of the salmon. It may be that the migratory pattern of the fish after they enter the river is influenced by river level, turbidity of water, etc; these conditions may vary from year to year. Different stocks of sockeye may also utilize different migration routes. Thus, the same relative percentage of the escapement may not utilize the test fishing area every year. This would account for some of the yearly variations in the regression equations relating the test fishing indices to the daily escapement counts. Unfortunately it is difficult to quantitatively evaluate the effect of the above differences on the relationship between the test fishing indices and the escapement counts.

On the basis of the Kvichak River data, it is apparent that yearly differences in regression coefficients (especially the constant coefficient a) result from differences in escapement sizes. Another probable cause of these yearly differences can be attributed to yearly variations in the size of the fish. Past studies have shown that the 5-3/8 inch mesh gill net used on the test boat is selective to the larger 3-ocean fish (as opposed to the smaller 2-ocean fish), i.e. the test fishing is selective toward one strata of the population sampled.

DISCUSSION - Use of Regression Equations for Predicting Daily Escapement

As mentioned above, the primary purpose of the inside test fishing studies is to provide a method for predicting escapement as nearly as possible after the salmon have passed through the commercial fishery. These predicted escapements are then checked by aerial survey after the sockeye reach the clear water portion of the river and finally the more accurate tower counts are obtained.

When a linear regression equation is used for repetitive prediction purposes, an average value of Y (in this case thousands of fish in the escapement) for given values X_0, X_1, ..., X_r of X (test fishing index) in the range of applicability of the linear regression equation is obtained. The confidence interval of estimate for an average $\hat{Y}_c$ value corresponding to some X_c is given by

$$\hat{Y}_c \pm \sqrt{2F} \quad S_{Y \cdot X} \sqrt{\frac{1}{n} + \frac{(X_c - \bar{X})^2}{\Sigma (X_i - \bar{X})^2}} \qquad (1)$$

where

F is the value of the F statistic at the $1-\alpha$ significance level for (2, n-2) degrees of freedom.

$S^2_{Y \cdot X}$ is the unbiased estimate of the variance of Y given X which is given by the formula

$$S^2_{Y \cdot X} = \frac{1}{n-2} \Sigma (Y_i - \hat{Y}_i)^2$$

X_c refers to values of X in the range of applicability of the linear regression equation.

The term $(X_c - \bar{X})^2$ in equation (1) will decrease when values of X_c are used which approach the mean $\bar{X}$. For these values the confidence limits for predicted values of Y will become narrower. As values of X_c are used which are farther from the mean the term $(X_c - \bar{X})^2$ will increase and the confidence limits for predicted values of Y will become wider.

The regression equation used for prediction does not necessarily have validity over all values and extrapolation, i.e. use of the line for prediction outside the range of data from which the line was computed, may lead to highly erroneous results.

Egegik River

On the basis of available data the equation to be used for estimating escapement to the Egegik River is

$$Y = 20.8 + 0.407\ X. \qquad (2)$$

Furthermore, since prediction is made at the 95% level and we have n = 44, the confidence interval for values of Y from Equation (1) is given by

$$\hat{Y}_o \pm 146.1 \sqrt{\frac{1}{44} + \frac{(X_o - 49.0)^2}{218,177}}$$

where X_o is the test fishing index of escapement.

Using Equation (2) to hindcast daily escapements in 1964 on the basis of daily test fishing indices, we obtain an estimate of 805,000 spawning sockeye. This represents a 5.3% error from the 850,000 salmon counted at the towers.

Ugashik River

On the basis of available data the equation to be used for estimating escapement to the Ugashik River is

$$Y = 0.162\ X. \qquad (3)$$

The corresponding confidence interval is given by

$$\hat{Y}_o \pm 77.8 \sqrt{\frac{1}{86} + \frac{(X_o - 111.4)^2}{673,412}}$$

Using Equation (3) to hindcast daily escapement to the Ugashik River in 1964 on the basis of daily test fishing indices, we obtain an estimate of 515,000 spawning sockeye. This represents an 8.9% error from the 473,000 fish counted at the towers.

Kvichak River

Since statistical analysis rejects the hypothesis that a common regression line can be used for the Kvichak data, a different approach for prediction must be used. From the five regression equations given in Table 4, is is apparent that the constant coefficient, a, exhibits the greatest yearly variations. Furthermore, it appears that these variations are due in large part to the size of the escapements. (Analysis indicates a highly significant positive linear correlation between the escapement size and the constant coefficient).

An intuitive approach to prediction of escapements from daily test fishing indices on the Kvichak would be to stratify escapement according to size and group the test fishing data accordingly. However, at present there is insufficient data to warrant this approach and available data does not justify this approach.

For prediction purposes in 1965, the following method will be used. An escapement of approximately 8 million sockeye is expected in the Kvichak River in 1965. As no test fishing data is available for years with escapements in this range, the predictions from the regression equations for the years 1960 and 1962 will be averaged. Note that the arithmetic mean of the escapements for 1960 and 1962 is 8.6 million. Thus, the regression equation will be

$$Y = 199.9 + 2.025\ X. \qquad (4)$$

Confidence intervals given by Equation (1) can not be used for estimates of Y from Equation (4) as standard regression methods were not used to derive Equation (4).

Assuming that test boat catches on the Kvichak River in 1965 will be similar to those in 1960, and calculating the predicted escapement in 1965 by substituting the 1960 data in Equation (4) we obtain an estimate of approximately 8.6 million sockeye.

It should be stressed again that estimated daily escapements based on Equation (4) should be used cautiously, especially since predictions are being made in a range for which no data is available. The use of Equation (4) is considered only as opposed to not utilizing past test fishing data at all.

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to Mr. Donald B. Siniff, now with the University of Minnesota, for some of his original analysis on the early test fishing data; to Mr. Kenneth Middleton, Bristol Bay Area Biologist for his many helpful suggestions for the report; to Mr. Steven Pennoyer, Bristol Bay Research Biologist, for many helpful and stimulating ideas as a fellow test-fisherman; to Mr. Jerry McCrary, Biometrics Section, for drawing the final maps and graphs and finally to Mrs. June Grant for typing the final report.

FIGURE I-1. DAILY ESCAPEMENT COUNTS AND TEST FISHING INDICES WITH FOUR DAYS ALLOWED FOR TRAVEL BETWEEN TEST FISHING SITE AND COUNTING TOWER

Kvichak River, 1960

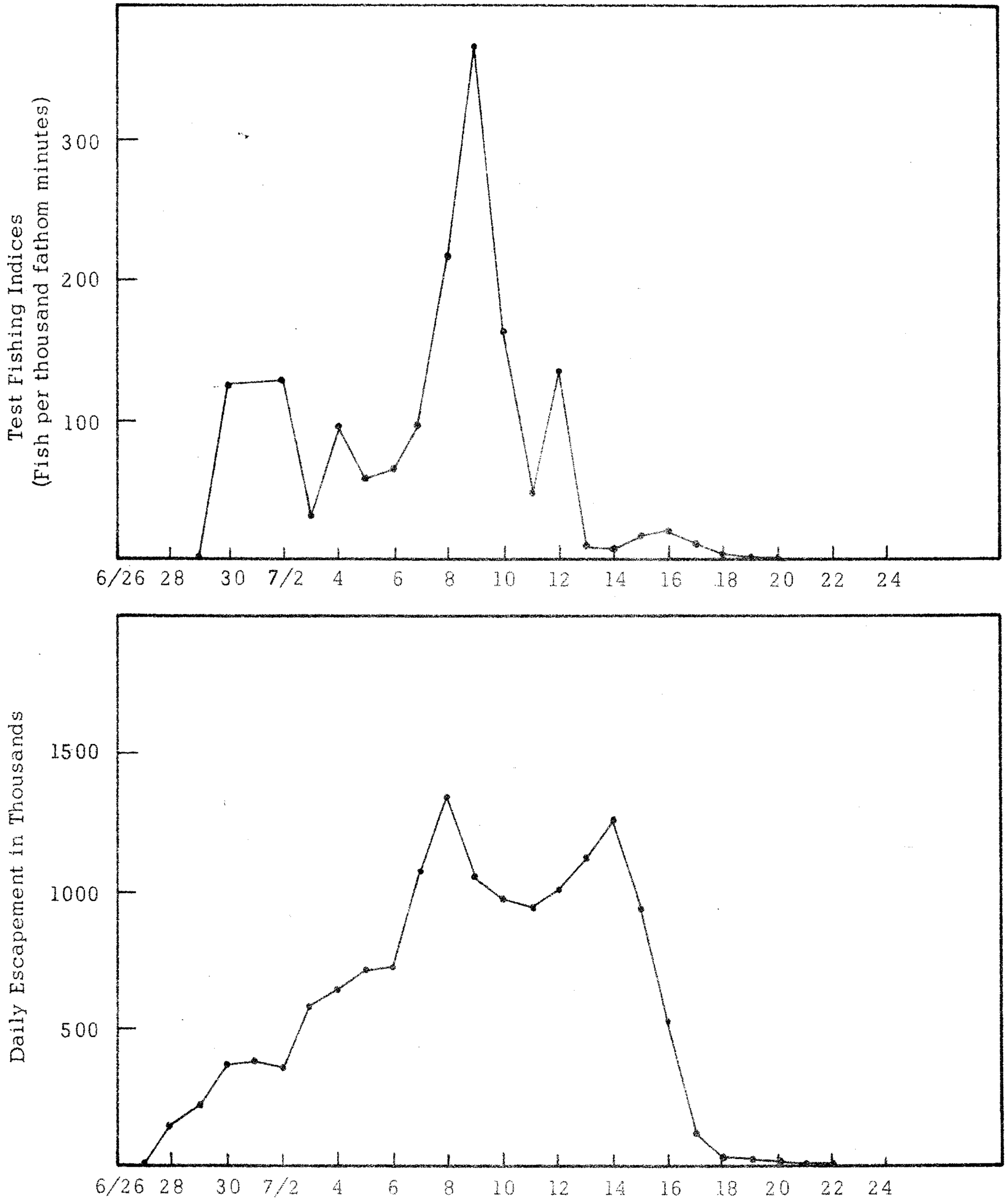


FIGURE I-2. DAILY ESCAPEMENT COUNTS AND TEST FISHING INDICES WITH THREE DAYS ALLOWED FOR TRAVEL BETWEEN TEST FISHING SITE AND COUNTING TOWER

Kvichak River, 1961

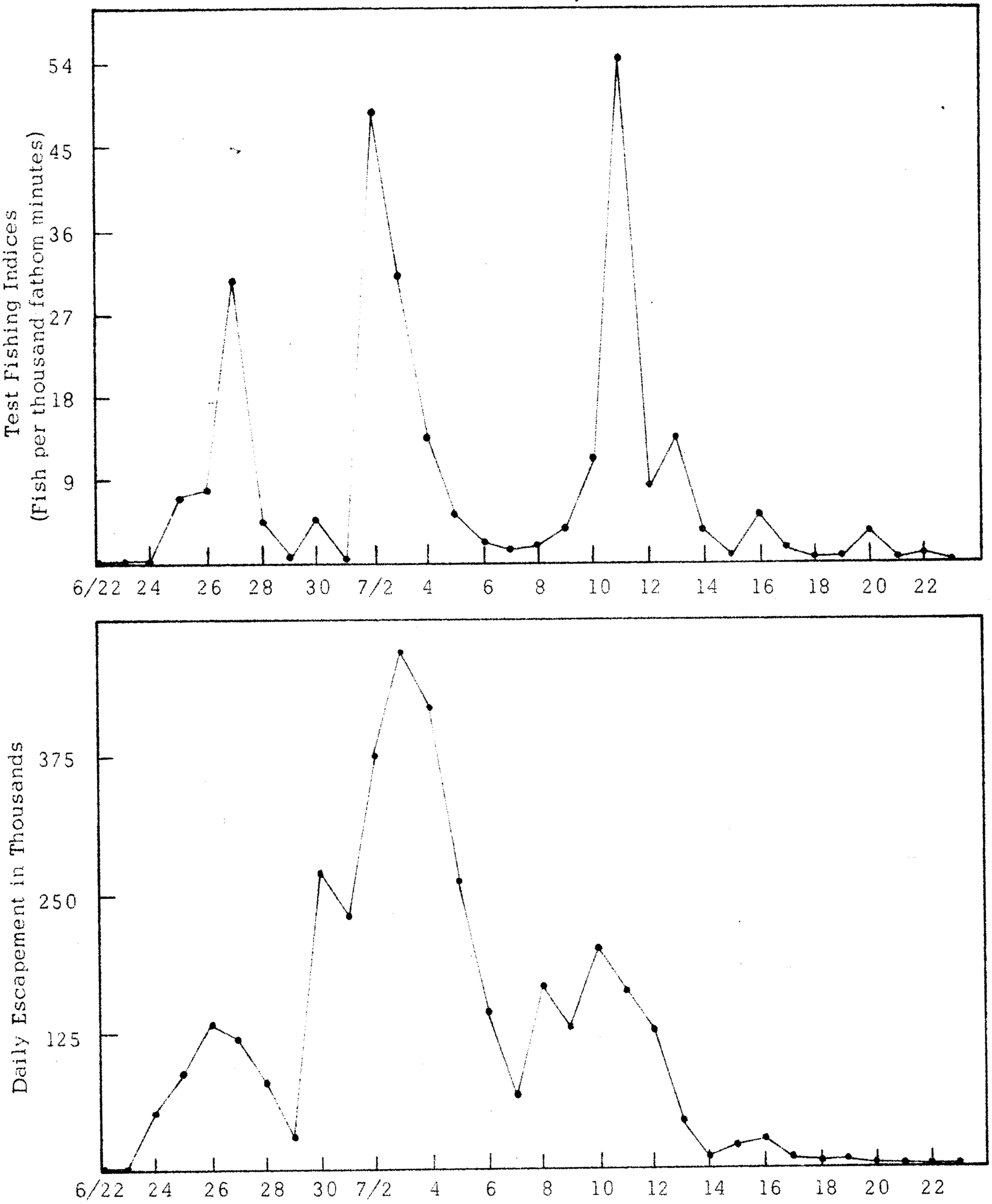


FIGURE I-3. DAILY ESCAPEMENT COUNTS AND TEST FISHING INDICES WITH FOUR DAYS ALLOWED FOR TRAVEL BETWEEN TEST FISHING SITE AND COUNTING TOWER

Kvichak River, 1962

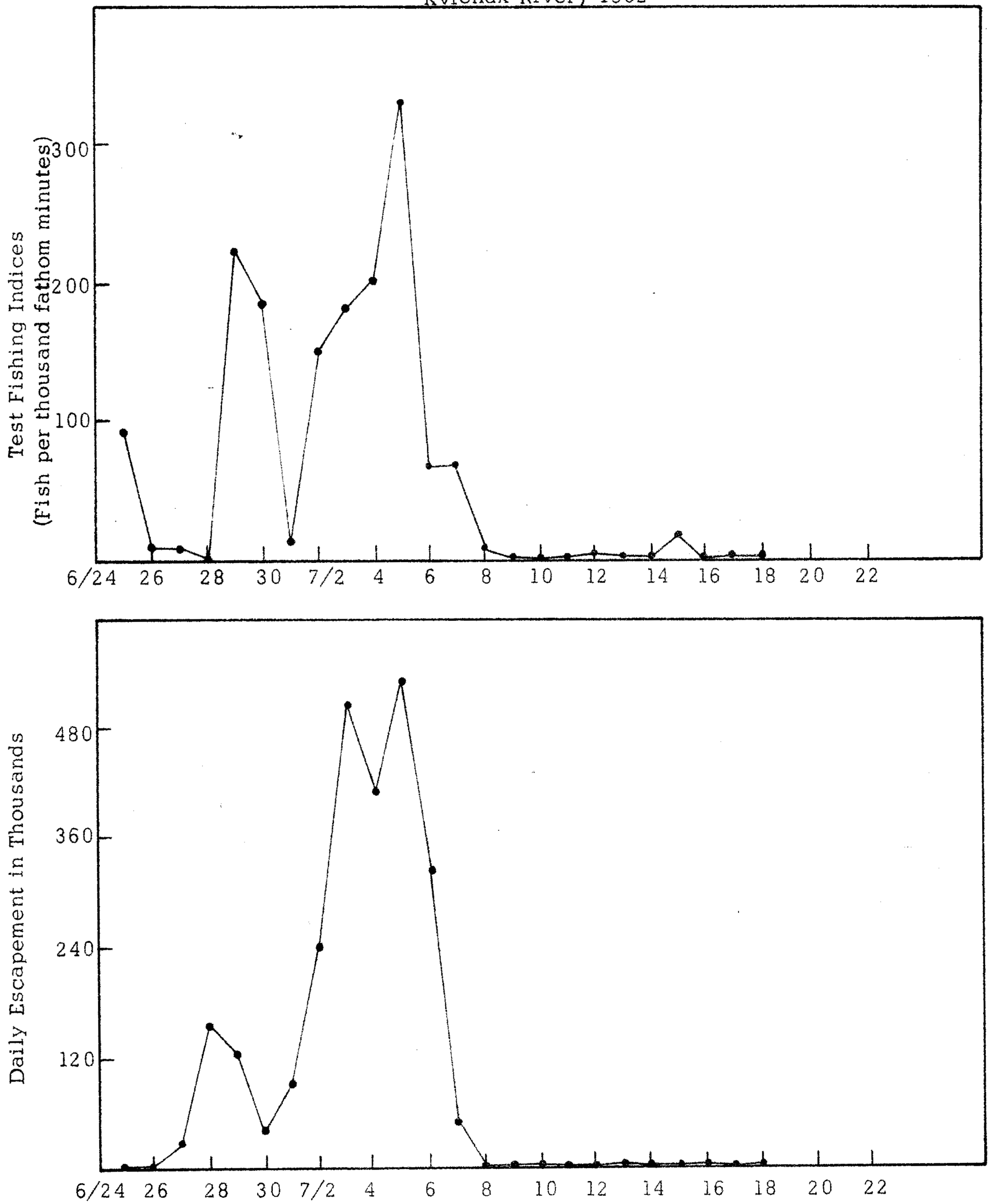


FIGURE I-4. DAILY ESCAPEMENT COUNTS AND TEST FISHING INDICES WITH TWO DAYS ALLOWED FOR TRAVEL BETWEEN TEST FISHING SITE AND COUNTING TOWER

Kvichak River, 1963

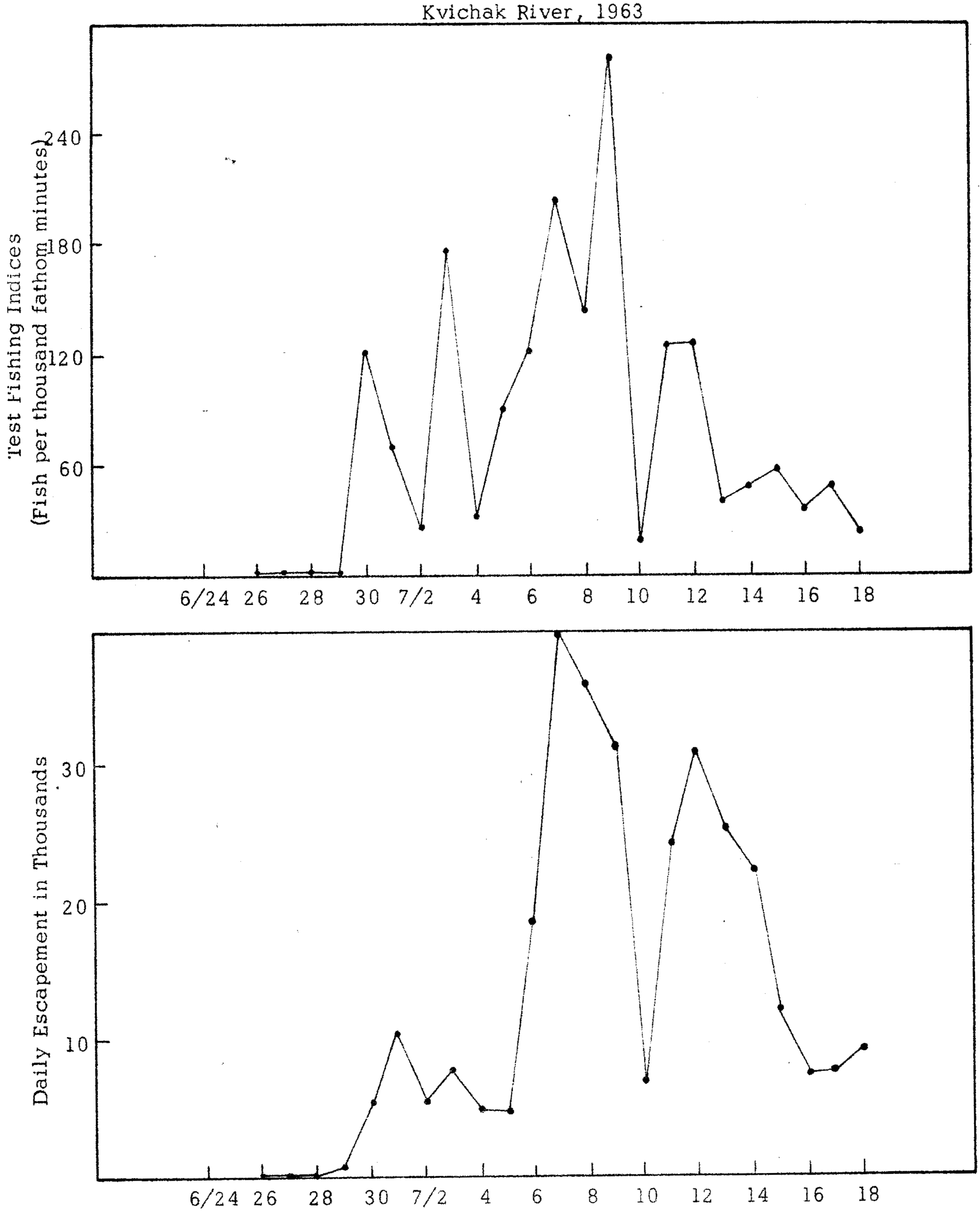


FIGURE I-5. DAILY ESCAPEMENT COUNTS AND TEST FISHING INDICES WITH SEVEN DAYS ALLOWED FOR TRAVEL BETWEEN TEST FISHING SITE AND COUNTING TOWER

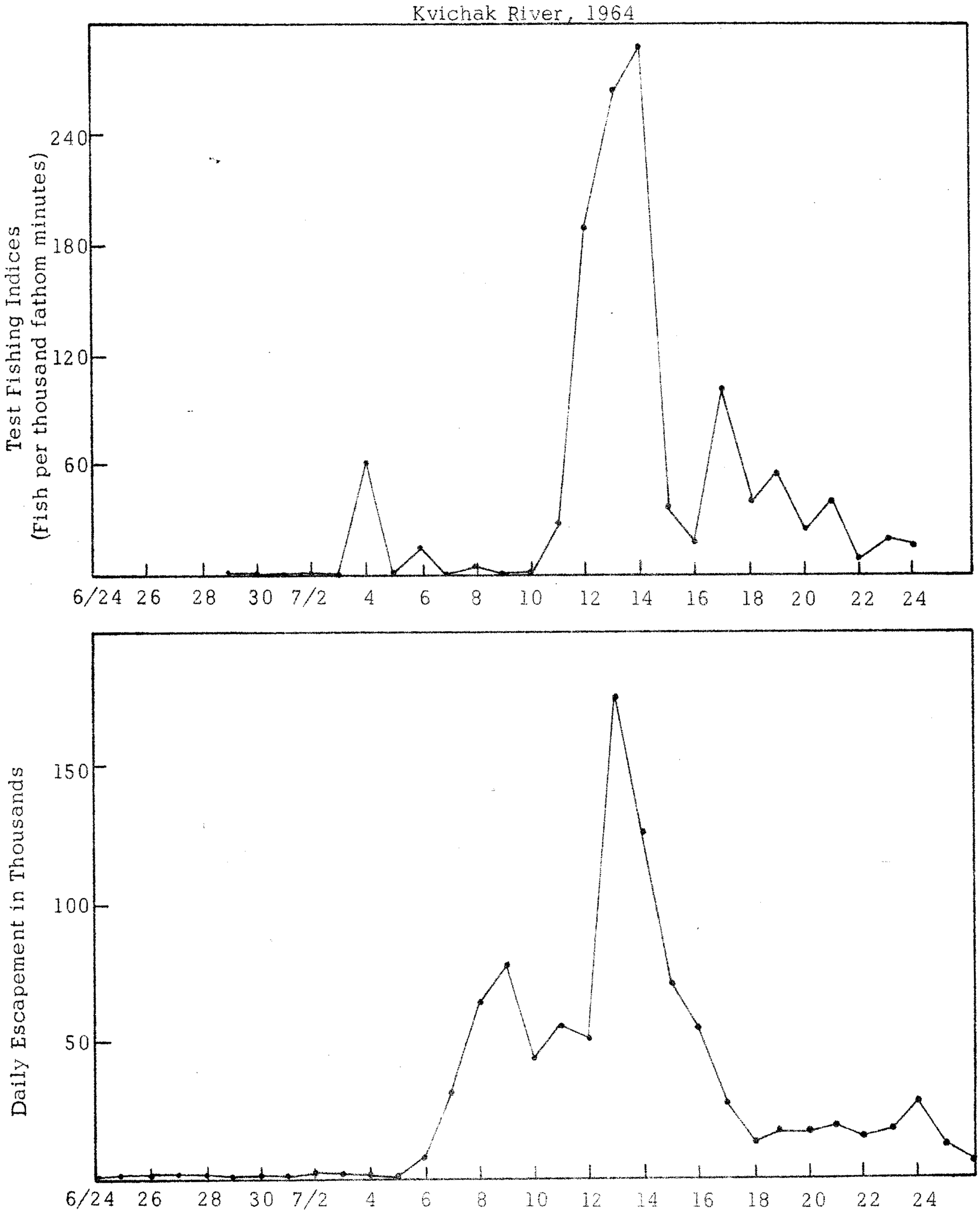


FIGURE I-6. DAILY ESCAPEMENT COUNTS AND TEST FISHING INDICES WITH SEVEN DAYS ALLOWED FOR TRAVEL BETWEEN TEST FISHING SITE AND COUNTING TOWER

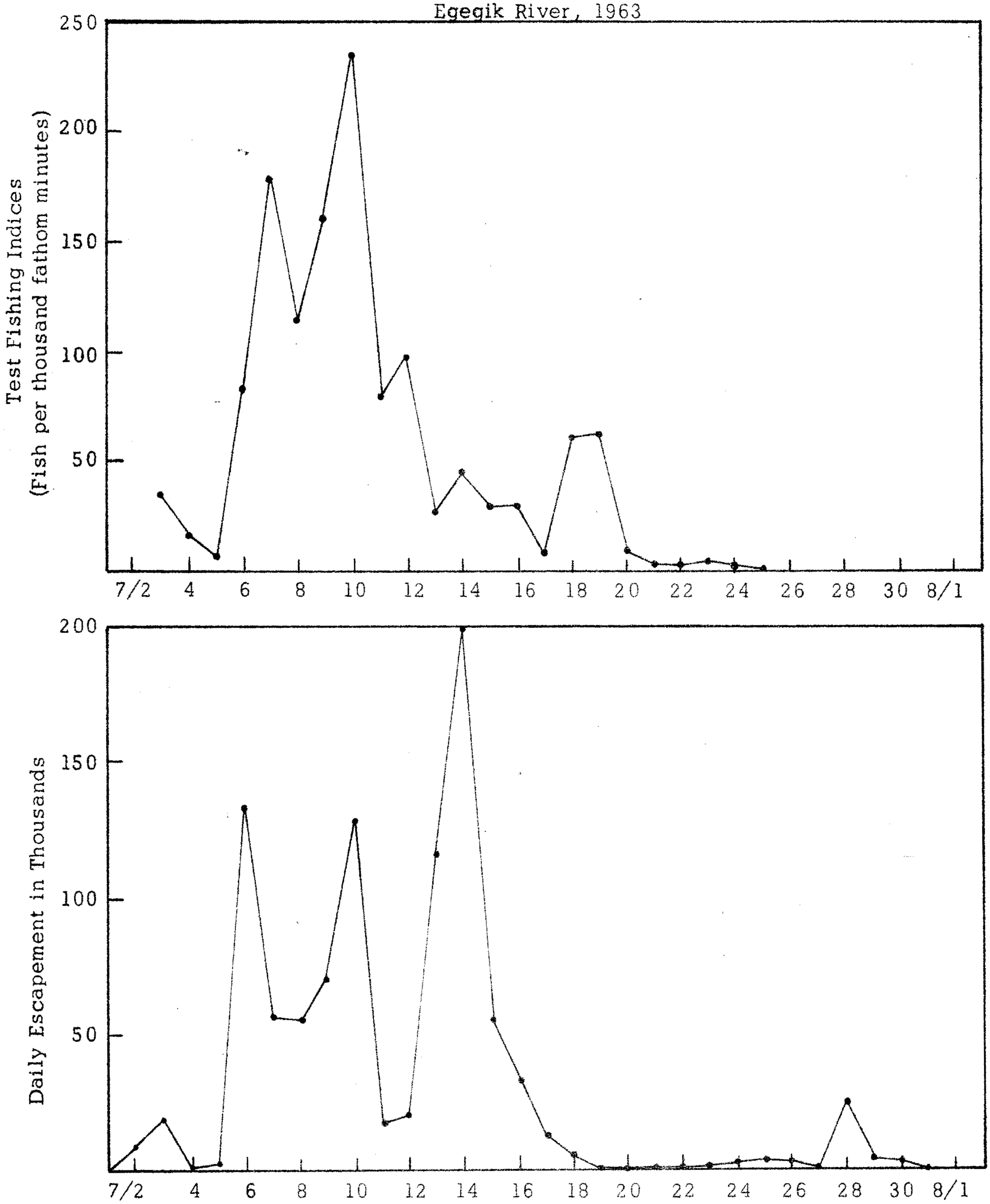


FIGURE I-7. DAILY ESCAPEMENT COUNTS AND TEST FISHING INDICES WITH SIX DAYS ALLOWED FOR TRAVEL BETWEEN TEST FISHING SITE AND COUNTING TOWER

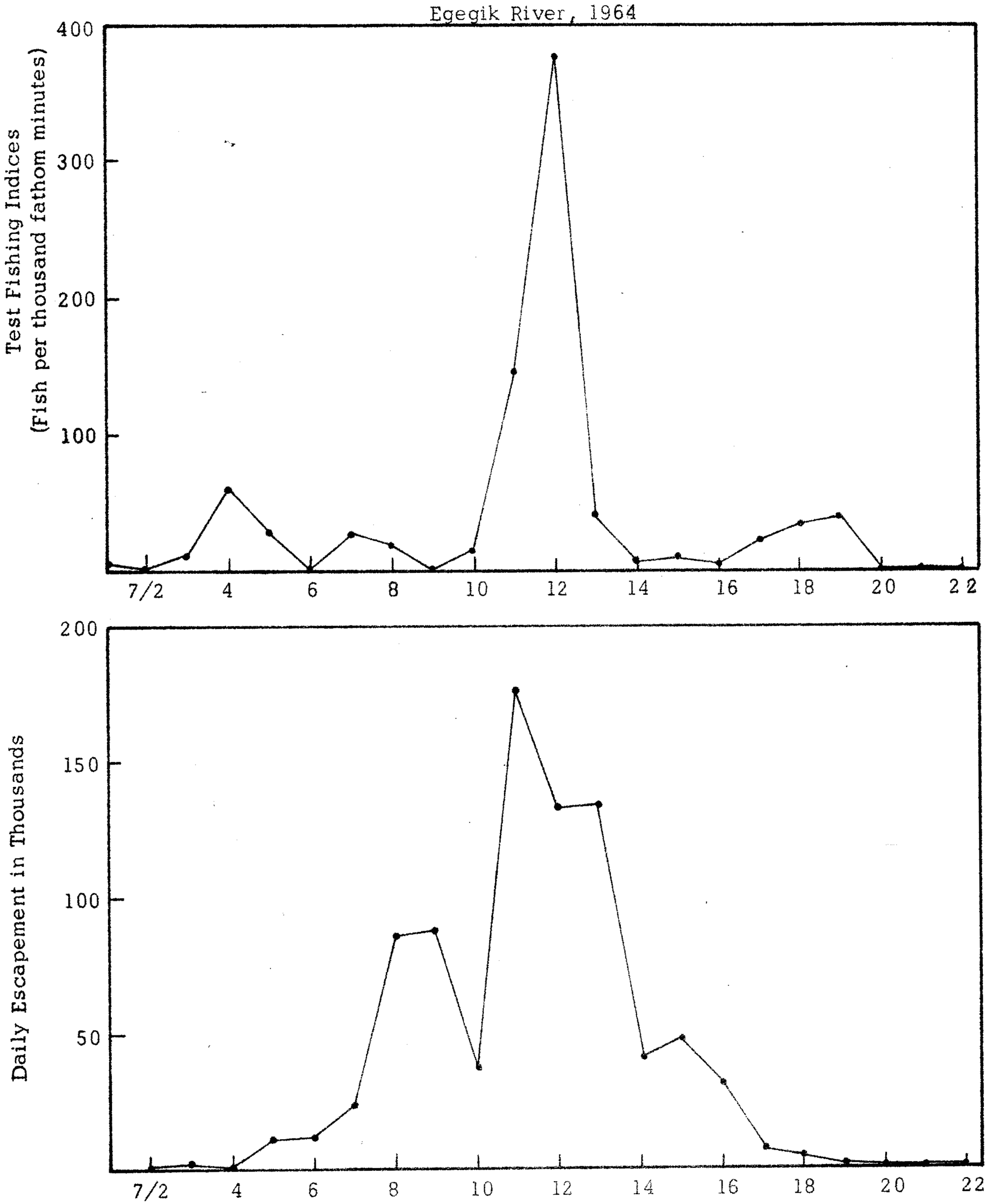


FIGURE I-8. DAILY ESCAPEMENT COUNTS AND TEST FISHING INDICES WITH TWO DAYS ALLOWANCE FOR TRAVEL BETWEEN TEST FISHING SITE AND COUNTING TOWER

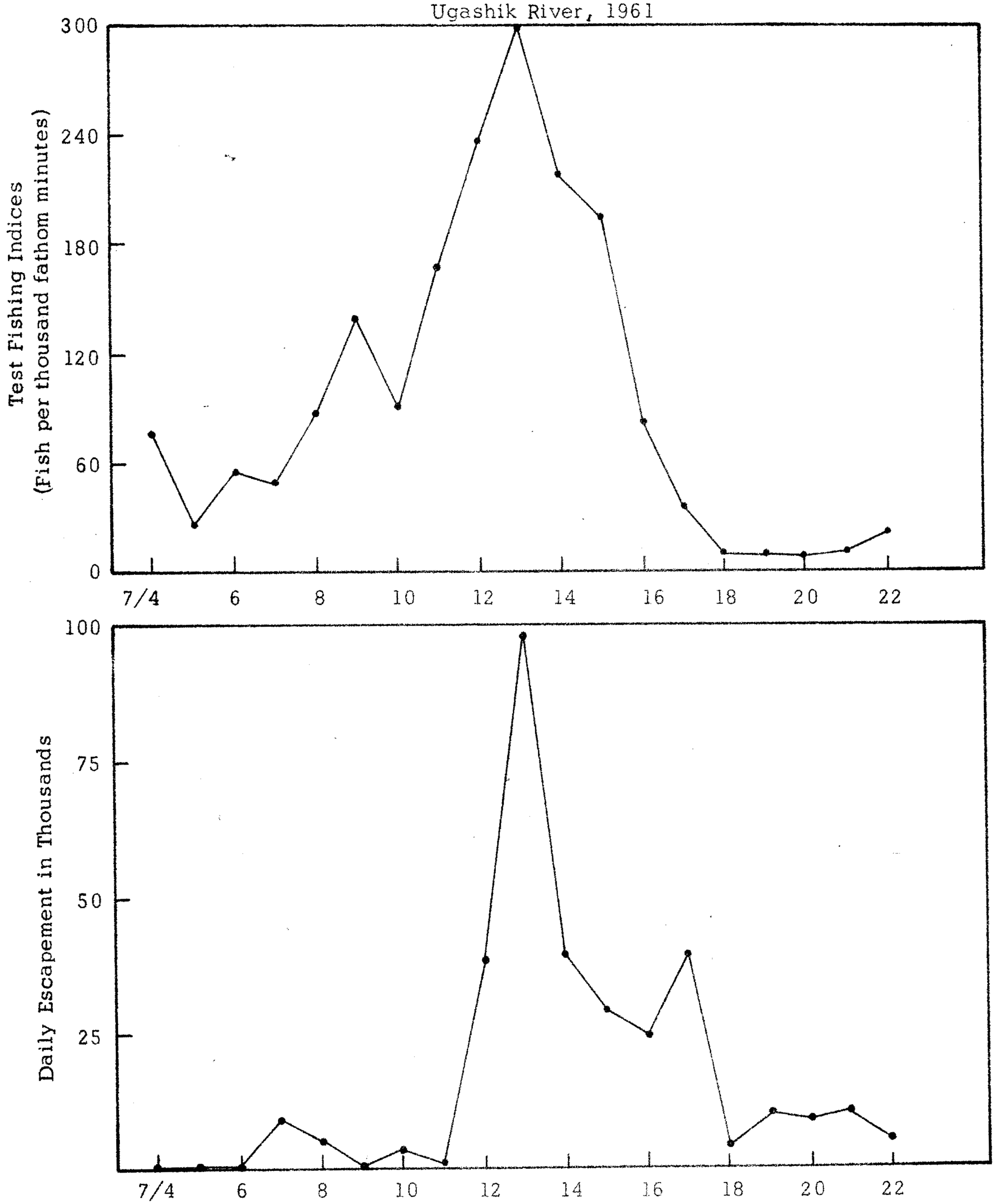


FIGURE I-9. DAILY ESCAPEMENT COUNTS AND TEST FISHING INDICES WITH EIGHT DAYS ALLOWANCE FOR TRAVEL BETWEEN TEST FISHING SITE AND COUNTING TOWER

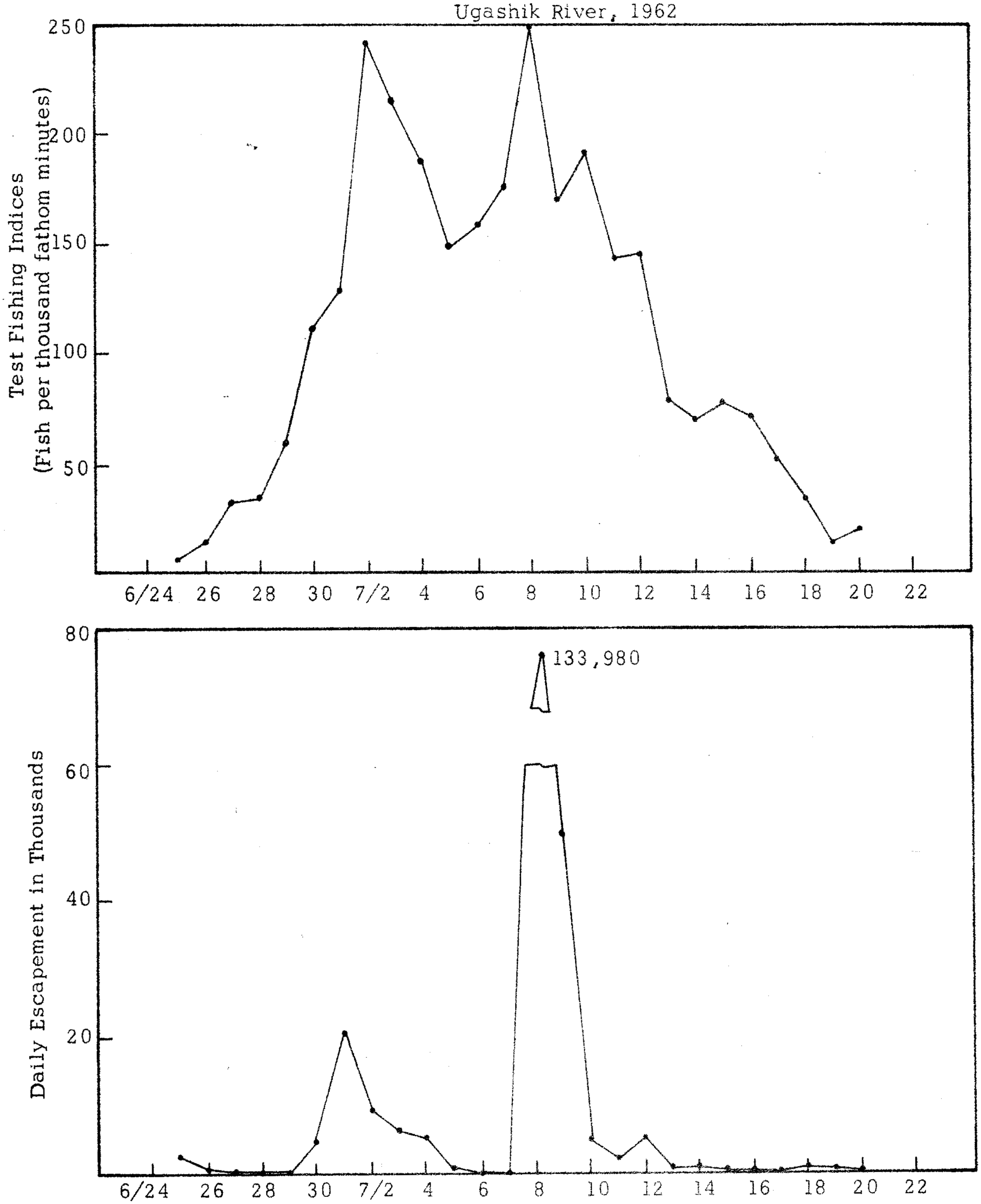


FIGURE I-10. DAILY ESCAPEMENT COUNTS AND TEST FISHING INDICES WITH ELEVEN DAYS ALLOWANCE FOR TRAVEL BETWEEN TEST FISHING SITE AND COUNTING TOWER

Ugashik River, 1963

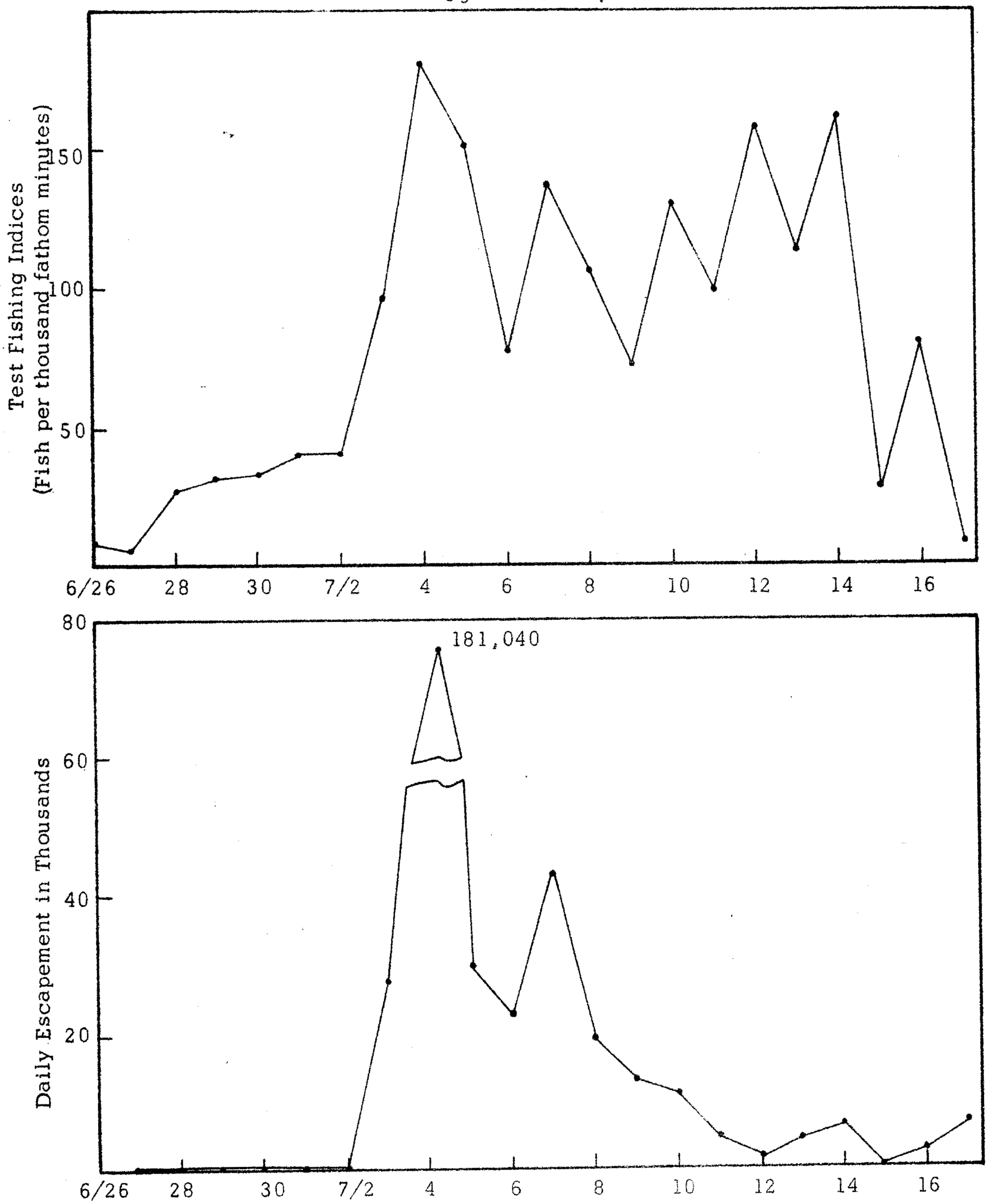


FIGURE I-11. DAILY ESCAPEMENT COUNTS AND TEST FISHING INDICES WITH EIGHT DAYS ALLOWANCE FOR TRAVEL BETWEEN TEST FISHING SITE AND COUNTING TOWER

Ugashik River, 1964

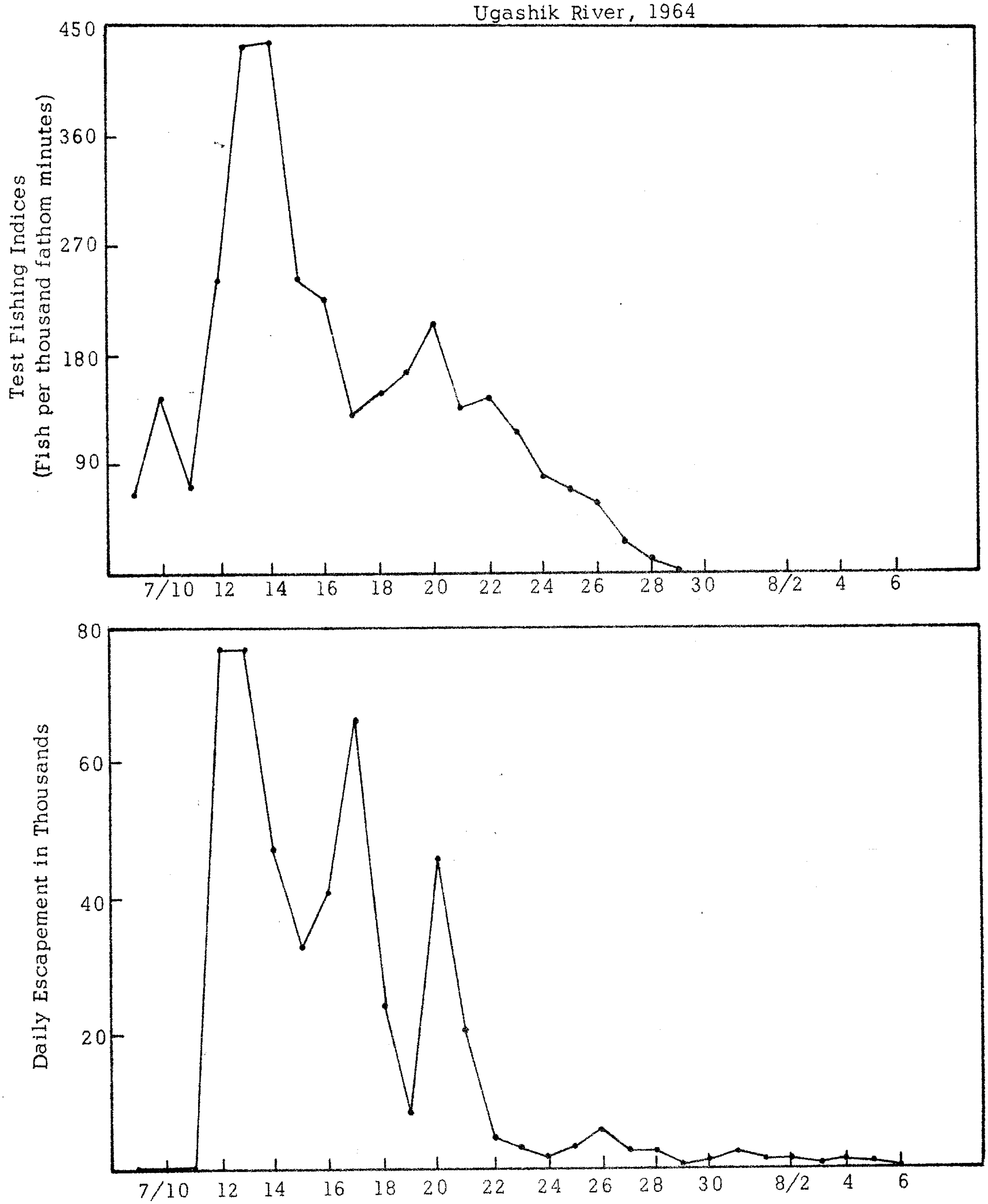


TABLE I-1. ANALYSIS OF VARIANCE TABLE, TEST OF HYPOTHESIS H_A: A difference in fit does exist between one- and two-parameter lines. Kvichak River Inside Test Fishing and Tower Count Data, 1960-64.

1960

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Sum of Squares
Deviation from one parameter line	6,018,958	25	240,758
Deviation from two parameter line	3,628,590	24	151,191
Difference: Attributed to improvement in fit of two-parameter line over one-parameter line	2,390,368	1	2,390,368

$$F = \frac{2,390,368}{151,191} = 15.8 \text{ with d.f. } (1,24)$$

Accept H_A

1961

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Sum of Squares
Deviation from one parameter line	469,895	31	15,158
Deviation from two parameter line	355,066	30	11,836
Difference	114,829	1	114,829

$$F = \frac{114,829}{11,836} = 9.7 \text{ with d.f. } (1,30)$$

Accept H_A

1962

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Sum of Squares
Deviation from one parameter line	272,532	23	11,849
Deviation from two parameter line	268,819	22	12,219
Difference	3,713	1	3,713

$$F = \frac{3,713}{12,219} = 0.3 \text{ with d.f. } (1,22)$$

Reject H_A

1963

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Sum of Squares
Deviation from one parameter line	1,898	22	86
Deviation from two parameter line	1,732	21	82
Difference	166	1	166

$$F = \frac{166}{82} = 2.0 \text{ with d.f. } (1,21)$$

Reject H_A

1964 Source of Variation	Sum of Squares	Degrees of Freedom	Mean Sum of Squares
Deviation from one parameter line	26,201	25	1,048
Deviation from two parameter line	20,974	24	874
Difference	5,227	1	5,227

$$F = \frac{5,227}{874} = 6.0 \text{ with d.f. } (1,24)$$

Accept H_A

Note: In the above tables, rejection of H_A is equivalent to accepting the hypothesis that regression through the origin provides an equally good fit as when general regression is used.

TABLE I-2. ANALYSIS OF VARIANCE TABLE, TEST OF HYPOTHESIS H_A: There is a difference in fit between the one- and two-parameter lines. Egegik River Test Fishing and Tower Count Data, 1963-64.

1963

Source of Variance	Sum of Squares	Degrees of Freedom	Mean Sum of Squares
Deviation from one parameter line	52,437	21	2,497
Deviation from two parameter line	49,575	20	2,479
Difference: Attributed to improvement in fit of two-parameter line over one-parameter line	2,862	1	2,862

$$F = \frac{2,862}{2,479} = 1.2 \text{ with d.f. } (1,20)$$

Reject H_A

1964

Source of Variance	Sum of Squares	Degrees of Freedom	Mean Sum of Squares
Deviation from one parameter line	47,358	21	2,255
Deviation from two parameter line	37,361	20	1,868
Difference	9,997	1	9,997

$$F = \frac{9,997}{1,868} = 5.4 \text{ with d.f. } (1,20)$$

Accept H_A

TABLE I-3. ANALYSIS OF VARIANCE TABLE, TEST OF HYPOTHESIS H_A: A difference in fit does exist between the one- and two-parameter lines. Ugashik River Test Fishing and Tower Count Data, 1961-64.

1961 Source of Variance	Sum of Squares	Degrees of Freedom	Mean Sum of Squares
Deviation from one parameter line	4,977	16	311
Deviation from two parameter line	4,835	15	322
Difference: Attributed to improvement in fit of two-parameter line over one-parameter line	142	1	142

$$F = \frac{142}{322} = 0.4 \text{ with d.f. } (1,15)$$

Reject H_A

1962			
Deviation from one parameter line	14,940	24	622
Deviation from two parameter line	13,974	23	608
Difference	966	1	966

$$F = \frac{966}{608} = 1.6 \text{ with d.f. } (1,23)$$

Reject H_A

1963			
Deviation from one parameter line	22,804	22	1,037
Deviation from two parameter line	21,306	21	1,015
Difference	1,498	1	1,498

$$F = \frac{1,498}{1,015} = 1.5 \text{ with d.f. } (1,21)$$

Reject H_A

1964			
Deviation from one parameter line	6,162	20	308
Deviation from two parameter line	6,069	19	319
Difference	93	1	93

$$F = \frac{93}{319} = 0.3 \text{ with d.f. } (1,19)$$

Reject H_A

TABLE I-4. ANALYSIS OF COVARIANCE TABLE, EGEGIK INSIDE TEST FISHING DATA, 1963-64.

Source of Variation	Sum of Squares	Degree of Freedom	Mean Sum of Squares
Due to common regression	4,839	6	806
Deviations from individual lines	46,549	78	597
Deviations from common regression line	51,388	84	612

$$F = \frac{806}{597} = 1.35 \text{ with d.f. } (6,78)$$

TABLE I-5. ANALYSIS OF COVARIANCE TABLE, UGASHIK INSIDE TEST FISHING DATA, 1961-64.

Source of Variation	Sum of Squares	Degree of Freedom	Mean Sum of Squares
Due to common regression	586	2	293
Deviations from individual lines	87,209	40	2,180
Deviations from common regression lines	87,795	42	2,090

$$F = \frac{293}{2,180} = 0.13 \text{ with d.f. } (2,40)$$

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