3A91-17

ESTIMATION OF IN-RIVER RUN STRENGTH OF YUKON RIVER CHINOOK SALMON, 1968 THROUGH 1981, BASED UPON THE MIGRATORY TIME DENSITY FUNCTION, EFFECT OF COMMERCIAL CATCH AND EFFORT ON TEST FISHERY CATCHES, AND PREDICTED MIGRATORY RATES OF CHINOOK SALMON

By

John E. Clark

and

John H. Clark

Regional Information Report[1] No. 3A91-17

Alaska Department of Fish and Game
Division of Commercial Fisheries, AYK Region
333 Raspberry Road
Anchorage, Alaska 99518

May 1991

---

[1] The Regional Information Report Series was established in 1987 to provide an information access system for all unpublished divisional reports. These reports frequently serve diverse ad hoc informational purposes or archive basic uninterpreted data. To accommodate timely reporting of recently collected information, reports in this series undergo only limited internal review and may contain preliminary data; this information may be subsequently finalized and published in the formal literature. Consequently, these reports should not be cited without prior approval of the author or the Division of Commercial Fisheries.

EDITOR'S NOTE

This report was prepared in draft form in 1983 for peer review and publication. The authors transfered to other positions during that process and the report did not develop beyond the draft stage since that time. It is not the intent of the authors to work on this report any further. However, they would like to insure that the document is archived such that it is not lost as a reference of some historical interest. The authors requested that this report be placed in the Regional Information Report series.

INTRODUCTION

The most important fisheries resource of the lower Yukon River in terms of commercial value is chinook salmon. Attempts to estimate the total abundance of this resource as it migrates through a defined geographic area have historically been restricted to tagging studies (see McBride and Wilcock, 1983, for a summary table). The physical character of the lower river and the numerous and generally inaccessible spawning streams preclude total escapement counts via traditional foot and aerial survey techniques. Sonar techniques are being researched and may provide a reliable in-season as well as annual stock assessment tool in future years. Lack of a reliable method to estimate total chinook abundance to date has limited management to allocating the resource on the basis of the relative size of the run, as determined by commercial catch-per-unit-effort (CPUE) statistics and test fishery catch rates. Relatively large daily catches per-boat-hour are believed to be diagnostic of high levels of total chinook salmon abundance.

The increase in catch and CPUE over the last several years (1977 to present) might be attributed more to an increase in efficiency of the commercial fleet than to higher levels of chinook salmon abundance. The precipitous increase in value of chinook salmon (from less than $6 per fish in 1972 to over $20 per fish in 1977) has enabled the ambitious fishermen to reinvest in gear. New outboard motors and boats are becoming more frequent, and the increased number of tenders and widespread use of Citizen Band radios has reduced the time of delivery and time of locating large concentrations of chinook salmon. The increasing proportion of drift net fishermen (working a drift net requires more effort and skill on the

part of the fisherman, but generally results in higher catches) and increased incidental catch during the fall season is indicative of the changing nature of the fishery.

Increased reductions in test fishery catches on days which are open to the commercial fishery also indicate that, for a given number of hours of commercial effort, the ratio of daily catch over total average daily abundance is increasing. Equations which express daily proportion of total abundance as a function of calendar day, wind speed, and commercial effort have been fitted to test fishery catches (Clark 1983). The effect of one day of commercial effort on test fishery catch was found to be consistently negative and responsible for larger reductions in test fishery catch in later years (Figure 1). The changing efficiency of the commercial fleet reduces the validity of relative estimates of chinook salmon abundance which rely on interannual comparisons of CPUE statistics.

The strategy employed in the present study is to quantitatively contrast test fishery catches on days of no commercial effort with test fishery catches during commercial openings. It is assumed that the reduction in observed test fishery catches, compared to the predicted catches under conditions of no commercial effort, are the result of chinook salmon being removed by the surrounding commercial fleet; and this decrease in chinook salmon abundance is representative of the subdistrict. Under conditions of low exploitation rates, CPUE is assumed to be directly proportional to daily abundance. The constant of proportionality is defined as catchability (q). Given the conditions of high exploitation rates, an exponential depletion rate,

$$Catch = (Abundance)\left(1-e^{-(q)(effort)}\right) \qquad (1)$$

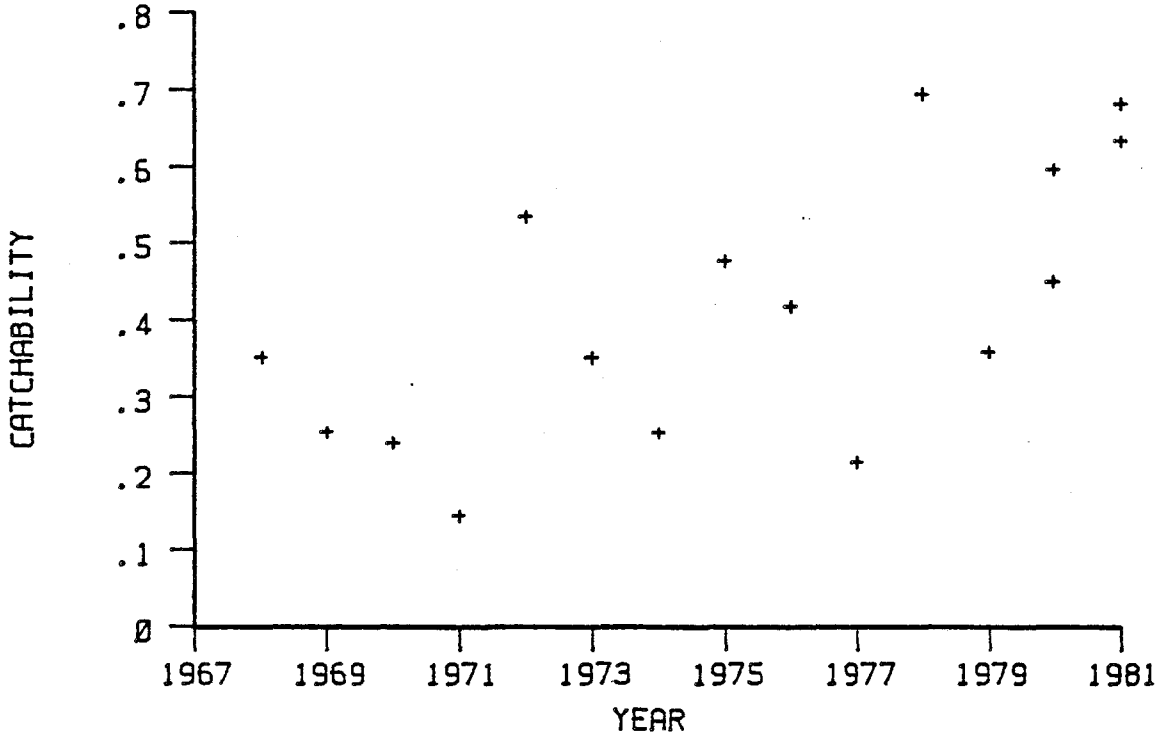

Figure 1. Historical change in fitted values of catchability from 1968 to 1981.

would be more appropriate. Once an estimate of (q) has been obtained, calculations of daily estimates of total numbers of chinook salmon migrating through District 1 are routine.

Daily abundance of chinook salmon in a defined geographic area is also a function of time (calendar date, or a covariate of date) and the rate of passage through the area (the inverse of this rate being the time spent in the district, and referred to here as the 'time of residence'). Estimates of abundance are computed as ratios of daily number of chinook salmon present in the district over the proportion of total abundance expected on the given day. The daily proportion of total abundance of a migratory species in a given area can be predicted by either empirical or conceptual methods (Brannian 1983; Clark 1983; Dahlberg 1968; Hornberger and Mathisen 1979, 1980, 1981; Mundy 1979, 1982a, 1982b; Preston 1966; Royce 1965; Vaughan 1954; Walters and Buckingham 1975), which quantify the migratory time density of the population as a function of time.

The daily proportion of total abundance of migrating chinook salmon in the Yukon River is also inversely proportional to the upriver swimming speed. A given proportion of the total population will be subjected to greater levels of commercial effort the longer the time of residence in the fishing district. From the standpoint of assessing total abundance, a reduction of the estimated residence time will results in an increase in estimates of population numbers. In summary, the ability to accurately assess the total number of chinook salmon migrating up the Yukon River relies on a quantitative understanding of test fishery and commercial catch dynamics, migratory timing of the population, and residence time:

$$\text{Total Annual Abundance} = \frac{\text{Catch}}{f(\text{effort})} \times f(\text{time, rate of migration}) \quad (2)$$

STUDY AREA AND DATA

Population estimates of the annual Yukon River chinook salmon run are based on catch data from the statistical area District 1, which encompasses the lower 101 river km (63 miles) of the Yukon River delta (Figure 2). Historically, the majority of fishing effort and, consequently, commercial catch has been concentrated in this district. The lower Yukon River commercial fishing season is divided into two periods, a "king season", when maximum mesh size of gill nets is not restricted, and a "fall season", when maximum mesh size is limited to 15.2 cm (6 inches). The smaller mesh "chum gill nets" are believed to selectively favor the smaller fall chum salmon, while the larger mesh "king gill nets" (21.6 cm - 8.5 inches) whose use is permitted only during king season, selectively catch chinook salmon.

A test fishery was initiated by Alaska Department of Fish and Game (ADF&G) in 1963 near the seaward boundary of the South Mouth of the Yukon River delta at the location known as Flat Island (Figute 2, site A). Until 1968, test net sites were chosen by ADF&G personnel. In 1968, the practice of renting more productive traditional set net sites from local residents was initiated and the success of the test fishery effort increased (1963 to 1967 21.6 cm mesh yearly average chinook salmon catch of 446 fish compared to a 1968 to 1978 yearly average of 708 chinook salmon). Therefore, years prior to 1968 are not incorporated into this analysis. Because of logistic considerations, the test fishery are relocated

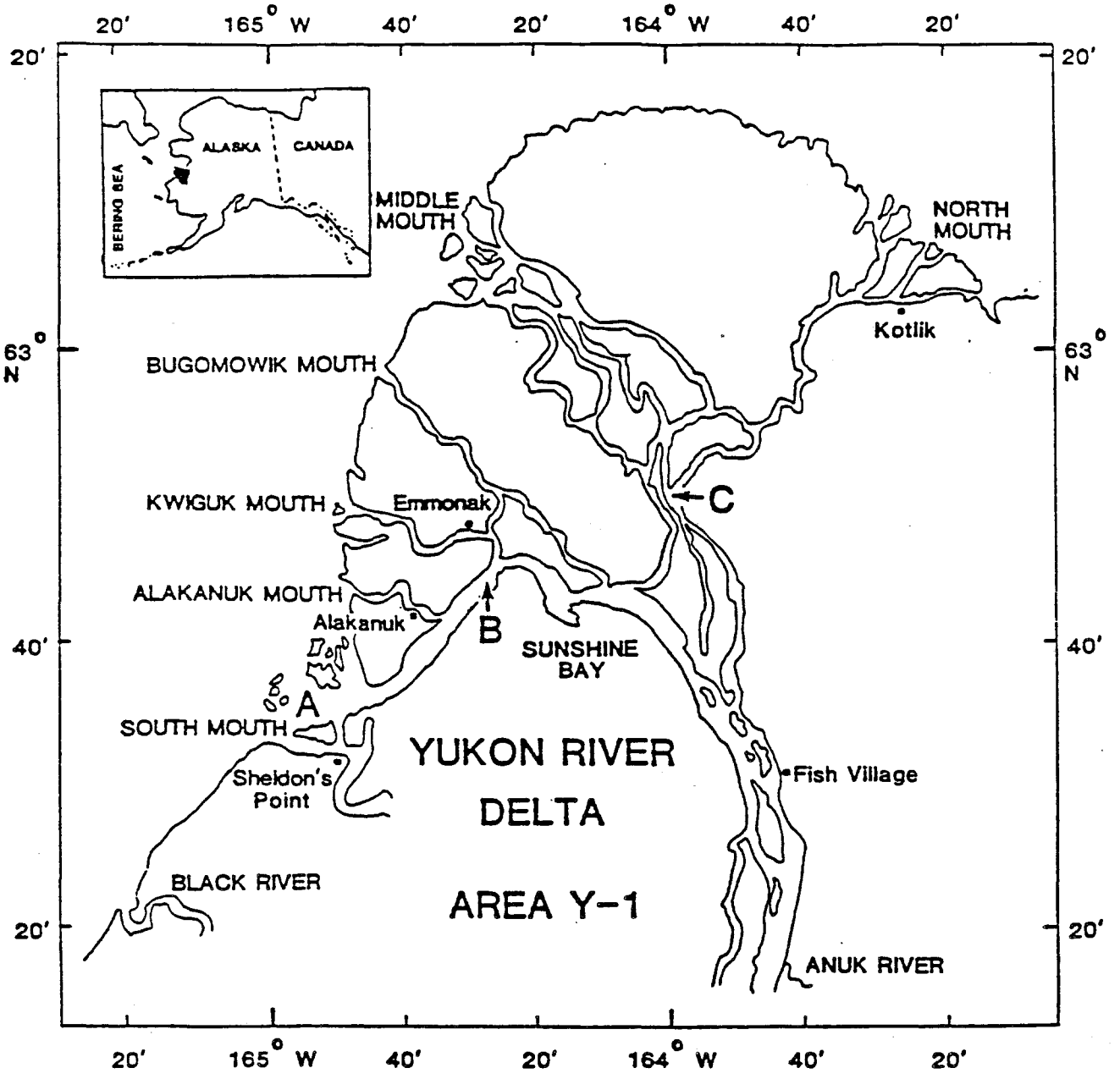

Figure 2. Detail of the Yukon River delta and fisheries statistical District 1, Site A is Flat Island test fishery, Site B is Big Eddy test fishery, and Site C is Middle Mouth test fishery.

in 1979 approximately 30 km upriver at Big Eddy (Figure 2, site B). Another test fishery, Middle Mouth, began in mid-season, 1979, approximately at the juncture of the Middle and North Mouth sloughs (Figure 2, site C). Two 45.7 m (25 fathoms) gill nets of 21.6 cm (8.5 inch) mesh and one 45.7 m, 14.0 cm (5.5 inch) mesh gill net were fished in locations judged to be productive and representative of the major river channels near the test fishery. Set nets were chosen to standardize the effort and ability of personnel. Except when circumstances prevented, each net fished 24 hours a day and was checked twice daily.

In the present study, observed daily test fishery catch is defined as the total recorded catch at the 3 net sites for 24 hours fished. Catches were adjusted upward proportionally on days of less than 24 hours of fishing. In 1979, the Middle Mouth test fishery did not begin until June 18, which was half way through the chinook salmon migration. Therefore the 1979 Middle Mouth data are not included in the analysis. Observed daily commercial catch is defined as total number of chinook salmon caught in District 1 during a given day of commercial harvest. Test fishery catches, commercial catches, fishing effort, and average daily wind speed for ADF&G test fisheries from 1968 to 1981 are presented in Tables 1 - 14. Data provided in Tables 1 - 14 are presented in this section of this report to familiarize the reader with much of the basic information used in this study to develop annual abundance estimates of Yukon River chinook salmon runs. These data were not developed nor collected as part of this but one used through statistical modeling methods outlined in the following section entitled "Statistical Methods" in this study to develop annual estimates of run strength of Yukon River chinook salmon. A summary of the lower Yukon River chinook salmon catch statistics and ADF&G test fishing operational procedures can also be found in the annual Lower Yukon test fishing reports (Mimeographed reports available

Table 1. Pertinent data concerning the 1968 Flat Island test fishery.

Date	Coded Day	Test Fishery Catch	Adjusted Catch	Commercial Catch in District 1	Average Wind Speed (mi per hr)	Commercial Effort (days)
June 1	1	0	0	0	7.1	0.00
June 2	2	0	0	0	5.8	0.00
June 3	3	0	0	1	3.5	0.25
June 4	4	5	5	23	7.5	1.00
June 5	5	3	3	38	9.8	0.25
June 6	6	14	14	11	8.3	0.25
June 7	7	24	24	508	9.5	1.00
June 8	8	45	45	825	6.9	0.75
June 9	9	84	84	0	8.2	0.00
June 10	10	78	78	29	6.3	0.25
June 11	11	31	31	5982	6.2	1.00
June 12	12	53	53	3863	9.6	0.25
June 13	13	68	68	180	11.4	0.25
June 14	14	3	3	8959	9.1	1.00
June 15	15	19	19	5278	5.8	0.75
June 16	16	41	41	0	8.6	0.00
June 17	17	19	19	184	7.6	0.25
June 18	18	14	14	3365	8.5	1.00
June 19	19	95	95	2555	9.5	0.25
June 20	20	29	29	568	7.5	0.25
June 21	21	44	44	9800	7.9	1.00
June 22	22	104	104	14839	6.3	0.75
June 23	23	23	23	0	9.8	0.00
June 24	24	84	84	265	10.5	0.25
June 25	25	22	22	9423	8.3	1.00
June 26	26	22	22	4108	8.5	0.25
June 27	27	36	36	436	11.9	0.25
June 28	28	0	0	3621	11.8	1.00
June 29	29	4	4	3005	12.9	0.75
June 30	30	4	4	0	10.4	0.00
July 1	31	27	27	13	9.1	0.25
July 2	32	15	15	1030	5.8	1.00
July 3	33	3	3	545	6.0	0.25
July 4	34	7	7	0	8.2	0.00
July 5	35	5	5	0	10.4	0.00
July 6	36	4	4	0	6.9	0.00
July 7	37	0	0	0	12.1	0.00

Net hours fished were not available and assumed to be 48 hours for each day of recorded catch (2 nets each fished for 24 hours). Commercial catch and commercial effort (proportion of day open to commercial fishing) were obtained from Lower Yukon Area annual management reports (Alaska Department of Fish and Game Annual Management Report, Yukon Area, 1968. Anchorage, AK). Average daily wind speed was recorded in Nome, Alaska.

Table 2. Pertinent data concerning the 1969 Flat Island test fishery.

Date	Coded Day	Test Fishery Catch	Adjusted Catch	Commercial Catch in District 1	Average Wind Speed (mi per hr)	Commercial Effort (days)
June 1	1	0	0	0	8.8	0.00
June 2	2	8	8	53	11.5	0.25
June 3	3	41	41	2107	11.8	1.00
June 4	4	18	18	1687	11.7	0.25
June 5	5	30	30	49	13.2	0.25
June 6	6	20	20	2205	13.2	1.00
June 7	7	50	50	1997	11.7	0.75
June 8	8	26	26	0	17.1	0.00
June 9	9	243	243	1889	18.0	0.25
June 10	10	102	102	9970	14.4	1.00
June 11	11	121	121	6856	12.9	0.25
June 12	12	61	61	598	11.9	0.25
June 13	13	15	15	8827	10.1	1.00
June 14	14	0	0	5422	8.1	0.75
June 15	15	22	22	0	11.1	0.00
June 16	16	21	21	563	8.6	0.25
June 17	17	17	17	3653	12.7	1.00
June 18	18	43	43	2040	11.2	0.25
June 19	19	67	67	1037	11.7	0.25
June 20	20	16	16	9372	9.9	0.75
June 21	21	12	12	0	7.1	0.00
June 22	22	136	136	0	5.8	0.00
June 23	23	35	35	821	3.7	0.25
June 24	24	33	33	7164	9.1	0.75
June 25	25	36	36	0	11.2	0.00
June 26	26	15	15	230	6.8	0.25
June 27	27	4	4	2088	9.6	1.00
June 28	28	29	29	1958	10.1	0.75
June 29	29	26	26	0	10.6	0.00
June 30	30	6	6	0	5.6	0.00
July 1	31	5	5	0	8.6	0.00
July 2	32	3	3	0	11.9	0.00
July 3	33	3	3	0	6.5	0.00
July 4	34	2	2	0	9.1	0.00
July 5	35	4	4	0	11.9	0.00
July 6	36	0	0	0	3.0	0.00
July 7	37	1	1	0	9.5	0.00
July 8	38	0	0	0	8.8	0.00

Net hours fished were not available and assumed to be 48 hours for each day of recorded catch (2 nets each fished for 24 hours). Commercial catch and commercial effort (proportion of day open to commercial fishing) were obtained from Lower Yukon Area annual management reports (Alaska Department of Fish and Game Annual Management Report, Yukon Area, 1969. Anchorage, AK). Average daily wind speed was recorded in Nome, Alaska.

Table 3. Pertinent data concerning the 1970 Flat Island test fishery.

Date	Coded Day	Test Fishery Catch	Hours Fished	Adjusted Catch	Commercial Catch in District 1	Average Wind Speed (mi per hr)	Commercial Effort (days)
June 1	1	0	0	0	0	9.2	0.00
June 2	2	0	0	0	0	8.6	0.00
June 3	3	0	48	0	0	10.6	0.00
June 4	4	0	48	0	0	9.6	0.00
June 5	5	0	48	0	0	8.8	0.00
June 6	6	4	48	4	9	15.2	0.75
June 7	7	5	48	5	0	9.9	0.00
June 8	8	20	48	20	18	6.3	0.25
June 9	9	21	48	21	224	7.6	1.00
June 10	10	16	48	16	230	9.6	0.25
June 11	11	79	48	79	70	11.5	0.25
June 12	12	11	48	11	1589	7.8	1.00
June 13	13	6	48	6	906	11.4	0.75
June 14	14	15	48	15	0	8.9	0.00
June 15	15	39	48	39	167	12.4	0.25
June 16	16	11	48	11	3883	8.1	1.00
June 17	17	104	76	66	1329	19.6	0.25
June 18	18	106	14	190	1500	13.2	0.25
June 19	19	30	24	60	7489	15.4	1.00
June 20	20	32	24	64	15335	13.1	0.75
June 21	21	79	39	96	0	9.8	0.00
June 22	22	39	48	39	249	10.4	0.25
June 23	23	4	48	4	3483	10.1	1.00
June 24	24	42	48	42	2801	12.7	0.25
June 25	25	85	48	85	809	16.5	0.25
June 26	26	85	48	85	10118	14.5	0.75
June 27	27	18	48	18	0	13.2	0.00
June 28	28	7	48	7	0	10.1	0.00
June 29	29	31	48	31	240	7.3	0.25
June 30	30	29	48	29	2906	10.6	1.00
July 1	31	4	48	4	2446	10.1	0.25
July 2	32	5	18	13	59	8.6	0.75
July 3	33	25	48	25	1642	7.9	0.00
July 4	34	24	48	24	0	9.8	0.00
July 5	35	19	48	19	0	8.3	0.00
July 6	36	19	48	19	0	7.5	0.00
July 7	37	12	48	12	0	8.2	0.00
July 8	38	10	48	10	0	13.5	0.00
July 9	39	2	48	2	0	12.2	0.00
July 10	40	0	48	0	0	10.5	0.00

Number of test net hours, commercial catch, and commercial effort (proportion of day open to commercial fishing) were obtained from Lower Yukon Area annual management reports (Alaska Department of Fish and Game Annual Management Report, Yukon Area, 1970. Anchorage, AK). Average daily wind speed was recorded in Nome, Alaska.

Table 4. Pertinent data concerning the 1971 Flat Island test fishery.

Date	Coded Day	Test Fishery Catch	Hours Fished	Adjusted Catch	Commercial Catch in District 1	Average Wind Speed (mi per hr)	Commercial Effort (days)
June 10	10	0	0	0	0	12.1	0.00
June 11	11	0	0	0	2	18.0	1.00
June 12	12	0	0	0	26	17.0	0.75
June 13	13	1	2	24	0	6.0	0.00
June 14	14	8	30	13	5	8.1	0.25
June 15	15	14	48	14	397	15.1	1.00
June 16	16	31	35	43	756	14.5	0.25
June 17	17	14	48	14	169	10.1	0.25
June 18	18	6	48	6	1426	8.3	1.00
June 19	19	31	48	31	2313	11.2	0.75
June 20	20	57	48	57	0	10.1	0.00
June 21	21	65	48	65	1023	9.5	0.25
June 22	22	20	48	20	8669	5.2	1.00
June 23	23	7	38	9	3389	6.8	0.25
June 24	24	67	48	67	1738	7.8	0.25
June 25	25	72	48	72	9219	5.3	1.00
June 26	26	34	48	34	11607	6.0	0.75
June 27	27	62	48	62	0	6.8	0.00
June 28	28	72	48	72	1484	7.6	0.25
June 29	29	0	0	102	16203	15.8	1.00
June 30	30	204	96	102	16910	10.8	0.25
July 1	31	15	48	15	722	6.2	0.25
July 2	32	0	48	0	5441	10.6	1.00
July 3	33	12	48	12	2898	9.4	0.75
July 4	34	54	48	54	0	12.1	0.00
July 5	35	12	48	12	0	5.8	0.00
July 6	36	21	48	21	0	8.2	0.00
July 7	37	46	48	46	0	9.1	0.00
July 8	38	42	48	42	0	10.1	0.00
July 9	39	48	48	48	0	8.2	0.00
July 10	40	138	48	138	0	8.2	0.00
July 11	41	43	19	20	0	9.8	0.00
July 12	42	0	0	13	114	15.7	0.25
July 13	43	35	125	13	363	15.7	1.00
July 14	44	7	24	14	526	15.2	0.75
July 15	45	2	18	5	12	4.0	0.25
July 16	46	0	0	0	107	6.0	1.00

Number of test net hours, commercial catch, and commercial effort (proportion of day open to commercial fishing) were obtained from Lower Yukon Area annual management reports (Alaska Department of Fish and Game Annual Management Reports, Yukon Area, 1971. Anchorage, AK). Average daily wind speed was recorded in Nome, Alaska.

Table 5. Pertinent data concerning the 1972 Flat Island test fishery.

Date	Coded Day	Test Fishery Catch	Hours Fished	Adjusted Catch	Commercial Catch in District 1	Average Wind Speed (mi per hr)	Commercial Effort (days)
June 10	10	0	0	0	36	7.3	.75
June 11	11	7	28	12	0	13.4	0.00
June 12	12	5	36	7	32	7.9	0.25
June 13	13	2	48	2	571	4.9	1.00
June 14	14	22	34	31	391	6.6	0.25
June 15	15	30	48	30	422	8.2	0.25
June 16	16	12	48	12	1355	7.3	1.00
June 17	17	11	45	12	1734	15.1	0.75
June 18	18	64	48	64	0	11.1	0.00
June 19	19	82	48	82	1953	10.2	0.25
June 20	20	28	48	28	9809	7.2	1.00
June 21	21	15	48	15	5181	6.9	0.25
June 22	22	3	48	3	405	8.2	0.25
June 23	23	8	48	8	6125	7.5	1.00
June 24	24	1	47	1	9775	9.4	0.75
June 25	25	8	48	8	0	8.9	0.00
June 26	26	18	48	18	925	9.2	0.25
June 27	27	4	48	4	6013	9.2	1.00
June 28	28	25	36	33	8476	10.2	0.25
June 29	29	28	48	28	1204	11.8	0.25
June 30	30	1	48	1	9244	7.2	1.00
July 1	31	4	48	4	4401	6.2	0.75
July 2	32	25	48	25	0	8.9	0.00
July 3	33	5	48	5	0	12.8	0.00
July 4	34	11	48	11	0	8.3	0.00
July 5	35	60	48	60	0	6.5	0.00
July 6	36	24	48	24	0	9.1	0.00
July 7	37	18	48	18	0	8.9	0.00
July 8	38	27	48	27	0	7.5	0.00
July 9	39	8	48	8	0	8.6	0.00
July 10	40	36	48	36	384	7.2	0.00
July 11	41	8	48	8	531	11.8	1.00
July 12	42	14	48	14	61	16.8	0.75
July 13	43	7	42	8	336	7.3	0.25
July 14	44	0	24	0	217	7.8	1.00

Number of test net hours, commercial catch, and commercial effort (proportion of day open to commercial fishing) were obtained from Lower Yukon Area annual management reports (Alaska Department of Fish and Game Annual Management Reports, Yukon Area, 1972. Anchorage, AK). Average daily wind speed was recorded in Nome, Alaska.

Table 6. Pertinent data concerning the 1973 Flat Island test fishery.

Date	Coded Day	Test Fishery Catch	Hours Fished	Adjusted Catch	Commercial Catch in District 1	Average Wind Speed (mi per hr)	Commercial Effort (days)
June 4	4	0	0	0	0	10.8	0.25
June 5	5	13	48	13	95	7.2	1.00
June 6	6	7	18	19	181	16.7	0.25
June 7	7	21	36	34	194	15.2	0.25
June 8	8	21	72	21	1105	8.6	1.25
June 9	9	16	71	16	1189	9.6	0.75
June 10	10	59	72	59	0	8.5	0.00
June 11	11	22	72	22	233	11.5	0.25
June 12	12	30	72	30	4204	4.8	1.00
June 13	13	5	70	5	2182	5.9	0.25
June 14	14	3	72	3	397	9.1	0.25
June 15	15	43	60	56	3611	10.8	1.00
June 16	16	54	72	54	8142	20.7	0.75
June 17	17	144	72	144	0	20.3	0.00
June 18	18	37	72	37	1333	10.2	0.25
June 19	19	13	72	13	5874	6.2	1.00
June 20	20	6	72	6	1847	7.1	0.25
June 21	21	14	72	14	893	8.6	0.25
June 22	22	15	72	15	4177	13.1	1.00
June 23	23	23	68	25	6909	9.5	0.75
June 24	24	52	72	52	0	7.6	0.00
June 25	25	59	72	59	1211	6.8	0.25
June 26	26	22	72	22	6075	4.6	1.00
June 27	27	14	67	15	2938	7.3	0.25
June 28	28	78	72	78	0	4.5	0.00
June 29	29	10	72	10	0	6.5	0.00
June 30	30	34	72	34	0	9.1	0.00
July 1	31	3	72	3	0	7.1	0.00
July 2	32	4	72	4	0	10.5	0.00
July 3	33	15	72	15	0	6.8	0.00
July 4	34	28	72	28	0	15.1	0.00
July 5	35	9	66	10	138	18.7	0.25
July 6	36	16	48	32	1249	14.8	1.00
July 7	37	6	54	10	1231	10.2	0.75
July 8	38	8	72	8	0	6.5	0.00
July 9	39	7	60	9	50	11.9	0.25
July 10	40	0	24	0	358	9.6	1.00
July 11	41	1	36	4	209	10.2	0.75
July 12	42	6	60	8	38	7.6	0.25
July 13	43	0	24	0	188	8.1	1.00
July 14	44	0	0	0	177	9.1	0.75

Number of test net hours, commercial catch, and commercial effort (proportion of day open to commercial fishing) were obtained from Lower Yukon Area annual management reports (Alaska Department of Fish and Game Annual Management Reports, Yukon Area, 1973. Anchorage, AK). Average daily wind speed was recorded in Nome, Alaska.

Table 7. Pertinent data concerning the 1974 Flat Island test fishery.

Date	Coded Day	Test Fishery Catch	Hours Fished	Adjusted Catch	Commercial Catch in District 1	Average Wind Speed (mi per hr)	Commercial Effort (days)
May 29	-2	0	0	0	0	7.2	0.00
May 30	-1	0	0	0	0	7.8	0.00
May 31	0	2	18	5	0	9.8	0.00
June 1	1	2	16	12	0	10.1	0.00
June 2	2	9	48	16	0	10.8	0.00
June 3	3	6	48	7	209	8.2	0.25
June 4	4	3	63	3	1668	7.8	1.00
June 5	5	23	72	23	1621	10.5	0.25
June 6	6	39	72	39	736	6.6	0.25
June 7	7	28	72	28	2675	10.6	1.00
June 8	8	24	70	25	4052	11.7	0.25
June 9	9	46	72	46	0	16.3	0.00
June 10	10	73	72	73	3409	14.1	0.25
June 11	11	33	72	33	8046	14.5	1.00
June 12	12	20	31	32	3247	14.4	0.25
June 13	13	47	63	55	1588	6.2	0.25
June 14	14	15	72	15	5193	7.9	1.00
June 15	15	10	72	10	4333	6.9	0.25
June 16	16	37	72	37	0	10.5	0.00
June 17	17	29	72	29	2984	11.1	0.25
June 18	18	21	72	21	11234	7.5	1.00
June 19	19	3	72	3	4627	8.2	0.25
June 20	20	6	72	6	128	8.1	0.25
June 21	21	2	72	2	1385	11.1	1.00
June 22	22	31	64	34	1326	9.2	0.25
June 23	23	4	54	4	0	12.2	0.00
June 24	24	8	72	8	528	10.2	0.25
June 25	25	12	72	12	4491	4.8	1.00
June 26	26	2	72	2	2176	5.2	0.25
June 27	27	3	66	3	343	6.9	0.25
June 28	28	0	48	0	2308	8.2	1.00
June 29	29	10	66	11	1150	13.4	0.25
June 30	30	11	72	11	0	17.7	0.00
July 1	31	10	72	10	0	14.0	0.00
July 2	32	2	72	2	0	10.4	0.00
July 3	33	2	72	2	0	7.2	0.00
July 4	34	1	66	1	91	6.5	0.25
July 5	35	0	48	0	441	6.8	1.00
July 6	36	2	66	2	225	7.9	0.25
July 7	37	5	72	5	0	8.9	0.00
July 8	38	2	66	2	30	8.2	0.25
July 9	39	0	48	0	222	11.5	1.00
July 10	40	1	66	1	105	9.1	0.25
July 11	41	1	66	1	49	8.6	0.25
July 12	42	0	0	1	113	15.4	1.00
July 13	43	1	108	1	61	6.8	0.25
July 14	44	1	72	1	0	8.3	0.00
July 15	45	0	0	0	10	7.8	0.25

Number of test net hours, commercial catch, and commercial effort (proportion of day open to commercial fishing) were obtained from Lower Yukon Area annual management reports (Alaska Department of Fish and Game Annual Management Reports, Yukon Area, 1974. Anchorage, AK). Average daily wind speed was recorded in Nome, Alaska.

Table 8. Pertinent data concerning the 1975 Flat Island test fishery.

Date	Coded Day	Test Fishery Catch	Hours Fished	Adjusted Catch	Commercial Catch in District 1	Average Wind Speed (mi per hr)	Commercial Effort (days)
June 8	8	0	0	0	0	6.1	0.00
June 9	9	0	0	0	0	8.3	0.25
June 10	10	2	48	4	104	8.3	1.00
une 11	11	0	48	0	96	11.4	0.25
June 12	12	2	54	3	6	15.0	0.25
June 13	13	0	72	0	284	8.2	1.00
June 14	14	2	72	2	156	8.8	0.25
June 15	15	0	72	0	0	9.8	0.00
June 16	16	1	72	1	40	9.5	0.25
June 17	17	1	72	1	692	6.5	1.00
June 18	18	4	72	4	352	7.3	0.25
June 19	19	20	72	20	889	10.4	0.25
June 20	20	0	72	0	3822	8.3	1.00
June 21	21	4	36	9	915	12.8	0.25
June 22	22	38	29	68	0	12.2	0.00
June 23	23	99	126	63	2827	11.1	0.25
June 24	24	16	72	16	10697	11.7	1.00
June 25	25	12	72	12	3579	12.4	0.25
June 26	26	10	72	10	2999	10.4	0.25
June 27	27	13	72	13	6809	5.3	0.75
June 28	28	5	72	5	0	12.2	0.00
June 29	29	0	0	41	0	12.1	0.00
June 30	30	82	166	41	1449	14.0	0.25
July 1	31	19	72	19	5834	10.8	0.75
July 2	32	14	72	14	0	8.3	0.00
July 3	33	15	72	15	44	9.6	0.25
July 4	34	7	72	7	1176	7.3	0.75
July 5	35	3	72	3	0	5.9	0.00
July 6	36	2	57	3	0	10.8	0.00
July 7	37	10	18	40	242	18.6	0.25
July 8	38	0	72	0	983	14.8	1.00
July 9	39	6	38	12	223	15.7	0.25
July 10	40	6	56	6	148	8.5	0.25
July 11	41	3	72	3	326	6.2	1.00
July 12	42	0	72	0	121	6.2	0.25
July 13	43	0	72	0	0	6.6	0.00
July 14	44	2	72	2	27	9.2	0.25
July 15	45	0	0	0	94	6.0	1.00

Number of test net hours, commercial catch, and commercial effort (proportion of day open to commercial fishing) were obtained from Lower Yukon Area annual management reports (Alaska Department of Fish and Game Annual Management Reports, Yukon Area, 1975. Anchorage, AK). Average daily wind speed was recorded in Nome, Alaska.

Table 9. Pertinent data concerning the 1976 Flat Island test fishery.

Date	Coded Day	Test Fishery Catch	Hours Fished	Adjusted Catch	Commercial Catch in District 1	Average Wind Speed (mi per hr)	Commercial Effort (days)
June 11	11	0	0	0	0	8.5	0.00
June 12	12	0	0	0	0	6.9	0.00
June 13	13	0	72	0	0	6.2	0.00
June 14	14	0	72	0	16	7.1	0.25
June 15	15	0	72	0	78	7.2	1.00
June 16	16	0	72	0	44	9.6	0.25
June 17	17	1	72	1	115	7.5	0.25
June 18	18	1	72	1	1667	7.5	1.00
June 19	19	5	72	5	1345	8.1	0.25
June 20	20	11	72	11	0	7.3	0.00
June 21	21	6	72	6	214	13.5	0.25
June 22	22	9	72	9	4412	10.6	1.00
June 23	23	21	64	32	5014	7.5	0.25
June 24	24	80	80	69	2831	6.9	0.25
June 25	25	5	72	5	9137	6.6	1.00
June 26	26	5	72	5	3394	8.3	0.25
June 27	27	44	72	44	0	9.4	0.00
June 28	28	32	72	32	1741	6.5	0.25
June 29	29	24	72	24	6984	8.3	1.00
June 30	30	92	72	92	5119	8.6	0.25
July 1	31	93	72	93	2512	11.5	0.25
July 2	32	44	72	44	11769	11.8	0.75
July 3	33	50	38	102	0	21.0	0.00
July 4	34	12	36	24	0	13.2	0.00
July 5	35	28	72	28	695	8.9	0.25
July 6	36	6	72	6	2081	6.8	0.75
July 7	37	10	72	10	0	5.9	0.00
July 8	38	24	72	24	299	8.1	0.25
July 9	39	0	72	0	954	7.5	0.75
July 10	40	8	72	8	0	6.2	0.00
July 11	41	12	72	12	0	6.5	0.00
July 12	42	16	72	16	271	12.5	0.25
July 13	43	0	72	0	607	12.5	1.00
July 14	44	2	72	2	231	13.4	0.25
July 15	45	2	72	2	116	7.5	0.25
July 16	46	0	0	0	248	6.0	1.00

Number of test net hours, commercial catch, and commercial effort (proportion of day open to commercial fishing) were obtained from Lower Yukon Area annual management reports (Alaska Department of Fish and Game Annual Management Reports, Yukon Area, 1976. Anchorage, AK). Average daily wind speed was recorded in Nome, Alaska.

Table 10. Pertinent data concerning the 1977 Flat Island test fishery.

Date	Coded Day	Test Fishery Catch	Hours Fished	Adjusted Catch	Commercial Catch in District 1	Average Wind Speed (mi per hr)	Commercial Effort (days)
June 6	6	0	0	0	0	6.2	0.00
June 7	7	0	21	0	0	14.7	0.00
June 8	8	0	60	0	0	16.4	0.00
June 9	9	1	48	2	0	12.4	0.00
June 10	10	1	48	2	0	9.4	0.00
June 11	11	0	48	0	2	9.2	0.25
June 12	12	0	48	0	0	6.2	0.00
June 13	13	0	72	0	4	8.2	0.25
June 14	14	0	72	0	35	6.8	0.75
June 15	15	2	72	2	0	6.2	0.00
June 16	16	2	72	2	129	6.3	0.25
June 17	17	2	72	2	1345	5.0	1.00
June 18	18	7	72	9	1106	5.9	0.25
June 19	19	11	72	13	0	6.1	0.00
June 20	20	10	72	10	1590	7.2	0.25
June 21	21	2	72	2	8804	9.2	0.75
June 22	22	10	72	13	0	10.6	0.00
June 23	23	7	72	9	3574	10.4	0.25
June 24	24	12	72	13	14425	9.2	1.00
June 25	25	23	72	23	8668	4.8	0.25
June 26	26	11	72	12	0	7.6	0.00
June 27	27	23	72	25	3274	8.8	0.25
June 28	28	31	72	33	14425	10.9	0.75
June 29	29	46	72	52	0	15.4	0.00
June 30	30	39	72	47	2025	16.7	0.25
July 1	31	4	72	4	6735	14.5	0.75
July 2	32	8	72	8	0	17.0	0.00
July 3	33	11	72	11	0	7.3	0.00
July 4	34	30	72	30	543	10.2	0.25
July 5	35	8	72	8	1408	10.1	0.75
July 6	36	4	72	4	0	11.7	0.00
July 7	37	7	72	7	219	14.2	0.25
July 8	38	0	72	0	387	7.5	1.00
July 9	39	2	72	2	53	7.6	0.25
July 10	40	5	72	5	0	6.9	0.00
July 11	41	3	72	3	75	9.1	0.25
July 12	42	4	72	4	373	11.9	0.75
July 13	43	3	72	3	0	13.7	0.00
July 14	44	1	72	1	55	6.9	0.25
July 15	45	0	0	0	183	7.1	1.00

Number of test net hours, commercial catch, and commercial effort (proportion of day open to commercial fishing) were obtained from Lower Yukon Area annual management reports (Alaska Department of Fish and Game Annual Management Reports, Yukon Area, 1977. Anchorage, AK). Average daily wind speed was recorded in Nome, Alaska.

Table 11. Pertinent data concerning the 1978 Flat Island test fishery.

Date	Coded Day	Test Fishery Catch	Hours Fished	Adjusted Catch	Commercial Catch in District 1	Average Wind Speed (mi per hr)	Commercial Effort (days)
May 28	-3	0	0	0	0	7.3	0.00
May 29	-2	2	21	7	0	8.3	0.00
May 30	-1	7	72	7	0	6.5	0.00
May 31	0	26	72	26	0	13.1	0.00
June 1	1	29	72	29	0	7.8	0.00
June 2	2	84	72	84	0	8.3	0.00
June 3	3	27	72	27	0	17.4	0.00
June 4	4	76	63	86	0	13.8	0.00
June 5	5	40	72	40	0	16.1	0.00
June 6	6	47	72	47	0	14.5	0.00
June 7	7	42	72	42	0	12.0	0.00
June 8	8	21	72	21	415	7.1	0.25
June 9	9	2	72	2	2052	7.8	0.75
June 10	10	67	72	67	0	13.5	0.00
June 11	11	44	72	44	0	7.8	0.00
June 12	12	9	72	9	899	7.1	0.25
June 13	13	7	72	6	4934	6.5	0.75
June 14	14	38	72	38	0	12.5	0.00
June 15	15	34	72	34	4067	16.5	0.25
June 16	16	26	72	26	8650	13.2	1.00
June 17	17	18	72	18	4888	15.1	0.25
June 18	18	21	64	23	0	11.2	0.00
June 19	19	52	54	52	1923	14.0	0.25
June 20	20	0	72	0	5564	7.3	0.75
June 21	21	9	72	9	0	12.1	0.00
June 22	22	43	54	52	2999	11.1	0.25
June 23	23	42	72	42	7785	11.5	1.00
June 24	24	6	63	7	3672	6.6	0.25
June 25	25	9	72	9	0	8.6	0.00
June 26	26	22	72	22	1371	13.8	0.25
June 27	27	9	72	9	3979	10.8	0.75
June 28	28	20	72	20	0	14.0	0.00
June 29	29	15	72	15	448	10.2	0.25
June 30	30	2	72	2	1065	9.4	1.00
July 1	31	6	72	6	471	10.1	0.25
July 2	32	2	72	2	0	10.6	0.00
July 3	33	3	72	3	165	11.9	0.25
July 4	34	1	72	1	767	7.5	0.75
July 5	35	2	72	2	0	6.6	0.00
July 6	36	3	72	3	99	10.6	0.25
July 7	37	2	72	2	435	11.2	1.00
July 8	38	2	72	2	130	9.8	0.25
July 9	39	8	72	8	0	10.1	0.00
July 10	40	4	72	4	124	13.2	0.25
July 11	41	5	72	5	335	10.1	0.75
July 12	42	3	72	3	0	11.1	0.00
July 13	43	0	72	0	32	9.2	0.25
July 14	44	0	72	0	226	10.6	1.00

Number of test net hours, commercial catch, and commercial effort (proportion of day open to commercial fishing) were obtained from Lower Yukon Area annual management reports (Alaska Department of Fish and Game Annual Management Reports, Yukon Area, 1978. Anchorage, AK). Average daily wind speed was recorded in Nome, Alaska.

Table 12. Pertinent data concerning the 1979 Flat Island test fishery.

Date	Coded Day	Test Fishery Catch	Hours Fished	Adjusted Catch	Commercial Catch in District 1	Average Wind Speed (mi per hr)	Commercial Effort (days)
May 25	-6	0	0	0	0	7.9	0.00
May 26	-5	7	36	14	0	10.4	0.00
May 27	-4	16	48	16	0	6.2	0.00
May 28	-3	6	48	6	0	10.1	0.00
May 29	-2	26	48	26	0	8.9	0.00
May 30	-1	8	48	8	0	8.6	0.00
May 31	0	6	48	6	0	7.8	0.00
June 1	1	9	48	9	0	9.1	0.00
June 2	2	19	48	19	0	10.2	0.00
June 3	3	21	48	21	0	5.9	0.00
June 4	4	14	48	14	8409	7.5	0.25
June 5	5	19	48	19	5263	6.3	0.75
June 6	6	87	48	87	0	9.8	0.00
June 7	7	174	48	174	1020	6.6	0.25
June 8	8	28	48	28	3883	6.6	0.75
June 9	9	8	48	8	0	17.0	0.00
June 10	10	0	48	0	0	18.7	0.00
June 11	11	141	64	160	4046	15.5	0.25
June 12	12	9	63	11	15464	11.1	0.75
June 13	13	15	56	19	0	8.9	0.00
June 14	14	19	48	19	929	13.2	0.25
June 15	15	7	48	7	6418	10.8	1.00
June 16	16	4	48	7	1921	13.1	0.25
June 17	17	40	48	40	0	13.4	0.00
June 18	18	42	48	42	2620	14.4	0.25
June 19	19	25	48	25	14089	11.1	0.75
June 20	20	35	48	35	0	07.9	0.00
June 21	21	13	48	13	1650	07.3	0.25
June 22	22	2	48	2	3647	08.6	0.75
June 23	23	6	48	6	0	09.8	0.00
June 24	24	9	48	9	0	12.2	0.00
June 25	25	23	48	23	1554	11.1	0.25
June 26	26	11	48	11	4388	10.6	0.75
June 27	27	42	48	42	0	11.1	0.00
June 28	28	60	48	60	1094	12.4	0.25
June 29	29	8	48	8	3135	06.8	0.75
June 30	30	4	48	4	0	10.2	0.00
July 1	31	5	48	5	0	10.4	0.00
July 2	32	20	48	20	495	13.4	0.25
July 3	33	4	48	4	985	13.1	0.75
July 4	34	9	48	9	0	17.7	0.00
July 5	35	12	48	12	236	12.8	0.25
July 6	36	1	48	1	1009	13.1	1.00
July 7	37	12	48	12	384	9.8	0.25
July 8	38	10	48	10	0	10.2	0.00
July 9	39	7	48	7	105	7.8	0.25
July 10	40	0	48	0	371	9.4	0.75
July 11	41	0	48	0	0	8.8	0.00
July 12	42	7	48	7	108	10.1	0.25
July 13	43	0	48	0	180	10.2	1.00
July 14	44	0	48	0	45	7.9	0.75

Number of test net hours, commercial catch, and commercial effort (proportion of day open to commercial fishing) were obtained from Lower Yukon Area annual management reports (Alaska Department of Fish and Game Annual Management Reports, Yukon Area, 1979. Anchorage, AK). Average daily wind speed was recorded in Nome, Alaska.

Table 13. Pertinent data concerning the 1980 Flat Island test fishery.

Date	Coded Day	Test Fishery Catch	Hours Fished	Adjusted Catch	Commercial Catch in District 1	Average Wind Speed (mi per hr)	Commercial Effort (days)
May 28	-3	0	24	0	0	8.8	0.00
May 29	-2	0	24	0	0	13.5	0.00
May 30	-1	1	29	2	0	9.1	0.00
May 31	0	8	48	8	0	15.0	0.00
June 1	1	3	48	3	0	11.1	0.00
June 2	2	13	57	21	0	11.1	0.00
June 3	3	34	48	46	0	11.5	0.00
June 4	4	55	48	68	0	9.6	0.00
June 5	5	66	72	66	0	10.2	0.00
June 6	6	56	72	56	0	8.6	0.00
June 7	7	39	72	39	0	10.1	0.00
June 8	8	77	72	77	0	10.1	0.00
June 9	9	44	72	44	1744	10.5	0.25
June 10	10	2	72	2	5072	13.4	0.75
June 11	11	82	72	82	0	10.1	0.00
June 12	12	91	72	91	3401	14.0	0.25
June 13	13	28	72	28	14271	11.9	1.00
June 14	14	94	72	94	6099	5.9	0.25
June 15	15	59	72	59	0	8.6	0.00
June 16	16	94	66	108	4506	12.9	0.25
June 17	17	45	54	60	10116	12.2	0.75
June 18	18	130	72	130	0	12.4	0.00
June 19	19	112	72	112	5805	20.0	0.25
June 20	20	42	36	95	14171	21.0	1.00
June 21	21	21	54	31	6185	8.3	0.25
June 22	22	14	51	18	0	7.5	0.00
June 23	23	5	66	6	2065	9.8	0.25
June 24	24	2	59	3	2422	11.9	0.75
June 25	25	4	72	4	0	8.8	0.00
June 26	26	27	72	27	984	8.6	0.25
June 27	27	32	72	32	2016	11.4	0.75
June 28	28	20	72	20	0	12.9	0.00
June 29	29	14	72	14	0	6.5	0.00
June 30	30	4	72	4	1206	5.6	0.25
July 1	31	9	72	9	2372	10.9	0.75
July 2	32	17	72	17	522	9.1	0.00
July 3	33	15	72	15	2498	6.3	0.25
July 4	34	8	72	8	221	8.6	1.00
July 5	35	9	72	9	0	17.0	0.25
July 6	36	4	72	4	0	8.8	0.00
July 7	37	4	72	4	181	6.8	0.25
July 8	38	2	72	2	657	6.2	0.75
July 9	39	2	72	2	0	5.3	0.00
July 10	40	0	72	0	44	5.9	0.25
July 11	41	0	72	0	463	14.8	1.00
July 12	42	4	72	4	187	16.7	0.25
July 13	43	0	72	0	0	6.0	0.00
July 14	44	2	72	2	67	5.9	0.25
July 15	45	0	72	0	322	6.8	0.75
July 16	46	0	0	0	0	7.5	0.00

Number of test net hours, commercial catch, and commercial effort (proportion of day open to commercial fishing) were obtained from Lower Yukon Area annual management reports (Alaska Department of Fish and Game Annual Management Reports, Yukon Area, 1980. Anchorage, AK). Average daily wind speed was recorded in Nome, Alaska.

Table 14. Pertinent data concerning the 1981 Flat Island test fishery.

Date	Coded Day	Test Fishery Catch	Hours Fished	Adjusted Catch	Commercial Catch in District 1	Average Wind Speed (mi per hr)	Commercial Effort (days)
May 28	-3	0	5	0	0	7.6	0.00
May 29	-2	2	36	2	0	8.9	0.00
May 30	-1	9	48	9	0	11.2	0.00
May 31	0	24	55	34	0	5.9	0.00
June 1	1	31	68	31	0	10.9	0.00
June 2	2	14	72	14	0	8.9	0.00
June 3	3	34	72	34	0	10.9	0.00
June 4	4	69	72	69	0	14.1	0.00
June 5	5	138	64	151	2779	10.1	0.25
June 6	6	18	54	18	8338	5.9	0.75
June 7	7	100	72	100	0	8.1	0.00
June 8	8	127	66	128	3904	8.2	0.25
June 9	9	23	54	23	11711	7.2	0.75
June 10	10	131	72	131	0	9.2	0.00
June 11	11	101	66	101	3621	6.9	0.25
June 12	12	20	54	20	10862	9.6	0.75
June 13	13	64	72	64	0	9.6	0.00
June 14	14	53	72	53	0	8.6	0.00
June 15	15	87	66	87	4576	8.9	0.25
June 16	16	36	54	36	13728	10.2	0.75
June 17	17	52	72	52	0	9.9	0.00
June 18	18	99	66	99	7130	14.8	0.25
June 19	19	41	54	59	21389	8.3	0.75
June 20	20	96	72	96	0	7.6	0.00
June 21	21	62	72	62	0	4.8	0.00
June 22	22	40	71	40	1039	6.0	0.25
June 23	23	11	72	11	3118	8.5	0.75
June 24	24	13	72	13	0	6.3	0.00
June 25	25	54	72	54	725	11.4	0.25
June 26	26	45	72	45	2176	12.2	0.75
June 27	27	35	72	35	0	6.5	0.00
June 28	28	28	72	28	0	10.6	0.00
June 29	29	64	72	64	387	12.5	0.25
June 30	30	18	72	18	1163	8.9	0.75
July 1	31	29	72	29	0	8.6	0.00
July 2	32	33	72	33	294	7.1	0.25
July 3	33	6	72	6	884	8.8	0.75
July 4	34	16	72	16	0	14.4	0.00
July 5	35	71	72	71	0	14.0	0.00
July 6	36	52	72	52	165	9.2	0.25
July 7	37	6	72	6	496	8.1	0.75
July 8	38	10	72	10	0	11.1	0.00
July 9	39	13	72	13	85	13.5	0.25
July 10	40	0	72	0	257	8.3	0.75
July 11	41	3	72	3	0	8.1	0.00
July 12	42	2	72	2	0	8.1	0.00
July 13	43	2	72	2	47	9.5	0.25
July 14	44	0	72	0	139	6.3	0.75
July 15	45	1	72	0	0	8.1	0.00
July 16	46	0	0	0	24	6.3	0.25

Number of test net hours, commercial catch, and commercial effort (proportion of day open to commercial fishing) were obtained from Lower Yukon Area annual management reports (Alaska Department of Fish and Game Annual Management Reports, Yukon Area, 1981. Anchorage, AK). Average daily wind speed was recorded in Nome, Alaska.

from ADF&G, Anchorage, Alaska) Mundy et al. (1981a, 1981b) Mundy (1982a, 1982b) and Clark (1983).

Weather observations recorded in Nome, Alaska and Emmonak, Alaska were obtained from the National Weather Service, Ashville, North Carolina. When available, the Emmonak wind speed was used (1979-1981). In 1979 a lapse in weather recording required that Nome wind speeds be substituted from July second to the end of the migration. Observed average wind speed is the arithmetic average of all observations on the given day. The rate of travel of chinook salmon in the Yukon River has been estimated at between 40 and 50 river km (25 to 30 miles) a day (Trasky 1973). Estimated residence time in District 1 is assumed to be 2-1/2 days (100 km traveled at an average rate of 40 km per day). When upriver migration is considered to commence immediately offshore of the Yukon River delta South Mouth chinook salmon would arrive at the Big Eddy test fishery approximately one day later. Chinook salmon migrating into the Middle Mouth would also arrive at the Middle Mouth test fishery approximately one day later. Therefore one day is subtracted from the estimated mean day of migration of the 1979, 1980, and 1981 time density distribution of chinook salmon test fishery catch so that Flat Island, Big Eddy, and Middle Mouth test fishery data can be compared interannually.

STATISTICAL METHODS

The derivative of the inverted exponential function with respect to time is one of several functions which may be used to quantify the time density of an assumed homogeneous population or subpopulation of Yukon River chinook salmon. The derivative of the two parameter logistic model,

$$Y'(t) = b[\exp(-(a+b))]/[(1+\exp(-(a+bt)))^2] \quad (3)$$

where $Y'(t)$ is the daily proportion of total abundance on day t, describes a bell-shaped curve similar to the normal curve,

$$Q(t) = \exp[-((t-\mu)^2/(2\sigma^2))]/(2\pi\sigma^2)^{1/2} \quad (4)$$

where $Q(t)$ is approximately equal to $Y'(t)$. The parameters, a and b of equation (3), are related to the mean (μ) and variance (σ^2) of the distribution:

$$\mu = -a/b \quad (5)$$

and

$$\sigma^2 = \pi^2 / (3b^2) \quad (6)$$

There are advantages inherent in the use of either the inverted exponential function or the normal distribution equation. The inverted exponential function is more prevalent in the fisheries literature and it can be integrated to yield an exact solution which describes the distribution of cumulative proportions $(Y(t))$ over time:

$$Y(t) = 1/[(1+\exp(-(a+bt)))] \quad (7)$$

The parameters of the normal distribution function are easily related to the shape of the distribution of daily catch over time, and the estimation procedure for the parameters μ and σ^2 reduces to classical mean and variance computations:

$$\mu = \sum_{t=1}^{n} (t)\left[\frac{C(t)}{CT}\right] \tag{8}$$

$$\sigma^2 = \sum_{t=1}^{n} (t-\mu)^2\left[\frac{C(t)}{CT}\right] \tag{9}$$

where C_T is the total annual catch, $C(t)$ is daily catch, and n is the last day of effort. The constants a and b of Equations (3) and (7) are found by solving equations (5) and (6) in terms of a and b.

The relationship of wind speed and migratory behavior is significant (Clark 1983) and assumed to be linear. The following expression quantifies the relationship of wind speed and migratory behavior:

$$\lambda_t = \beta_0 + \beta_1 w_t \tag{10}$$

where w_t is the average wind speed on day t (or $t-1$ for years 1979-1981), and β_0 and β_1 are constants to be estimated. The variable λ_t approximates the proportion of the offshore population which initiates upstream migration, becoming vulnerable to the test fishery. The abundance of the offshore population is quantified by its migratory time density (equation 3). It should be noted that the linear relationship used in the following analysis does not imply a direct dependence of migration on wind. Wind speed, like calendar day, is a convenient covariate of other factors responsible for the inhibition or stimulation of migration.

Daily proportion of total catch can now be quantified as a product of the inherent time density distribution of the population (Equation 3 or 4), and the effect of

daily wind speed (Equation 10) and commercial effort. Commercial effort, f_t, is defined as the proportion of day t open to commercial fishing. The time density of the population characterizes the proportion of the total population that is 'present and able' to enter the lower river. The effect of wind speed and removal of fish down river from the test nets modify the distribution of catch as measured by the test fishery. The number of chinook salmon, $N(t)$, which migrate into the lower river on any given day, t, is assumed to be a percent of the sum of the daily increase in offshore numbers (λ_t) due to either offshore arrivals of physiological maturation $(Y'(t)$ of equation 3) and the number remaining behind on day $t-1$ $(R'(t-1))$:

$$N(t) = \lambda_t[R'_{t-1} + Y'(t)N_T] \tag{11}$$

where N_T is the total abundance of the population. Cursory inspection of the temporal distribution of test fishery catch reveals that large immigration of chinook salmon into the lower Yukon River is a one or two day phenomenon, usually followed by exceptionally low abundance of migrants. It is suggested that the "offshore pool" of chinook salmon physiologically ready to migrate up river is temporally depleted after a peak in migratory activity. The proportional compliment of equation (11) is derived by dividing equation (11) by N_T:

$$N(t)N_T = \lambda_t[R'_{t-1}/NT + Y'(t)] \tag{12}$$

Note that $R'(t-1)$ is equivalent to $(1-\lambda_t)$ of the potential immigrants on day $t-1$. Defining R_{t-1} as R'_{t-1}/N_T, and constraining the values of λ_t to the interval $[0,1]$ (i.e., $0 < \beta_0 + \beta_1 w_t < 1$), the equation quantifying the proportion of total abundance present in the lower Yukon delta on day t,

$$N(t)/N_T = (\beta_0 + \beta_1 w_t)(R_{t-1} + Y'(t)] \qquad (13)$$

satisfies the criteria of a probability density function. The sum of $(\beta_0 + \beta_1 w_{t-1})[R_{t-1} + Y'(t)]$ equals one over the interval $-\infty$ to $+\infty$, and all values of $N(t)/N_T$ lie in the interval $[0,1]$.

The test fishery catch $C(t)$ is a function of the number of fish migrating up the Yukon River and the commercial effort surrounding the test fishery sites on day t. Given that the test fishery catch is directly proportional to daily abundance in the lower river on days of no commercial effort, and directly proportional to a fraction of the total abundance on days of commercial effort, the fraction being a linear function of effort $(qf_t$ where q is referred to as catchability$)$, the following relationship can be derived:

$$C(t)/C_T = [1-qf_t][N(t)/N_T] \qquad (14)$$

where constants and variables have been previously defined. Equating equation (13) to equation (14) we obtain:

$$[C(t)/C_T]/(1-qf_t) = N(t)/N_T = (\beta_0 + \beta_1 w_t)[R_{t-1}/N_T + Y'(t)] \qquad (15)$$

The method of maximum likelihood can be utilized to obtain estimates for the parameters a, b, β_0, β_1, and q. Letting $Z(t) = [C(t)/C_T]/(1-qf_t)$, the natural logarithm of the likelihood function, $Ln\ L$, is:

$$Ln\ L = Z(1)(\lambda_1)(Y'(1) + R_0) + Z(2)(\lambda_2)(Y'(2) + R_1) +\ldots+$$
$$Z(t)(\lambda_t)(Y'(t) + R_{t-1}) +\ldots+ Z(n)(\lambda_n)(Y'(n) + R_{n-1}) \qquad (16)$$

where n is the total number of observations.

To develop an expression for R_0, which is a function of the migratory history of the population before the test fishery initiates in a given year, we can regress backwards in time:

$$R_0 = (1-\lambda_0)[Y(0) + R_{-1}] \tag{17}$$

Since

$$R_{-1} = (1-\lambda_{-1})[Q(-1) + R_{-2}] \tag{18}$$

the expression for R_{-1} can be substituted into equation (17) in place of R_{-1},

$$R_0 = (1-\lambda_0)[Y'(t)(0)] + (1-\lambda_{-1})[Y'(t)(-1) + R_{-2}] \tag{19}$$

Therefore, if equation (13) is expanded backwards in time to $t = -\infty$, it is shown by induction that:

$$R_0 = \sum_{t=-\infty}^{0} Y'(t) \prod_{k=t}^{0} (1-\lambda_k) \tag{20}$$

Equation (2) can be simplified by either assuming that all the chinook salmon arriving offshore during time interval $[-\infty,0]$ which are physiologically able have immigrated the day before nets were set (day 1) (i.e., at $t = 0$, $\lambda_t = 1$), and $R_0 = 0$), or no chinook salmon have entered the lower Yukon delta prio to day 1 (i.e., at $t=0$, $\lambda_{-\infty}$ to $\lambda_0 = 0$), and

$$\prod_{k=t}^{0} (1-\lambda_k) = 1 \tag{21}$$

Therefore, under the second assumption, the number of chinook salmon remaining in the 'offshore pool' on day 1 is

$$R_0 = \sum_{t=-\infty}^{0} Y'(t) \tag{22}$$

$Y'(t)$ can be integrated exactly over the interval of $-\infty$ to 0:

$$R_0 = 1/(1+\exp(-(a))) \tag{23}$$

The difference in parameter values assuming either total offshore depletion or assuming total offshore retention is minimal. The latter assumption is considered to be more relevant in view of (1) observations of other investigators that many salmon populations mill offshore for various period of time before ascending their home river, (2) the supposed difficulty in entering the Yukon River during ice breakup, and (3) the promptness of test net placement after breakup. Taking the partial serivative of equation (16) with respect to each of the parameters (a, b, β_0, β_1), setting the resulting expressions equal to zero, and solving for each of the parameters, equations are derived (see Clark 1983) which can be solved by iteration techniques. The value of q is not known but can be approximated by regressing the ratio of observed catch to expected catch ignoring the effect of commercial effort $[(C(t)/C_T)/Z(t)]$ against effort with a given intercept of one (when effort = 0, $C(t)/C_T = Z(t)$):

$$q = \frac{\sum_{t=1}^{n} (f_t)\left[\dfrac{C(t)/C_T}{\lambda_t(C_T)(Y'(t)+R_{t-1})} - 1\right]}{\sum_{t=1}^{n} (f_t)^2} \tag{24}$$

In the present analysis, equation (24) is solved by an iteration scheme which calculates a new q for the new parameter values.

RESULTS AND DISCUSSION

The estimated values of mean, variance, β_0, β_1, and q for the functions describing the entry pattern of Yukon River chinook salmon migration from 1980 to 1981 developed through equation (15) are presented in Table 15. Sum of squares are included within Table 15 for comparative purposes. Daily estimates of the total annual abundance of Yukon River chinook salmon can be calculated by combining the predicted daily proportion of the annual entry pattern with estimates of annual catchability (q). A running average of these values provides a family of total annual abundance estimates (Tables 16-29). However, post-season total abundance estimates are believed to be better approximated by dividing the average estimated abundance of chinook salmon in District 1 by the average proportion of total population estimated to be present in District 1 (t' defined as coded day of commercial catch):

$$N_T = \frac{\sum_{t'=1}^{n} \left[\frac{C(t')}{q f_{t'}} \right]}{\sum_{t'=1}^{n} \sum_{t=t'}^{t'+2.5} \lambda_t \left[R_{t-1} + Y'(t) \right]} \qquad (25)$$

This averaging method weights days of larger catch proportionally more than days of smaller catch. Annual total abundance estimates, averaged over the entire year, and the ranges of total abundance estimates based on daily catches are compared in Table 30. A comparison of these average estimates with commercial and subsistence catches and with tagging studies is presented in Table 31.

Table 15. The estimated value of the mean and variance of a homogeneous population migrating past the test fisheries, and the values of the coefficients quantifying the effect of wind speed (β_0 and β_1) and commercial effort (q) on the annual migrations of Yukon River chinook salmon[1].

Year	Site	Mean	Variance	B_0	B_1	q	Sum of Squares
1968	Flat Island	14.704	38.482	0.2434	.00000	0.3524	.0223267
1969	Flat Island	7.302	7.116	0.0735	.00433	0.2536	.0297612
1970	Flat Island	19.953	46.045	0.3688	.03752	0.2394	.0143960
1971	Flat Island	27.653	59.287	0.1146	.03131	0.1439	.0186809
1972	Flat Island	15.150	4.696	0.0320	.00590	0.5347	.0213226
1973	Flat Island	18.185	62.721	0.0000	.02874	0.3510	.0134308
1974	Flat Island	7.762	15.864	0.0145	.01242	0.2526	.0068396
1975	Flat Island	25.703	37.293	0.0000	.03415	0.4769	.0300980
1976	Flat Island	28.263	19.530	0.2618	.00773	0.4167	.0220395
1977	Flat Island	27.206	32.399	0.4614	.00424	0.2136	.0175581
1978	Flat Island	12.726	86.259	0.0597	.02354	0.6942	.0173667
1979	Big Eddy	5.247	20.923	0.0443	.00491	0.3583	.0363204
1980	Big Eddy	13.115	50.602	0.0137	.02329	0.4496	.0067951
1980	Middle Mouth	16.801	62.846	0.0292	.01726	0.5957	.0101368
1980	Total Test Fishery	15.433	62.506	0.0268	.01856	0.5313	.0067193
1981	Big Eddy	4.550	7.509	0.0048	.00936	0.6332	.0069554
1981	Middle Mouth	13.627	74.399	0.2659	.01025	0.6823	.0113025
1981	Total Test Fishery	4.964	8.829	0.0267	.00748	0.6935	.0059759

[1] The derivation of the inverted exponential function, linearly fitted by wind (equation 15) is fitted to observed test fishery catch data by maximization of its function (equation 16).

Table 16. Total Yukon River chinook salmon abundance estimates for 1968.

Coded Day	Commercial Catch in District 1	Cumulative Commercial Catch	Commercial Effort (days)	Wind Speed (mi/hr)	Estimated Abundance	Running Average of Estimated Abundance
1	0	0	0.00	7.10	0	0
2	0	0	0.00	5.80	0	0
3	1	1	0.25	3.50	846	846
4	23	24	1.00	7.50	4021	2433
5	38	62	0.25	9.80	21740	8869
6	11	73	0.25	8.30	6907	8378
7	508	581	1.00	9.50	43288	15360
8	825	1406	0.75	6.90	83678	26747
9	0	1406	0.00	8.20	0	26747
10	29	1435	0.25	6.30	5008	23641
11	5982	7417	1.00	6.20	217237	47841
12	3863	11280	0.25	9.60	546826	103284
13	180	11460	0.25	11.40	114469	104402
14	8959	20419	1.00	9.10	254760	118071
15	5278	25697	0.75	5.80	231108	127491
16	0	25697	0.00	8.60	0	127491
17	184	25881	0.25	7.60	14945	118833
18	3365	29246	1.00	8.50	68318	115225
19	2555	31801	0.25	9.50	228976	122809
20	568	32369	0.25	7.50	89037	120698
21	9800	42169	1.00	7.90	232651	127283
22	14839	57008	0.75	6.30	533215	149835
23	0	57008	0.00	9.80	0	149835
24	265	57273	0.25	10.50	29029	143477
25	9423	66696	1.00	8.30	293953	151001
26	4108	70804	0.25	8.50	703618	177316
27	436	71240	0.25	11.90	269442	181503
28	3621	74861	1.00	11.80	256137	184748
29	3005	77866	0.75	12.90	320763	190416
30	0	77866	0.00	10.40	0	190416
31	13	77879	0.25	9.10	4621	182984
32	1030	78909	1.00	5.80	114826	180362
33	545	79454	0.25	6.00	356762	186896
34	0	79454	0.00	8.20	0	186896

Estimation is based on commercial catch data of District 1, and assumes a 2-1/2 day time of passage through the district. Total abundance is estimated using a single day's catch.

Table 17. Total Yukon River chinook salmon abundance estimates for 1969.

Coded Day	Commercial Catch in District 1	Cumulative Commercial Catch	Commercial Effort (days)	Wind Speed (mi/hr)	Estimated Abundance	Running Average of Estimated Abundance
1	0	0	0.00	8.80	0	0
2	53	53	0.25	11.50	211134	211134
3	2107	2160	1.00	11.80	790769	500951
4	1687	3847	0.25	11.70	1342540	781480
5	49	3896	0.25	13.20	115336	614944
6	2205	6101	1.00	13.20	157859	523527
7	1997	8098	0.75	11.70	130905	458090
8	0	8098	0.00	17.10	0	458090
9	1889	9987	0.25	18.00	172269	417258
10	9970	19957	1.00	14.40	204781	390699
11	6856	26813	0.25	12.90	604037	414403
12	598	27411	0.25	11.90	145545	387517
13	8827	36238	1.00	10.10	260930	376009
14	5422	41660	0.75	8.10	270166	367189
15	0	41660	0.00	11.10	0	367189
16	563	42223	0.25	8.60	82072	345257
17	3653	45876	1.00	12.70	149606	331282
18	2040	47916	0.25	11.20	408611	336437
19	1037	48953	0.25	11.70	268399	332185
20	9372	58325	0.75	9.90	748528	356675
21	0	58325	0.00	7.10	0	356675
22	0	58325	0.00	5.80	0	356675
23	821	59146	0.25	3.70	328509	355111
24	7164	66310	0.75	9.10	1104850	394571
25	0	66310	0.00	11.20	0	394571
26	230	66540	0.25	6.80	109613	380323
27	2088	68628	1.00	9.60	292206	376127
28	1958	70586	0.75	10.10	505767	382019
29	0	70586	0.00	10.60	0	382019

Estimation is based on commercial catch data of District 1, and assumes a 2-1/2 day time of passage through the district. Total abundance is estimated using a single day's catch.

Table 18. Total Yukon River chinook salmon abundance estimates for 1970.

Coded Day	Commercial Catch in District 1	Cumulative Commercial Catch	Commercial Effort (days)	Wind Speed (mi/hr)	Estimated Abundance	Running Average of Estimated Abundance
5	0	0	0.00	8.80	0	0
6	9	9	0.25	15.20	12470	12470
7	0	9	0.00	9.90	0	12470
8	18	27	0.75	6.30	4893	8682
9	224	251	0.25	7.60	158428	58597
10	230	481	1.00	9.60	35862	52914
11	70	551	0.25	11.50	34296	49190
12	1589	2140	0.25	7.80	464909	118477
13	906	3046	1.00	11.40	79801	112952
14	0	3046	0.00	8.90	0	112952
15	167	3213	0.75	12.40	9572	100029
16	3883	7096	0.25	8.10	621161	157933
17	1329	8425	1.00	19.60	73747	149514
18	1500	9925	0.25	13.20	213646	155344
19	7489	17414	0.25	15.40	833975	211897
20	15335	32749	1.00	13.10	560438	238708
21	0	32749	0.00	9.80	0	238708
22	249	32998	0.75	10.40	10607	222415
23	3483	36481	0.25	10.10	443736	237169
24	2801	39282	1.00	12.70	112315	229366
25	809	40091	0.25	16.50	144623	224381
26	10118	50209	0.75	14.50	463495	237665
27	0	50209	0.00	13.20	0	237665
28	0	50209	0.00	10.10	0	237665
29	240	50449	0.25	7.30	58286	228224
30	2906	53355	1.00	10.60	210837	227355
31	2446	55801	0.25	10.10	819469	255551
32	59	55860	0.25	8.60	133681	250011
33	1642	57502	0.75	7.90	337770	253827
34	0	57502	0.00	9.80	0	253827

Estimation is based on commercial catch data of District 1, and assumes a 2-1/2 day time of passage through the district. Total abundance is estimated using a single day's catch.

Table 19. Total Yukon River chinook salmon abundance estimates for 1971.

Coded Day	Commercial Catch in District 1	Cumulative Commercial Catch	Commercial Effort (days)	Wind Speed (mi/hr)	Estimated Abundance	Running Average of Estimated Abundance
11	2	2	1.00	18.00	1744	1744
12	26	28	0.75	17.00	20683	11214
13	0	28	0.00	6.00	0	11214
14	5	33	0.25	8.10	10695	11041
15	397	430	1.00	15.10	153736	46715
16	756	1186	0.25	14.50	724660	182304
17	169	1355	0.25	10.10	157966	178247
18	1426	2781	1.00	8.30	295264	194964
19	2313	5094	0.75	11.20	553485	239779
20	0	5094	0.00	10.10	0	239779
21	1023	6117	0.25	9.50	435558	261532
22	8669	14786	1.00	5.20	928545	328234
23	3389	18175	0.25	6.80	1531590	437629
24	1738	19913	0.25	7.80	792498	467202
25	9219	29132	1.00	5.30	756300	489440
26	11607	40739	0.75	6.00	1229770	542321
27	0	40739	0.00	6.80	0	542321
28	1484	42223	0.25	7.60	351980	529631
29	16203	58426	1.00	15.80	773935	544900
30	16910	75336	0.25	10.80	2892070	682969
31	722	76058	0.25	6.20	340921	663967
32	5441	81499	1.00	10.60	514525	656101
33	2898	84397	0.75	9.40	308999	638746
34	0	84397	0.00	12.10	0	638746
35	0	84397	0.00	5.80	0	638746
36	0	84397	0.00	8.20	0	638746
37	0	84397	0.00	9.10	0	638746
38	0	84397	0.00	10.10	0	638746
39	0	84397	0.00	8.20	0	638746
40	0	84397	0.00	8.20	0	638746
41	0	84397	0.00	9.80	0	638746
42	114	84511	0.25	15.70	67495	611544
43	363	84874	1.00	15.70	58716	586415
44	526	85400	0.75	15.20	144596	567206
45	12	85412	0.25	4.00	56724	545936
46	107	85519	1.00	6.00	108129	528423

Estimation is based on commercial catch data of District 1, and assumes a 2-1/2 day time of passage through the district. Total abundance is estimated using a single day's catch.

Table 20. Total Yukon River chinook salmon abundance estimates for 1972.

Coded Day	Commercial Catch in District 1	Cumulative Commercial Catch	Commercial Effort (days)	Wind Speed (mi/hr)	Estimated Abundance	Running Average of Estimated Abundance
9	7	7	1.00	10.00	44611	44611
10	36	43	0.75	7.30	95057	69834
11	0	43	0.00	13.40	0	69834
12	32	75	0.25	7.90	24176	54615
13	571	646	1.00	4.90	57546	55348
14	391	1037	0.25	6.60	106295	65537
15	422	1459	0.25	8.20	70634	66387
16	1355	2814	1.00	7.30	37020	62191
17	1734	4548	0.75	15.10	45845	60148
18	0	4548	0.00	11.10	0	60148
19	1953	6501	0.25	10.20	77665	62094
20	9809	16310	1.00	7.20	130401	68925
21	5181	21491	0.25	6.90	384787	97640
22	405	21896	0.25	8.20	160754	102899
23	6125	28021	1.00	7.50	160352	107319
24	9775	37796	0.75	9.40	300079	121087
25	0	37796	0.00	8.90	0	121087
26	925	38721	0.25	9.20	73957	117945
27	6013	44734	1.00	9.20	143280	119529
28	8476	53210	0.25	10.20	886785	164661
29	1204	54414	0.25	11.80	310354	172755
30	9244	63658	1.00	7.20	385951	183976
31	4401	68059	0.75	6.20	368156	193185
32	0	68059	0.00	8.90	0	193185
33	0	68059	0.00	12.80	0	193185
34	0	68059	0.00	8.30	0	193185
35	0	68059	0.00	6.50	0	193185
36	0	68059	0.00	9.10	0	193185
37	0	68059	0.00	8.90	0	193185
38	0	68059	0.00	7.50	0	193185
39	0	68059	0.00	8.60	0	193185
40	0	68059	0.00	7.20	0	193185
41	384	68443	1.00	11.80	29958	185413
42	531	68974	0.75	16.80	67634	180059
43	61	69035	0.25	7.30	52613	174518
44	336	69371	1.00	7.80	56929	169618
45	217	69588	0.75	5.50	65639	165459

Estimation is based on commercial catch data of District 1, and assumes a 2-1/2 day time of passage through the district. Total abundance is estimated using a single day's catch.

Table 21. Total Yukon River chinook salmon abundance estimates for 1973.

Coded Day	Commercial Catch in District 1	Cumulative Commercial Catch	Commercial Effort (days)	Wind Speed (mi/hr)	Estimated Abundance	Running Average of Estimated Abundance
4	0	0	0.00	10.80	0	0
5	95	95	1.00	7.20	15552	15552
6	181	276	0.25	16.70	88146	51849
7	194	470	0.25	15.20	72366	58688
8	1105	1575	1.00	8.60	83888	64988
9	1189	2764	0.75	9.60	160083	84007
10	0	2764	0.00	8.50	0	84007
11	233	2997	0.25	11.50	54763	79133
12	4204	7201	1.00	4.80	228802	100514
13	2182	9383	0.25	5.90	554969	157321
14	397	9780	0.25	9.10	204623	162577
15	3611	13391	1.00	10.80	154677	161787
16	8142	21533	0.75	20.70	263966	171076
17	0	21533	0.00	20.30	0	171076
18	1333	22866	0.25	10.20	88213	164171
19	5874	28740	1.00	6.20	172385	164803
20	1847	30587	0.25	7.10	436919	184239
21	893	31480	0.25	8.60	250646	188667
22	4177	35657	1.00	13.10	143244	185828
23	6909	42566	0.75	9.50	252523	189751
24	0	42566	0.00	7.60	0	189751
25	1211	43777	0.25	6.80	159886	188092
26	6075	49852	1.00	4.60	262154	191990
27	2938	52790	0.25	7.30	623599	213570
28	0	52790	0.00	4.50	0	213570
29	0	52790	0.00	6.50	0	213570
30	0	52790	0.00	9.10	0	213570
31	0	52790	0.00	7.10	0	213570
32	0	52790	0.00	10.50	0	213570
33	0	52790	0.00	6.80	0	213570
34	0	52790	0.00	15.10	0	213570
35	138	52928	0.25	18.70	26635	204669
36	1249	54177	1.00	14.80	60603	198120
37	1231	55408	0.75	10.20	160101	196467
38	0	55408	0.00	6.50	0	196467
39	50	55458	0.25	11.90	56223	190623
40	358	55816	1.00	9.60	123202	187926
41	209	56025	0.75	10.20	141141	186127
42	38	56063	0.25	7.60	173107	185645
43	188	56251	1.00	8.10	181428	185494
44	177	56428	0.75	9.10	287012	188995

Estimation is based on commercial catch data of District 1, and assumes a 2-1/2 day time of passage through the district. Total abundance is estimated using a single day's catch.

Table 22. Total Yukon River chinook salmon abundance estimates for 1974.

Coded Day	Commercial Catch in District 1	Cumulative Commercial Catch	Commercial Effort (days)	Wind Speed (mi/hr)	Estimated Abundance	Running Average of Estimated Abundance
2	0	0	0.00	10.80	0	0
3	209	209	0.25	8.20	127415	127415
4	1668	1877	1.00	7.80	195570	161492
5	1621	3498	0.25	10.50	564722	295902
6	736	4234	0.25	6.60	228414	279030
7	2675	6909	1.00	10.60	149555	253135
8	4052	10961	0.25	11.70	603813	311582
9	0	10961	0.00	16.30	0	311582
10	3409	14370	0.25	14.10	270740	305747
11	8046	22416	1.00	14.50	163395	287953
12	3247	25663	0.25	14.40	314321	290883
13	1588	27251	0.25	6.20	209860	282781
14	5193	32444	1.00	7.90	197018	274984
15	4333	36777	0.25	6.90	840467	322108
16	0	36777	0.00	10.50	0	322108
17	2984	39761	0.25	11.10	473271	333736
18	11234	50995	1.00	7.50	474917	343820
19	4627	55622	0.25	8.20	1098290	394118
20	128	55750	0.25	8.10	292849	387789
21	1385	57135	1.00	11.10	172715	375137
22	1326	58461	0.25	9.20	398828	376454
23	0	58461	0.00	12.20	0	376454
24	528	58989	0.25	10.20	180974	366165
25	4491	63480	1.00	4.80	475774	371646
26	2176	65656	0.25	5.20	1615360	430870
27	343	65999	0.25	6.90	716588	443857
28	2308	68307	1.00	8.20	645426	452621
29	1150	69457	0.25	13.40	994929	475217
30	0	69457	0.00	17.70	0	475217
31	0	69457	0.00	14.00	0	475217
32	0	69457	0.00	10.40	0	475217
33	0	69457	0.00	7.20	0	475217
34	91	69548	0.25	6.50	174615	463193

-Continued-

Table 22. Total Yukon River chinook salmon abundance estimates for 1974 (continued).

Coded Day	Commercial Catch in District 1	Cumulative Commercial Catch	Commercial Effort (days)	Wind Speed (mi/hr)	Estimated Abundance	Running Average of Estimated Abundance
35	441	69989	1.00	6.80	305055	457111
36	255	70244	0.25	7.90	842228	471374
37	0	70244	0.00	8.90	0	471374
38	30	70274	0.25	8.20	92179	457832
39	222	70496	1.00	11.50	185664	448447
40	105	70601	0.25	9.10	424613	447652
41	49	70650	0.25	8.60	270946	441952
42	113	70763	1.00	15.40	173706	433569
43	61	70824	0.25	6.80	346367	430927
44	0	70824	0.00	8.30	0	430927
45	10	70834	0.25	7.80	94134	421021

Estimation is based on commercial catch data of District 1, and assumes a 2-1/2 day time of passage through the district. Total abundance is estimated using a single day's catch.

Table 23. Total Yukon River chinook salmon abundance estimates for 1975.

Coded Day	Commercial Catch in District 1	Cumulative Commercial Catch	Commercial Effort (days)	Wind Speed (mi/hr)	Estimated Abundance	Running Average of Estimated Abundance
10	104	104	1.00	8.30	122357	122357
11	96	200	0.25	11.40	268304	195330
12	6	206	0.25	15.00	39671	143444
13	284	490	1.00	8.20	76184	126629
14	156	646	0.25	8.80	144232	130150
15	0	646	0.00	9.80	0	130150
16	40	686	0.25	9.50	16060	111135
17	692	1378	1.00	6.50	56296	103301
18	352	1730	0.25	7.30	118617	105215
19	889	2619	0.25	10.40	198476	115577
20	3822	6441	1.00	8.30	151124	119132
21	915	7356	0.25	12.80	146939	121660
22	0	7356	0.00	12.20	0	121660
23	2827	10183	0.25	11.10	186747	127084
24	10697	20880	1.00	11.70	196725	132441
25	3579	24459	0.25	12.40	314242	145427
26	2999	27458	0.25	10.40	265777	153450
27	6809	34267	0.75	5.30	192963	155920
28	0	34267	0.00	12.20	0	155920
29	0	34267	0.00	12.10	0	155920
30	1449	35716	0.25	14.00	65117	150578
31	5834	41550	0.75	10.80	107850	148205
32	0	41550	0.00	8.30	0	148205
33	44	41594	0.25	9.60	3791	140604
34	1176	42770	0.75	7.30	39836	135565
35	0	42770	0.00	5.90	0	135565
36	0	42770	0.00	10.80	0	135565
37	242	43012	0.25	18.60	26318	130363
38	983	43995	1.00	14.80	25964	125618
39	223	44218	0.25	15.70	44896	122108
40	148	44366	0.25	8.50	76243	120197
41	326	44692	1.00	6.20	57885	117705
42	121	44813	0.25	6.20	174735	119898
43	27	44840	0.25	6.60	100013	119162
44	94	44934	1.00	9.20	52454	116779
45	0	44934	0.00	6.00	0	116779

Estimation is based on commercial catch data of District 1, and assumes a 2-1/2 day time of passage through the district. Total abundance is estimated using a single day's catch.

Table 24. Total Yukon River chinook salmon abundance estimates for 1976.

Coded Day	Commercial Catch in District 1	Cumulative Commercial Catch	Commercial Effort (days)	Wind Speed (mi/hr)	Estimated Abundance	Running Average of Estimated Abundance
13	0	0	0.00	6.20	0	0
14	16	16	0.25	7.10	586636	586636
15	78	94	1.00	7.20	357846	472241
16	44	138	0.25	9.60	431627	458703
17	115	253	0.25	7.50	525096	475301
18	1667	1920	1.00	7.50	967091	573659
19	1345	3265	0.25	8.10	1935890	800698
20	0	3265	0.00	7.30	0	800698
21	214	3479	0.25	13.50	94821	699859
22	4412	7891	1.00	10.60	316442	651932
23	5014	12905	0.25	7.50	1073770	698803
24	2831	15736	0.25	6.90	562561	685178
25	9137	24873	1.00	6.60	348705	654590
26	3394	28267	0.25	8.30	401727	633518
27	0	28267	0.00	9.40	0	633518
28	1741	30008	0.25	6.50	102037	592635
29	6984	36992	1.00	8.30	102251	557607
30	5119	42111	0.25	8.60	300599	540473
31	2512	44623	0.25	11.50	176998	517756
32	11769	56392	0.75	11.80	220157	500250
33	0	56392	0.00	21.00	0	500250
34	0	56392	0.00	13.20	0	500250
35	695	57087	0.25	8.90	42453	474817
36	2081	59168	0.75	6.80	65842	453292
37	0	59168	0.00	5.90	0	453292
38	299	59467	0.25	8.10	42017	432728
39	954	60421	0.75	7.50	61424	415047
40	0	60421	0.00	6.20	0	415047
41	0	60421	0.00	6.50	0	415047
42	271	60692	0.25	12.50	114716	401396
43	607	61299	1.00	12.50	100871	388330
44	231	61530	0.25	13.40	244806	382349
45	116	61646	0.25	7.50	237012	376536
46	248	61894	1.00	6.00	181914	369050

Estimation is based on commercial catch data of District 1, and assumes a 2-1/2 day time of passage through the district. Total abundance is estimated using a single day's catch.

Table 25. Total Yukon River chinook salmon abundance estimates for 1977.

Coded Day	Commercial Catch in District 1	Cumulative Commercial Catch	Commercial Effort (days)	Wind Speed (mi/hr)	Estimated Abundance	Running Average of Estimated Abundance
10	0	0	0.00	9.40	0	0
11	2	2	0.25	9.20	30519	30519
12	0	2	0.00	6.20	0	30519
13	4	6	0.25	8.20	22195	26357
14	35	41	0.75	6.80	41386	31367
15	0	41	0.00	6.20	0	31367
16	129	170	0.25	6.30	194335	72109
17	1345	1515	1.00	5.00	355524	128792
18	1106	2621	0.25	5.90	867404	251894
19	0	2621	0.00	6.10	0	251894
20	1590	4211	0.25	7.20	630133	305928
21	8804	13015	0.75	9.20	917471	382371
22	0	13015	0.00	10.60	0	382371
23	3574	16589	0.25	10.40	698904	417541
24	14029	30618	1.00	9.20	613842	437171
25	8668	39286	0.25	4.80	1409100	525529
26	0	39286	0.00	7.60	0	525529
27	3274	42560	0.25	8.80	396988	514817
28	14425	56985	0.75	10.90	560659	518343
29	0	56985	0.00	15.40	0	518343
30	2025	59010	0.25	16.70	217992	496890
31	6735	65745	0.75	14.50	262743	481280
32	0	65745	0.00	17.00	0	481280
33	0	65745	0.00	7.30	0	481280
34	543	66288	0.25	10.20	84625	456489
35	1408	67696	0.75	10.10	91623	435026
36	0	67696	0.00	11.70	0	435026
37	219	67915	0.25	14.20	56284	413985
38	387	68302	1.00	7.50	35013	394039
39	53	68355	0.25	7.60	36297	376152
40	0	68355	0.00	6.90	0	376152
41	75	68430	0.25	9.10	58325	361017
42	373	68803	0.75	11.90	137272	350847
43	0	68803	0.00	13.70	0	350847
44	55	68858	0.25	6.90	122084	340901
45	183	69041	1.00	7.10	168357	333711

Estimation is based on commercial catch data of District 1, and assumes a 2-1/2 day time of passage through the district. Total abundance is estimated using a single day's catch.

Table 26. Total Yukon River chinook salmon abundance estimates for 1978.

Coded Day	Commercial Catch in District 1	Cumulative Commercial Catch	Commercial Effort (days)	Wind Speed (mi/hr)	Estimated Abundance	Running Average of Estimated Abundance
7	0	0	0.00	12.00	0	0
8	415	415	0.25	7.10	34511	34511
9	2052	2467	0.75	7.80	70089	52300
10	0	2467	0.00	13.50	0	52300
11	0	2467	0.00	7.80	0	52300
12	899	3366	0.25	7.10	56702	53767
13	4934	8300	0.75	6.50	138379	74920
14	0	8300	0.00	12.50	0	74920
15	4067	12367	0.25	16.50	196877	99311
16	8650	21017	1.00	13.20	116191	102125
17	4888	25905	0.25	15.10	309130	131697
18	0	25905	0.00	11.20	0	131697
19	1923	27828	0.25	14.00	109815	128962
20	5564	33392	0.75	7.30	148586	131142
21	0	33392	0.00	12.10	0	131142
22	2999	36391	0.25	11.10	239729	142001
23	7785	44176	1.00	11.50	179355	145397
24	3672	47848	0.25	6.60	478069	173119
25	0	47848	0.00	8.60	0	173119
26	1371	49219	0.25	13.80	152054	171499
27	3979	53198	0.75	10.80	153889	170241
28	0	53198	0.00	14.00	0	170241
29	448	53646	0.25	10.20	57897	162751
30	1065	54711	1.00	9.40	53147	155901
31	471	55182	0.25	10.10	155853	155898
32	0	55182	0.00	10.60	0	155898
33	165	55347	0.25	11.90	43208	149638
34	767	56114	0.75	7.50	88491	146420
35	0	56114	0.00	6.60	0	146420
36	99	56213	0.25	10.60	56296	141913
37	435	56648	1.00	11.20	72856	138625
38	130	56778	0.25	9.80	133681	138400
39	0	56778	0.00	10.10	0	138400
40	124	56902	0.25	13.20	124713	137805
41	335	57237	0.75	10.10	161293	138784
42	0	57237	0.00	11.10	0	138784
43	32	57269	0.25	9.20	74873	136227
44	226	57495	1.00	10.60	189135	138262

Estimation is based on commercial catch data of District 1, and assumes a 2-1/2 day time of passage through the district. Total abundance is estimated using a single day's catch

Table 27. Total Yukon River chinook salmon abundance estimates for 1979.

Coded Day	Commercial Catch in District 1	Cumulative Commercial Catch	Commercial Effort (days)	Wind Speed (mi/hr)	Estimated Abundance	Running Average of Estimated Abundance
3	0	0	0.00	5.90	0	0
4	840	840	0.25	7.50	170701	170701
5	5263	6103	0.75	6.30	324220	247460
6	0	6103	0.00	9.80	0	247460
7	1020	7123	0.25	6.60	124788	206569
8	3883	11006	0.75	6.60	154006	193429
9	0	11006	0.00	17.00	0	193429
10	0	11006	0.00	18.70	0	193429
11	4046	15052	0.25	15.50	261247	206992
12	15464	30516	0.75	11.10	395816	238463
13	0	30516	0.00	8.90	0	238463
14	929	31445	0.25	13.20	96018	218114
15	6418	37863	1.00	10.80	182770	213696
16	1921	39784	0.25	13.10	283223	221421
17	0	39784	0.00	13.40	0	221421
18	2620	42404	0.25	14.40	329246	232203
19	14089	56493	0.75	11.10	692855	274081
20	0	56493	0.00	7.90	0	274081
21	1650	58143	0.25	7.30	355200	280841
22	3647	61790	0.75	8.60	348309	286031
23	0	61790	0.00	9.80	0	286031
24	0	61790	0.00	12.20	0	286031
25	1554	63344	0.25	11.10	437370	296841
26	4388	67732	0.75	10.60	487181	309530
27	0	67732	0.00	11.10	0	309530
28	1094	68826	0.25	12.40	417790	316296
29	3135	71961	0.75	6.80	490641	326552
30	0	71961	0.00	10.20	0	326552
31	0	71961	0.00	10.40	0	326552
32	495	72456	0.25	13.40	284516	324216
33	985	73441	0.75	13.10	223806	318932
34	0	73441	0.00	17.70	0	318932
35	236	73677	0.25	12.80	157340	310852
36	1009	74686	1.00	13.10	204969	305810
37	384	75070	0.25	9.80	472910	313406
38	0	75070	0.00	10.20	0	313406
39	105	75175	0.25	7.80	143065	305999
40	371	75546	0.75	9.40	204861	301785
41	0	75546	0.00	8.80	0	301785
42	108	75654	0.25	10.10	197967	297633
43	180	75834	1.00	10.20	108528	290359
44	45	75879	0.75	7.90	88209	282872

Estimation is based on commercial catch data of District 1, and assumes a 2-1/2 day time of passage through the district. Total abundance is estimated using a single day's catch

Table 28. Total Yukon River chinook salmon abundance estimates for 1980.

Coded Day	Commercial Catch in District 1	Cumulative Commercial Catch	Commercial Effort (days)	Wind Speed (mi/hr)	Estimated Abundance	Running Average of Estimated Abundance
8	0	0	0.00	10.10	0	0
9	1744	1744	0.25	10.50	243656	243656
10	5072	6816	0.75	13.40	220090	231873
11	0	6816	0.00	10.10	0	231873
12	3401	10217	0.25	14.00	292332	252026
13	14271	24488	1.00	11.90	324429	270127
14	6099	30587	0.25	5.90	670569	350215
15	0	30587	0.00	8.60	0	350215
16	4506	35093	0.25	12.90	387988	356511
17	10116	45209	0.75	12.20	253032	341728
18	0	45209	0.00	12.40	0	341728
19	5805	51014	0.25	20.00	308974	337634
20	14171	65185	1.00	21.00	200762	322426
21	6185	71370	0.25	8.30	427537	332937
22	0	71370	0.00	7.50	0	332937
23	2065	73435	0.25	9.80	243774	324831
24	2422	75857	0.75	11.90	109904	306921
25	0	75857	0.00	8.80	0	306921
26	984	76841	0.25	8.60	99013	290928
27	2016	78857	0.75	11.40	93004	276790
28	0	78857	0.00	12.90	0	276790
29	0	78857	0.00	6.50	0	276790
30	1206	80063	0.25	5.60	189121	270946
31	2372	82435	0.75	10.90	208667	267053
32	522	82957	0.25	9.10	202064	263230
33	2498	85455	1.00	6.30	205788	260039
34	221	85676	0.25	8.60	171256	255366
35	0	85676	0.00	17.00	0	255366
36	0	85676	0.00	8.80	0	255366
37	181	85857	0.25	6.80	55970	245397
38	657	86514	0.75	6.20	150900	240897
39	0	86514	0.00	5.30	0	240897
40	44	86558	0.25	5.90	44683	231978
41	463	87021	1.00	14.80	117249	226990
42	187	87208	0.25	16.70	198171	225789
43	0	87208	0.00	6.00	0	225789
44	67	87275	0.25	5.90	90304	220370
45	322	87597	0.75	6.80	347226	225249
46	0	87597	0.00	7.50	0	225249

Estimation is based on commercial catch data of District 1, and assumes a 2-1/2 day time of passage through the district. Total abundance is estimated using a single days's catch.

Table 29. Total Yukon River chinook salmon abundance estimates for 1981.

Coded Day	Commercial Catch in District 1	Cumulative Commercial Catch	Commercial Effort (days)	Wind Speed (mi/hr)	Estimated Abundance	Running Average of Estimated Abundance
4	0	0	0.00	14.10	0	0
5	2779	2779	0.25	10.10	161210	161210
6	8338	11117	0.75	5.90	167081	164146
7	0	11117	0.00	8.10	0	164146
8	3904	15021	0.25	8.20	192074	173455
9	11711	26732	0.75	7.20	199549	179979
10	0	26732	0.00	9.20	0	179979
11	3621	30353	0.25	6.90	160410	176065
12	10862	41215	0.75	9.60	191297	178604
13	0	41215	0.00	9.60	0	178604
14	0	41215	0.00	8.60	0	178604
15	4576	45791	0.25	8.90	250848	188924
16	13728	59519	0.75	10.20	326672	206143
17	0	59519	0.00	9.90	0	206143
18	7130	66649	0.25	14.80	461332	234497
19	21389	88038	0.75	8.30	580186	269066
20	0	88038	0.00	7.60	0	269066
21	0	88038	0.00	4.80	0	269066
22	1039	89077	0.25	6.00	153653	258574
23	3118	92195	0.75	8.50	199904	253685
24	0	92195	0.00	6.30	0	253685
25	725	92920	0.25	11.40	112784	242846
26	2176	95096	0.75	12.20	131733	234910
27	0	95096	0.00	6.50	0	234910
28	0	95096	0.00	10.60	0	234910
29	387	95483	0.25	12.50	83697	224829
30	1163	96646	0.75	8.90	94831	216704
31	0	96646	0.00	8.60	0	216704
32	294	96940	0.25	7.10	93418	209452
33	884	97824	0.75	8.80	124975	204759
34	0	97824	0.00	14.40	0	204759
35	0	97824	0.00	14.00	0	204759
36	165	97989	0.25	9.20	55965	196927
37	496	98485	0.75	8.10	86815	191422
38	0	98485	0.00	11.10	0	191422
39	85	98570	0.25	13.50	50326	184703
40	257	98827	0.75	8.30	60443	179055
41	0	98827	0.00	8.10	0	179055
42	0	98827	0.00	8.10	0	179055
43	47	98874	0.25	9.50	49647	173428
44	139	99013	0.75	6.30	63288	168839
45	0	99013	0.00	8.10	0	168839
46	24	99037	0.25	6.30	37687	163593

Estimation is based on commercial catch data of District 1, and assumes a 2-1/2 day time of passage through the district. Total abundance is estimated using a single day's catch.

Table 30. Summary of total abundance estimates.

Year	Final Running Average of Total Abundance Estimates	Lowest Annual Estimate	Highest Abundance Estimate	Estimated Total Abundance
1968	186,896	846	703,618	213,860
1969	382,019	82,072	1,342,560	301,862
1970	253,827	4,893	833,975	298,987
1971	528,423	1,744	2,892,070	806,708
1972	165,459	24,176	886,785	196,733
1973	188,995	15,552	623,599	205,114
1974	421,021	92,179	1,615,360	385,678
1975	116,779	3,791	314,242	134,697
1976	389,050	42,017	1,935,790	225,265
1977	333,711	22,195	1,409,100	432,879
1978	138,262	34,511	478,069	167,733
1979	282,872	88,209	692,855	302,759
1980	225,249	44,683	670,569	282,739
1981	163,593	37,587	580,186	240,066

Table 31. Estimated total abundance, observed catch, and estimated total abundance by tagging studies.

Year	Estimated Number	Alaskan Commercial Catch	Canadian Commercial Catch	Subsistence Catch	Sports Catch	Tagging Estimate
1968	213,860	106,526	2,212	15,006		190,000
1969	301,862	90,223	1,640	15,000		161,000
1970	298,987	80,269	2,611	15,974		227,000
1971	806,708	110,507	3,178	28,044		
1972	196,733	92,840	1,769	21,868		
1973	205,114	75,353	1,871	26,433		29,000
1974	385,678	97,919	2,214	23,343		11,100 36,700
1975	134,697	63,740	3,000	15,645		
1976	225,265	88,671	3,500	19,329		
1977	432,879	96,414	4,620	20,388	100	
1978	167,733	97,602	2,975	30,297	163	
1979	302,759	129,056	6,175	35,205	515	
1980	282,739	155,088	9,500	38,224	941	
1981	240,066	157,607	8,593	38,534		

[1] Total abundance estimate.

[2] Canadian stocks (above River mile 1,289).

Total abundance estimates are generally within the ragen of numbers of chinook believed by the authors to migrate up the Yukon River, and are corroborated by estimates derived from lower Yukon and upper Yukon River tagging studies (Table 31). Each annual estimate exceeds the observed number of chinook salmon documented in Alaskan and Canadian commercial, subsistence, and sports catch, and enumerated in stream escapement counts. The 1971 total abundance estimate calculated via our methods may be an outlier. The estimate of 806,708 chinook salmon is almost twice the magnitude of the next highest estimate; 432,879 in 1977. However, a total abundance estimate of 400,000 to 600,000 chinook salmon in 1967, which was estimated based on tagging returns, indicate that a run magnitude of 800,000 is in the range of possible values.

Escapement strength as calcualted by a combination of 5 index streams as continuously monitored from 1968 to 1981 and escapement calculated from our abundance estimates (total abundance minus commercial, subsistence, and sports catch) are poorly correlated (Table 32). The largest discrepancy between the independent measures of escapement strength occurs in later years (1978-1981) when our lower than average estimated escapements coincided with peak index stream counts.

The relationship of test fishery catch to commercial effort and the residence time in District 1 are principal components in the total abundance estimation methods. The change in estimates of total abundance as a result of varying values of residence time and catchability is graphically presented in Figures 3-16. Given longer residence times, the estimates of total abundance are smaller and relatively more sensitive to potential errors in set values of catchability *(q)*. Shorter residence times produce larger abundance estimates, and are relatively less sensitive to potential errors in set values of catchability *(q)* .

Table 32. Comparisons of estimated escapement and observed escapement of 5 index streams (Andreafsky River, Anvik River, Salcha River, Nisatlin River, and Whitehorse Dam counts).

Year	Estimated Escapement	Observed Index Escapement
1968	90,122	2,609
1969	194,999	1,701
1970	200,133	4,729
1971	664,979	4,836[1]
1972	80,256	4,454
1973	101,457	2,739
1974	262,202	2,934[2]
1975	52,312	3,751
1976	113,765	4,530
1977	311,357	6,417
1978	36,696	10,396
1979	131,808	10,474
1980	61,286	12,911
1981	35,332	9,998

[1] No data available for Anvik River in 1971.

[2] No data available for East Fork of Andreafsky River in 1974.

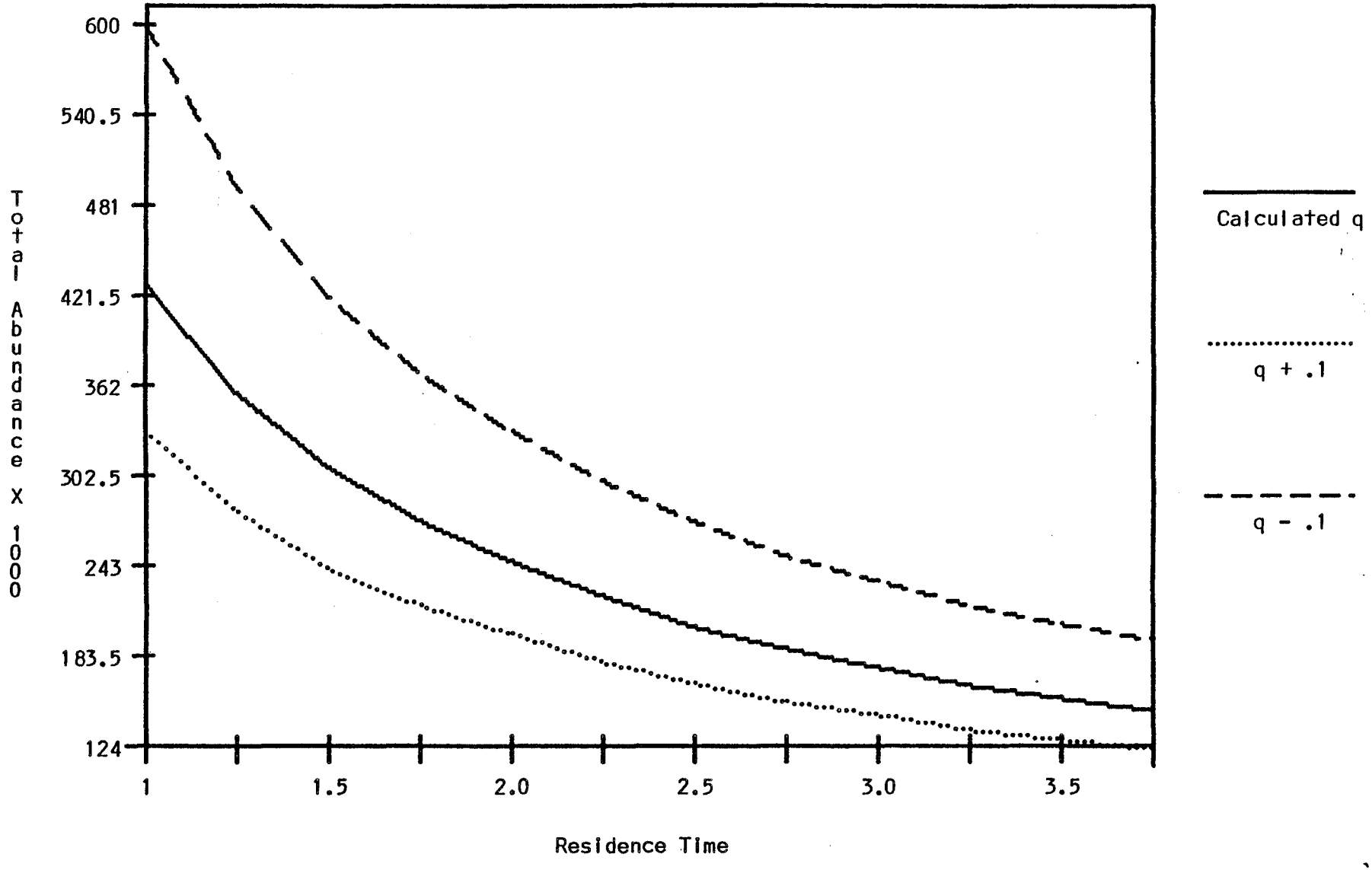

Figure 3. Abundance estimates for 1968.

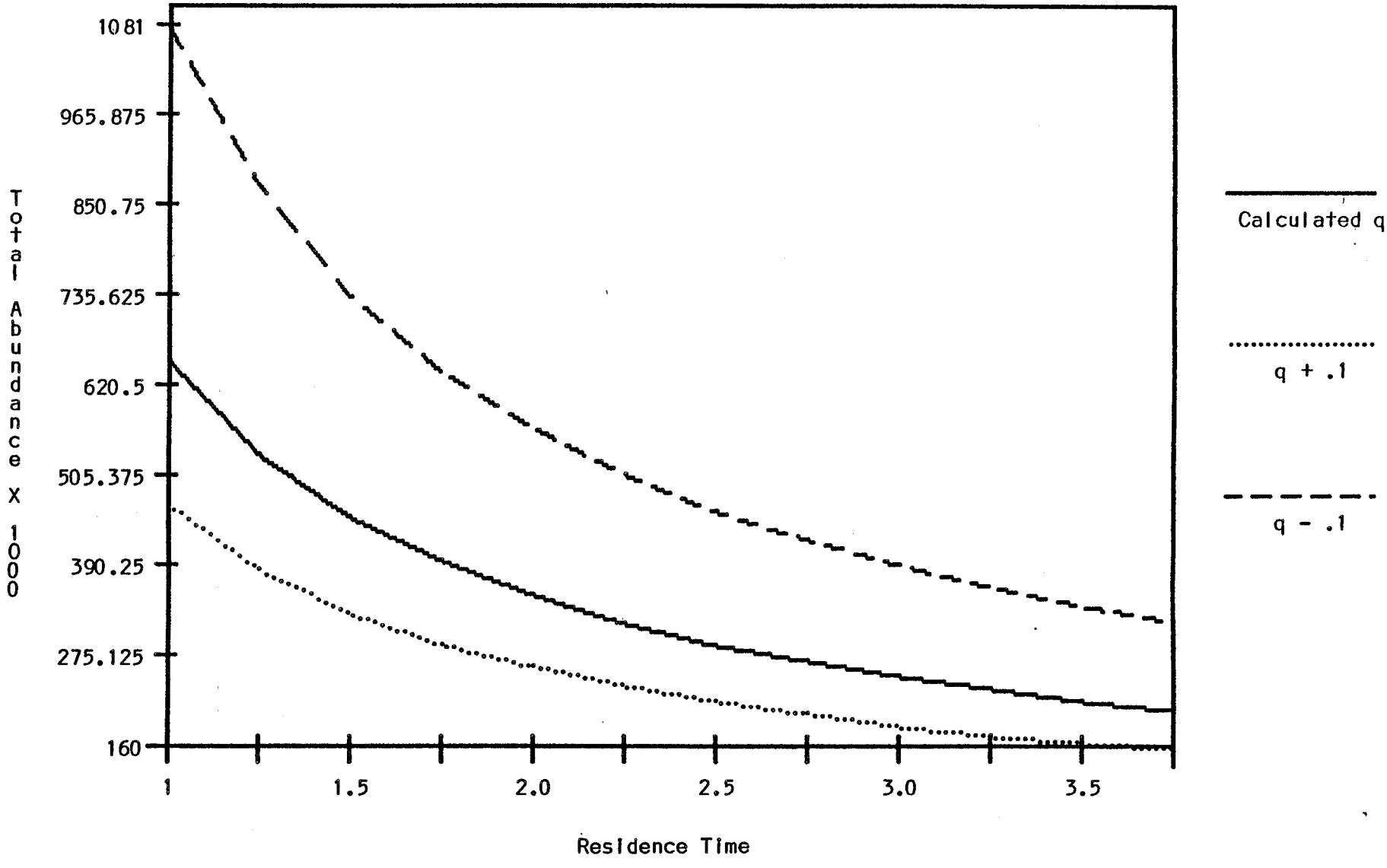

Figure 4. Abundance estimates for 1969.

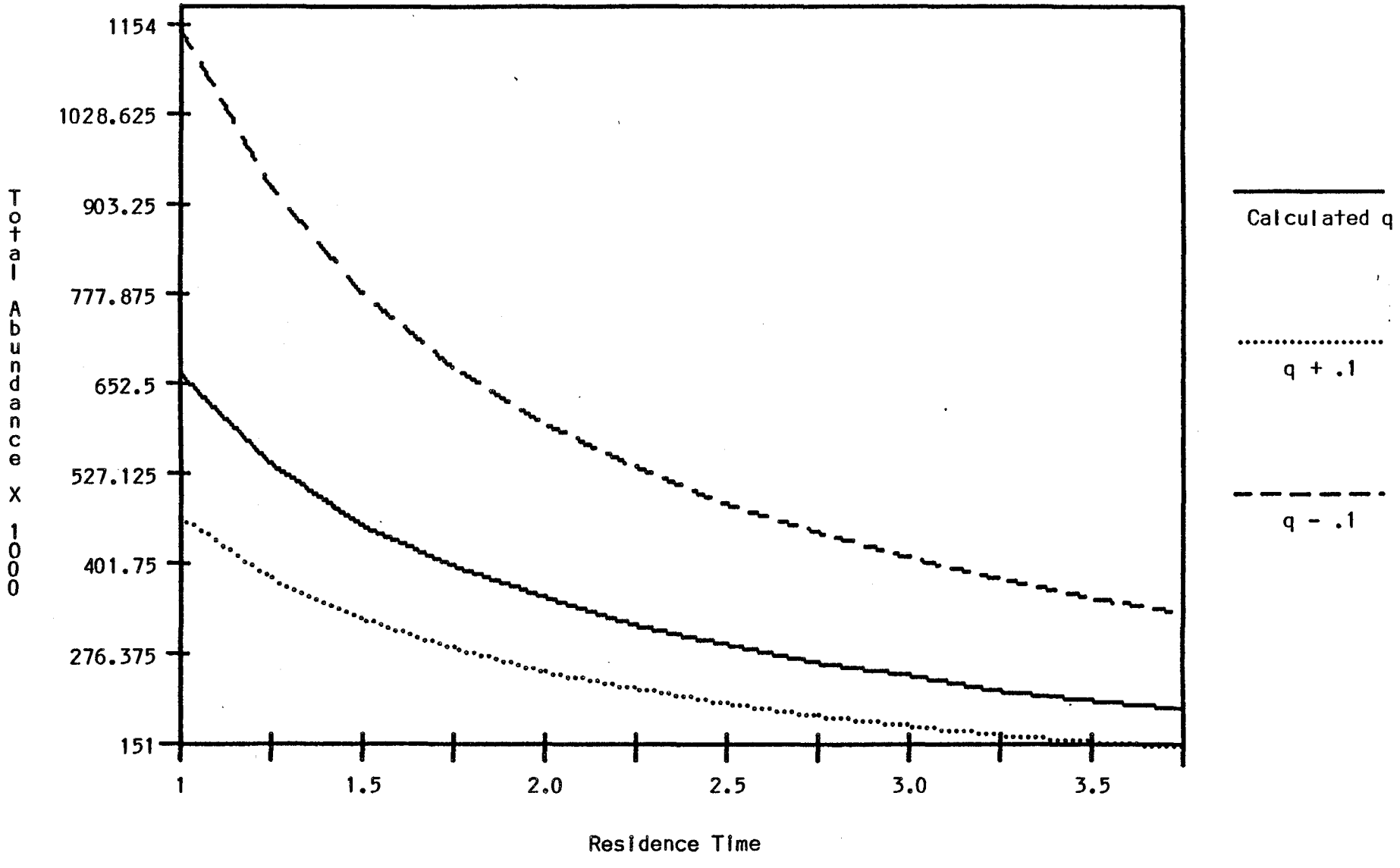

Figure 5. Abundance estimates for 1970.

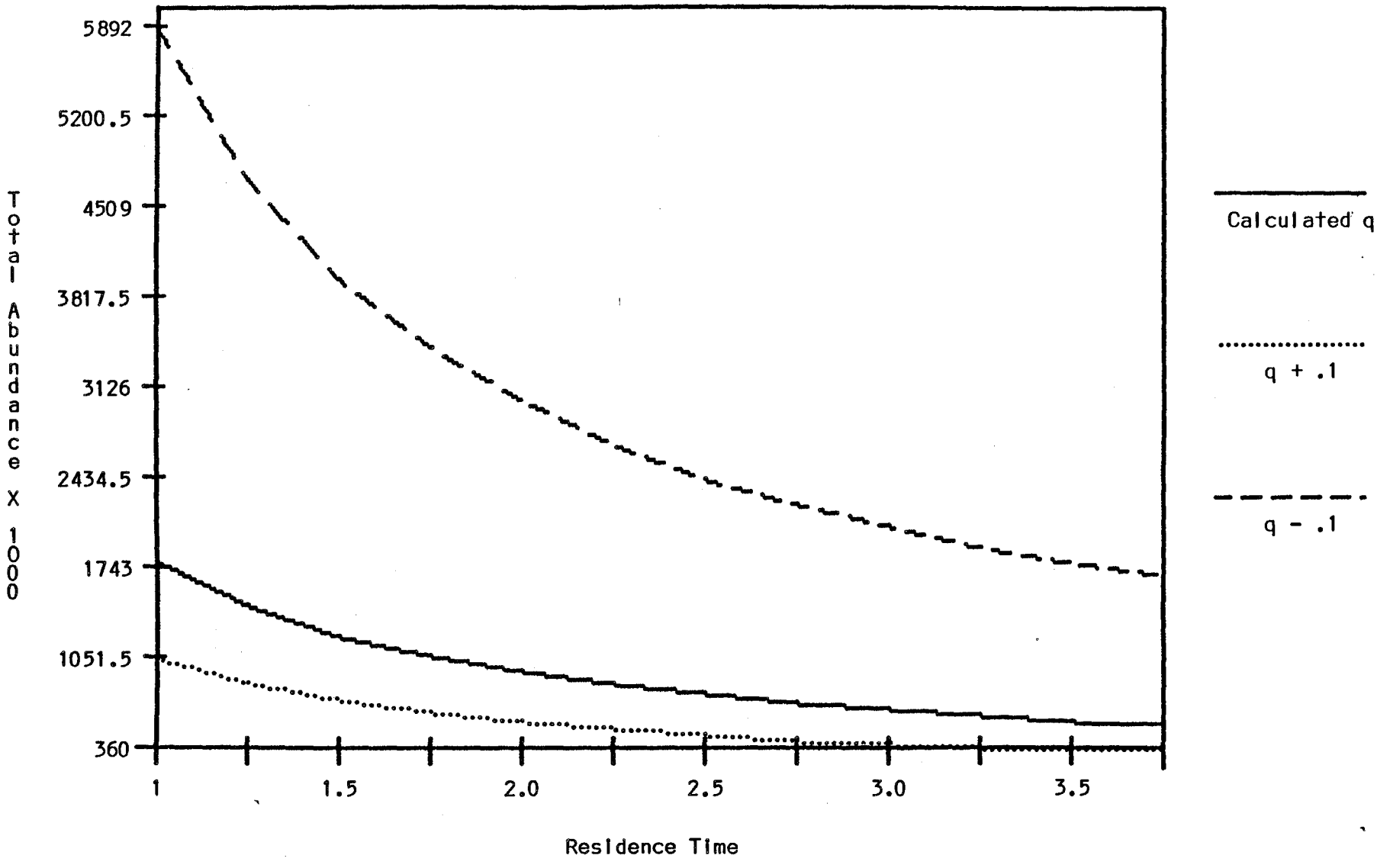

Figure 6. Abundance estimates for 1971.

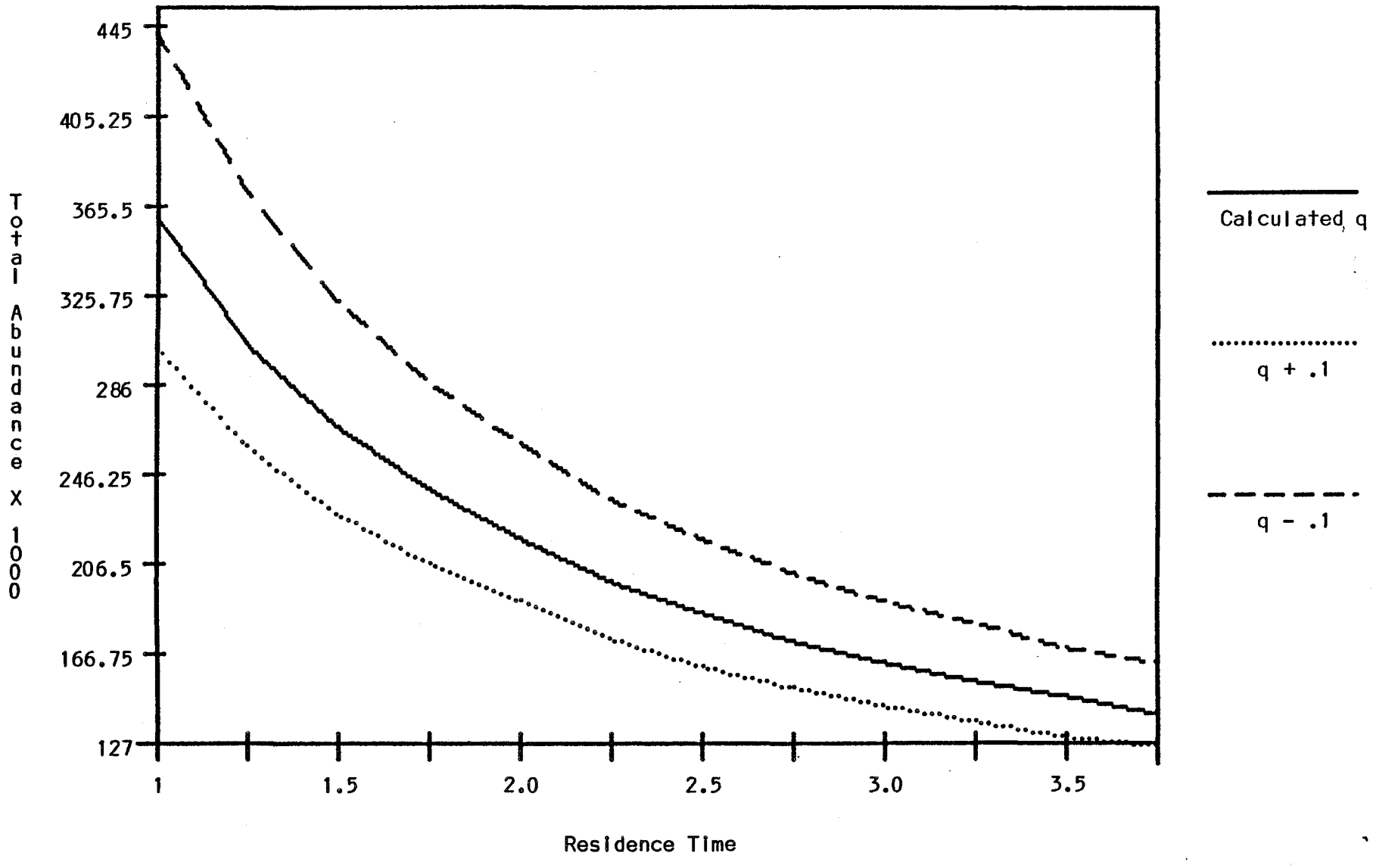

Figure 7. Abundance estimates for 1972.

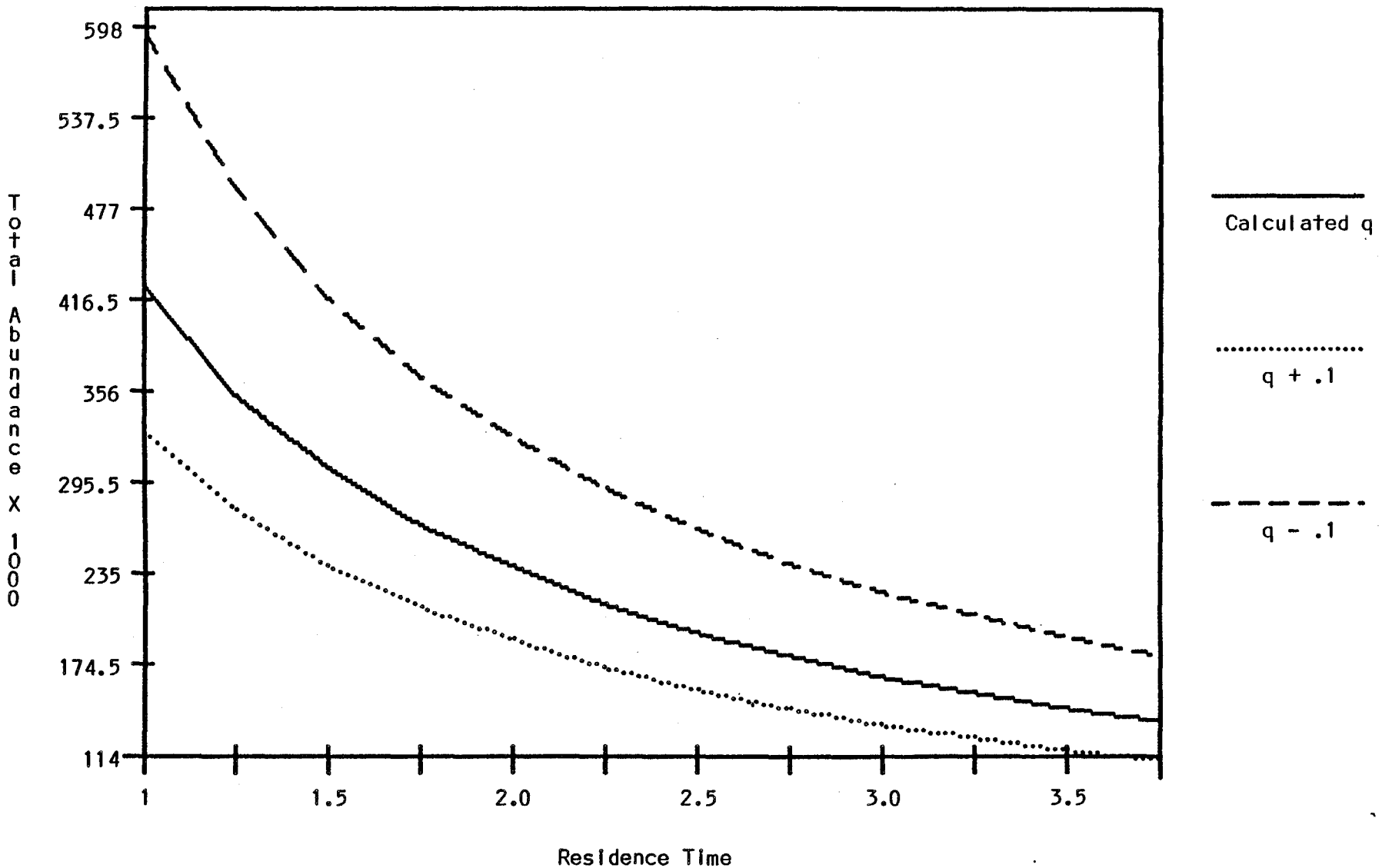

Figure 8. Abundance estimates for 1973.

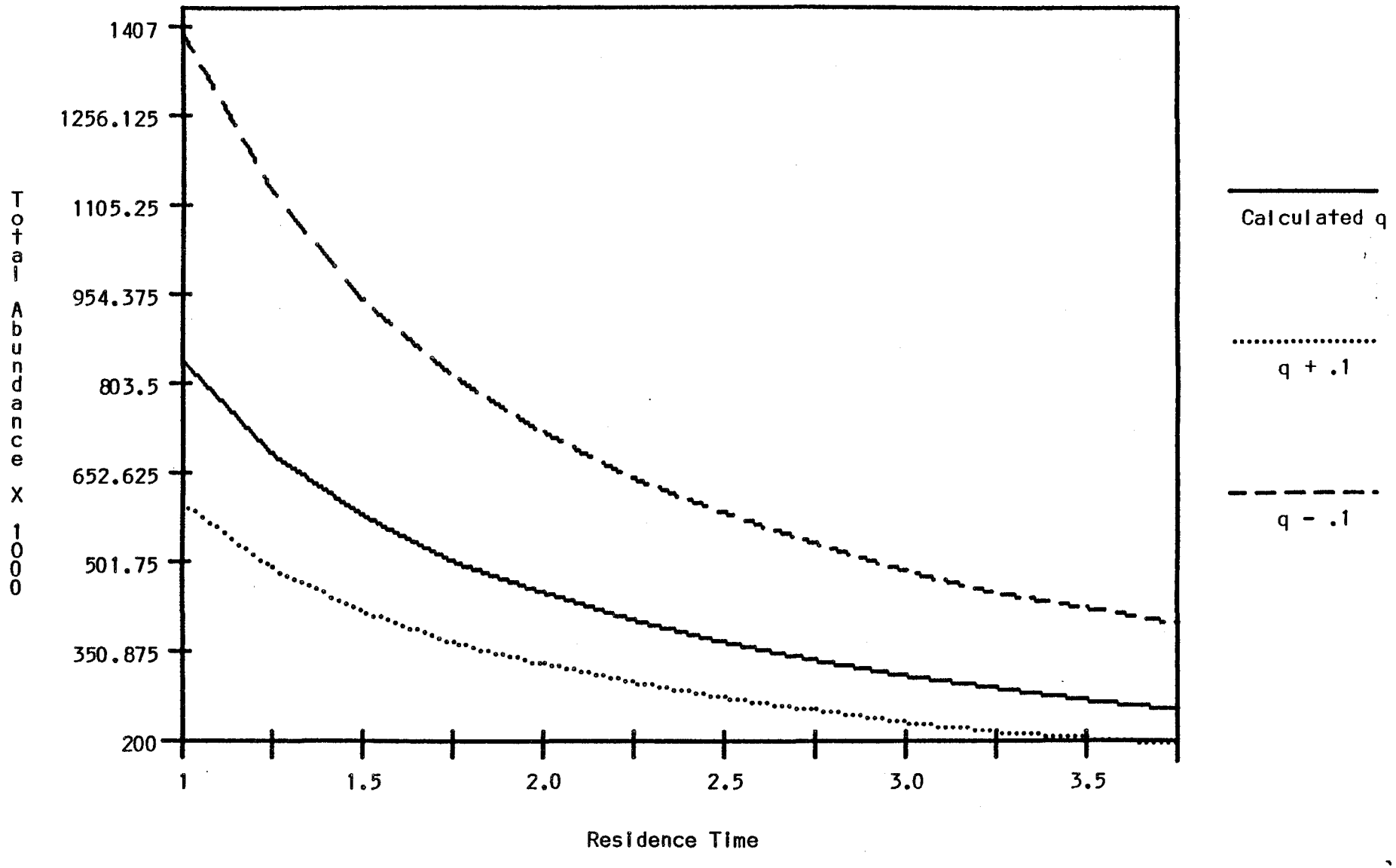

Figure 9. Abundance estimates for 1974.

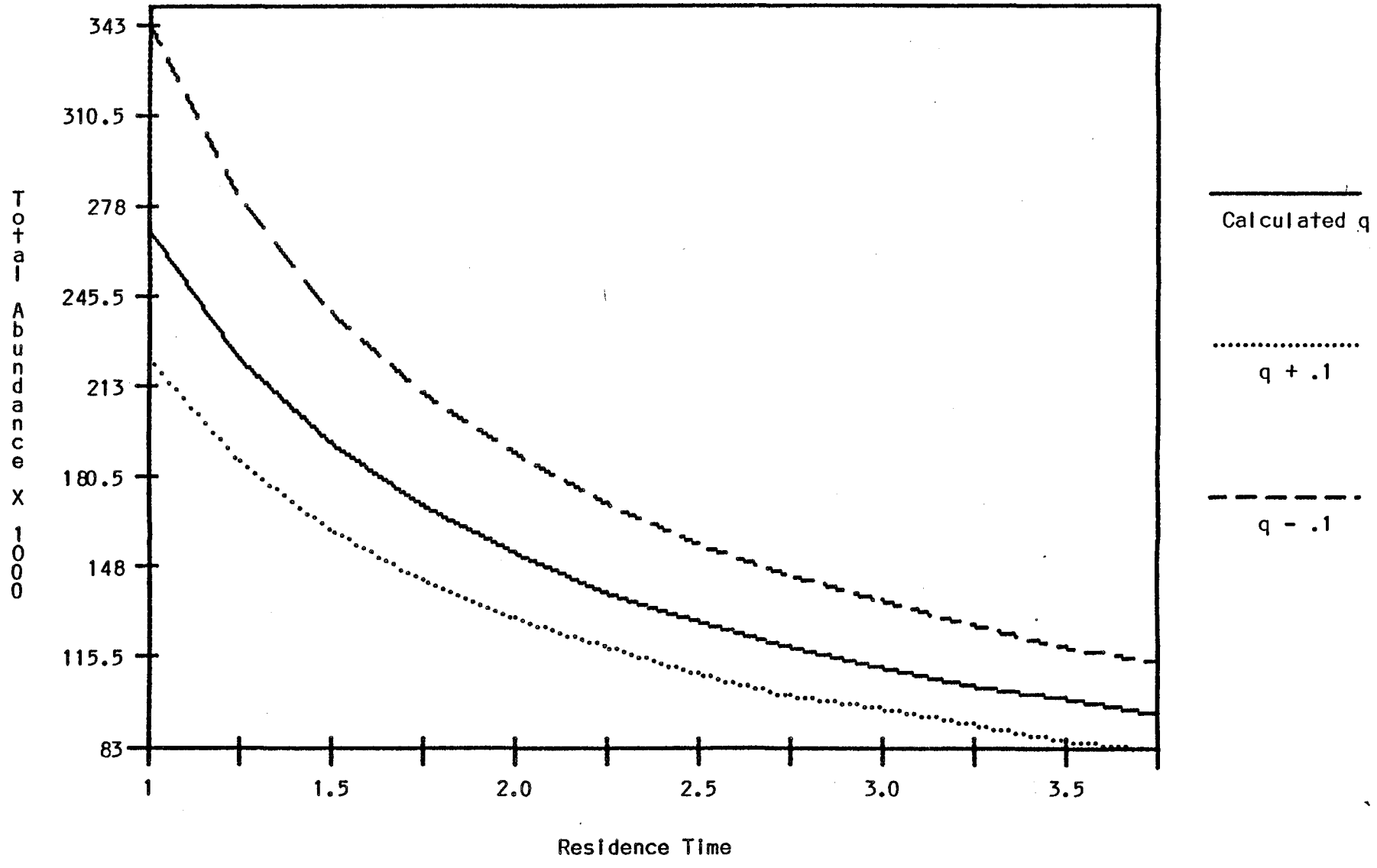

Figure 10. Abundance estimates for 1975.

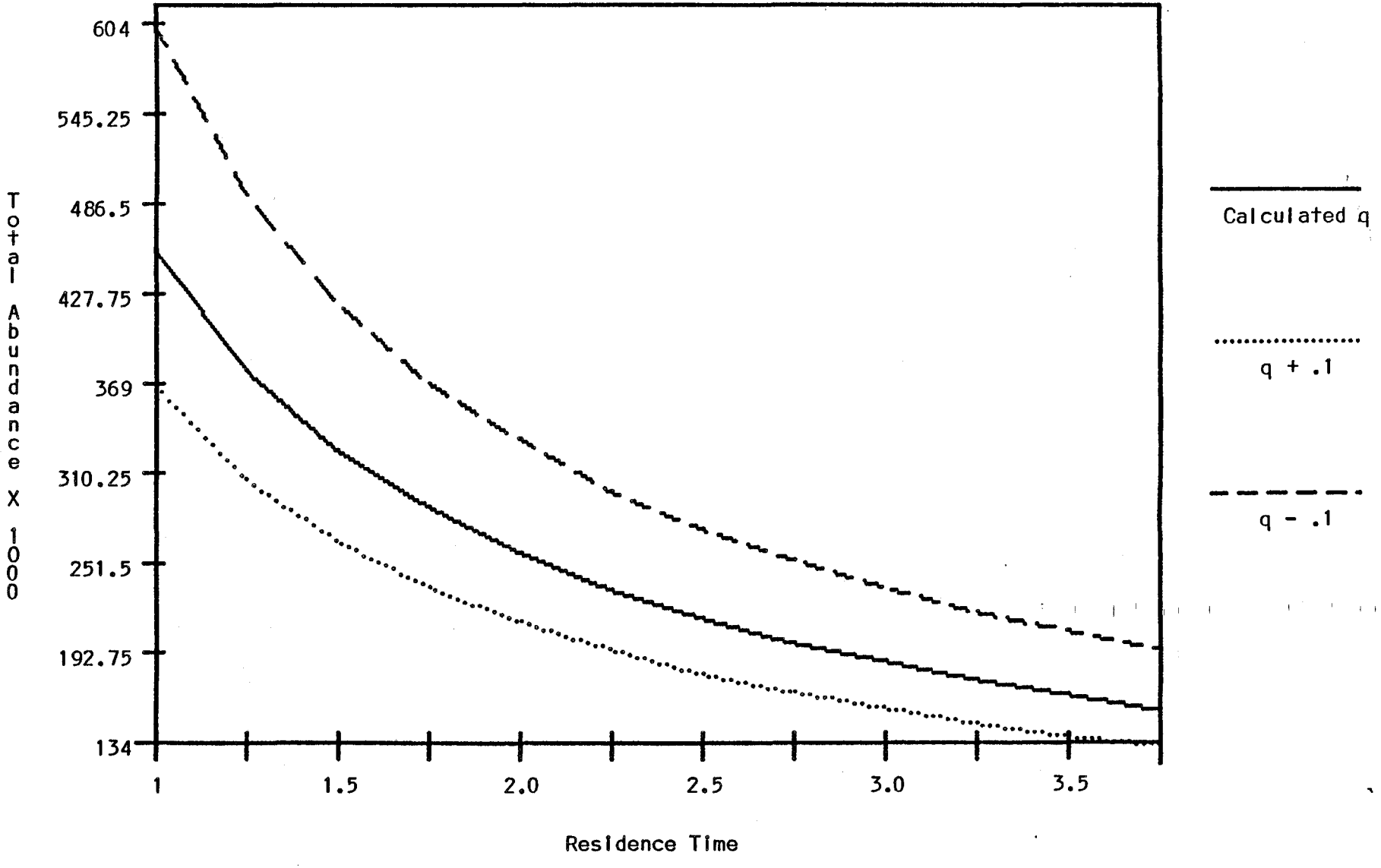

Figure 11. Abundance estimates for 1976.

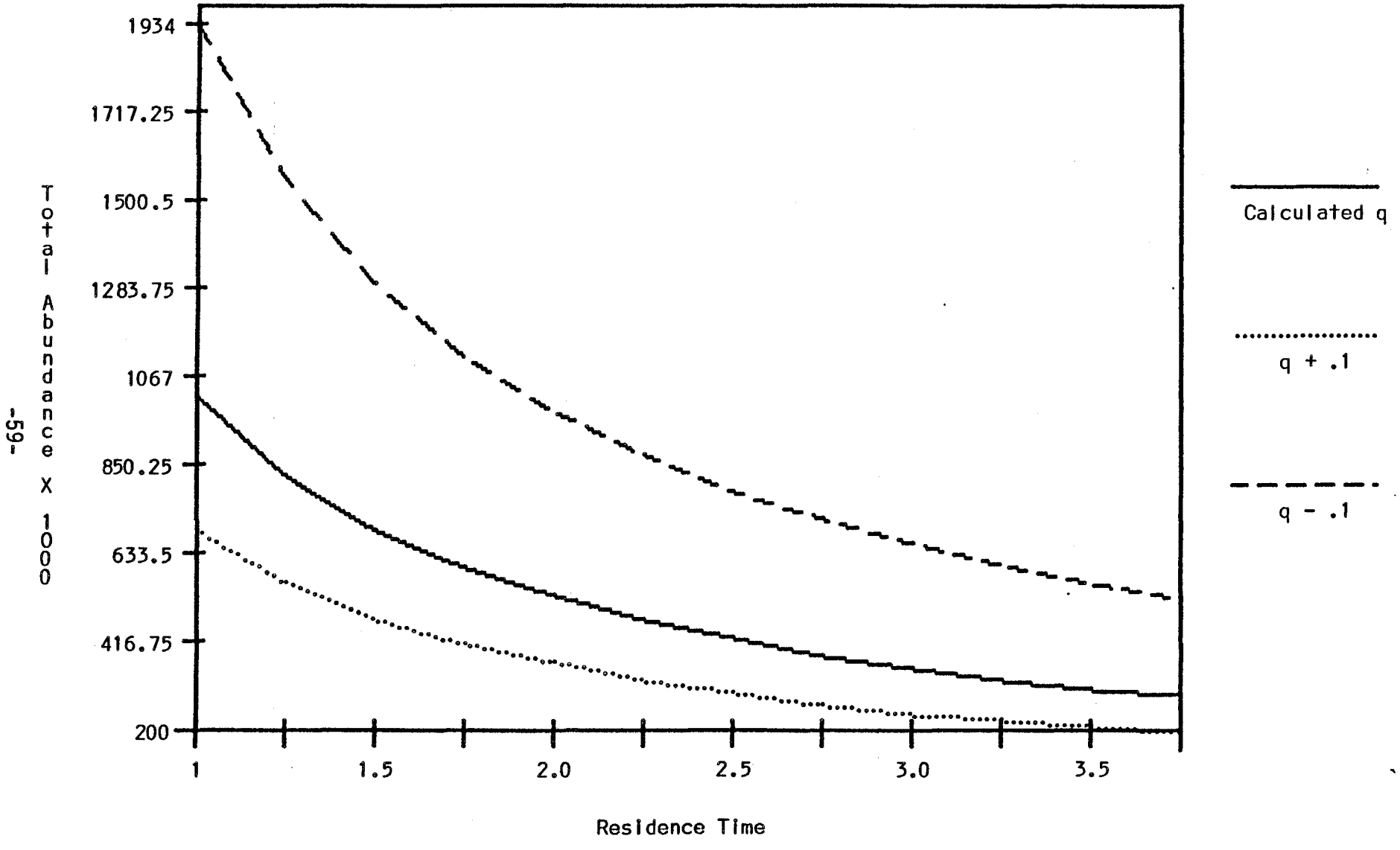

Figure 12. Abundance estimates for 1977.

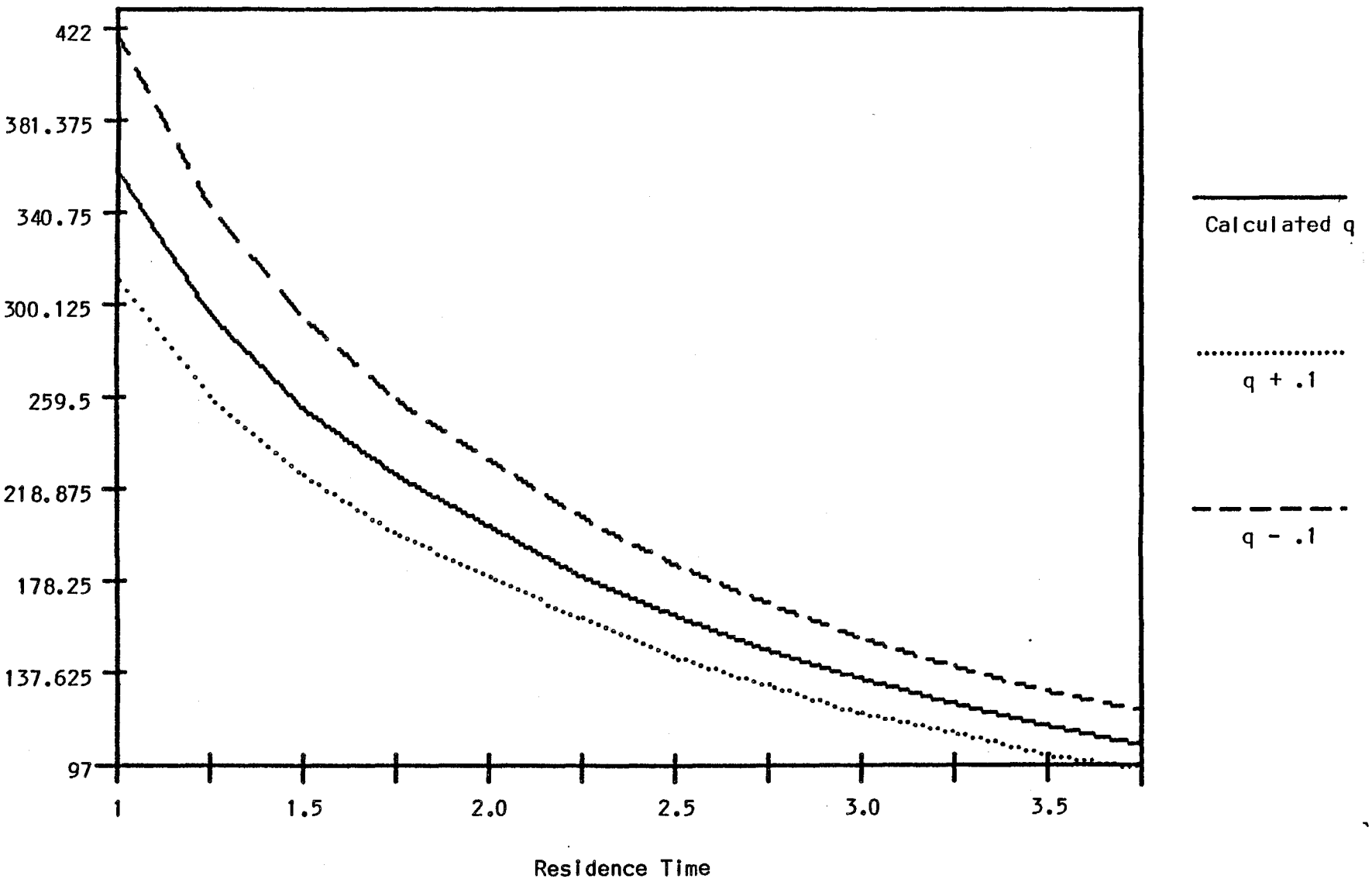

Figure 13. Abundance estimates for 1978.

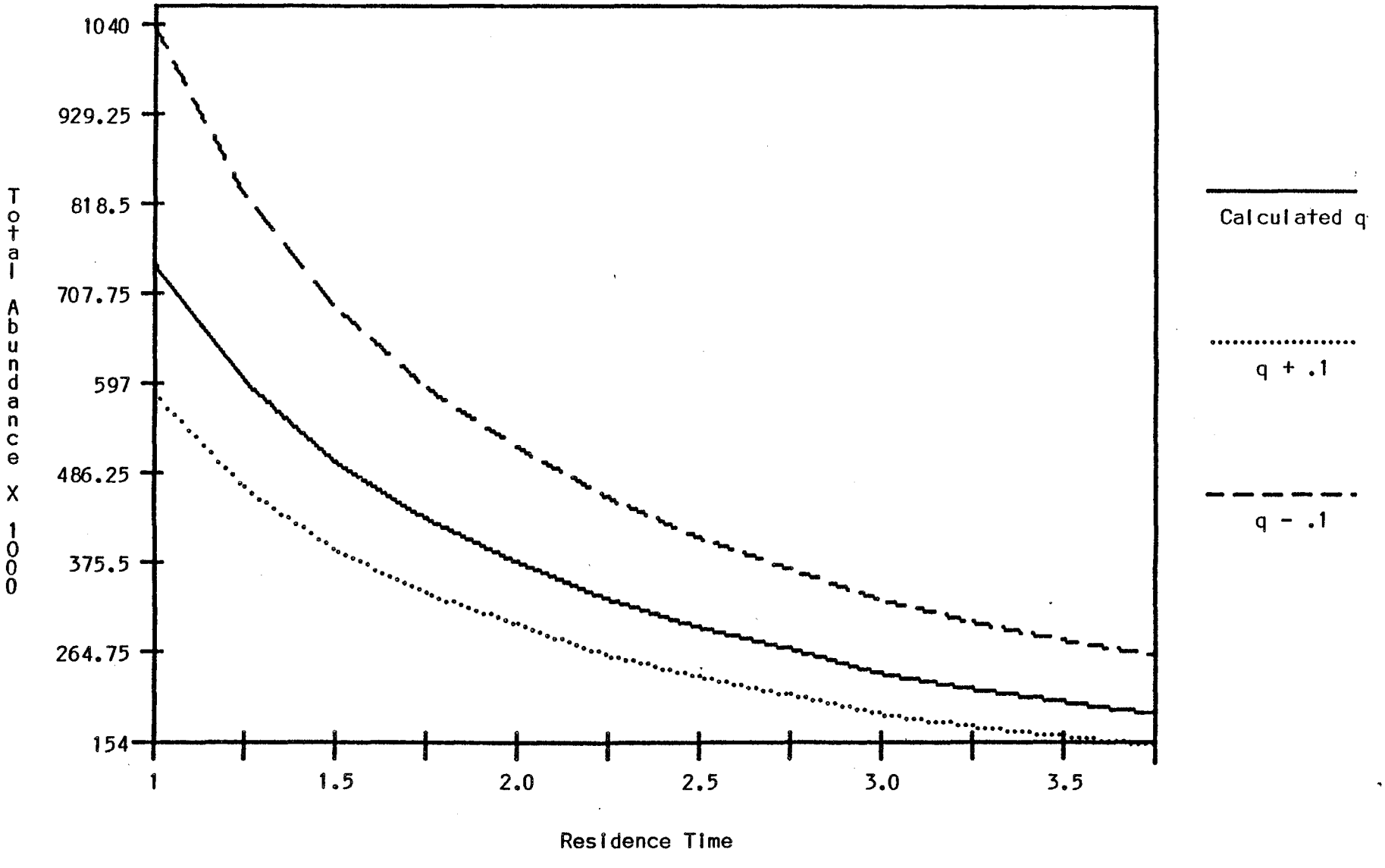

Figure 14. Abundance estimates for 1979.

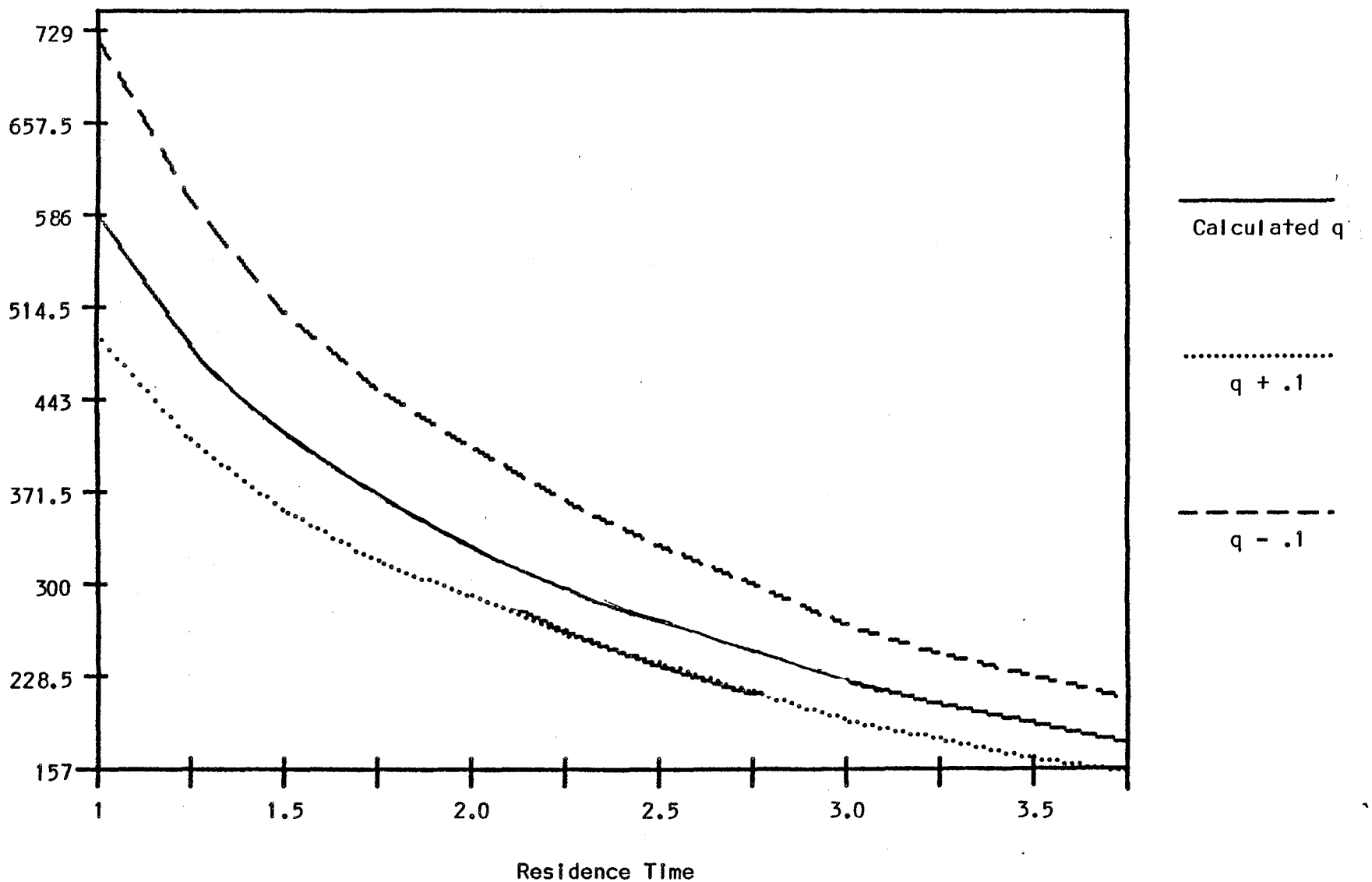

Figure 15. Abundance estimates for 1980.

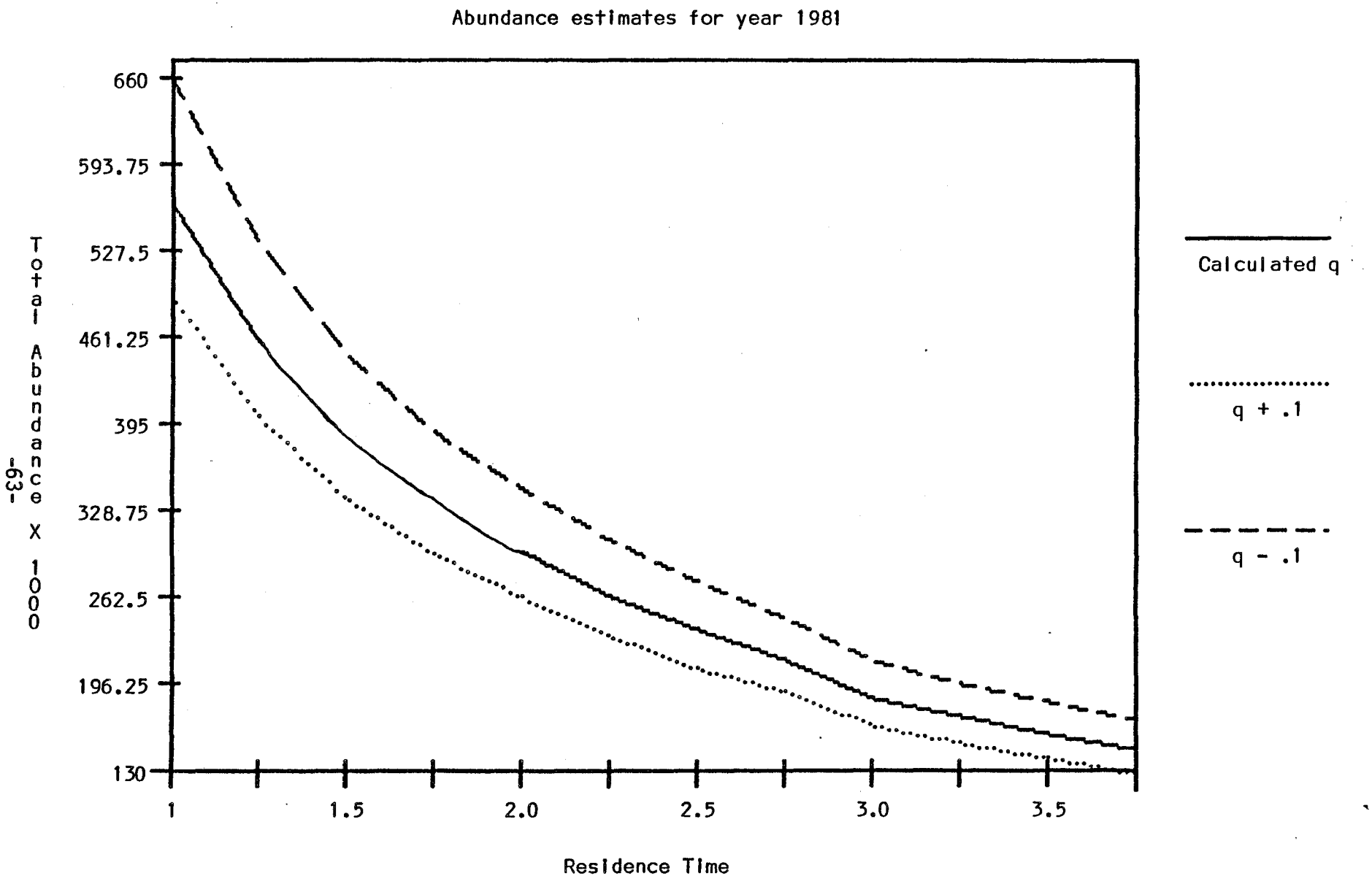

Figure 16. Abundance estimates for 1981.

The estimated speed of migration for Yukon River chinook salmon has historically been estimated at 40-50 km per day, based on average distance traveled through time by tagged salmon (Trasky 1973). By regression techniques, the same tagging data yields estimates of 51 to 63 km per day (1968 was 55 km per day, 1969 was 62 km per day, and 1970 was 51 km per day; data obtained from Geiger et al. 1969; Lebida 1970; Lebida 1971). It was noted in the 1968, 1969, and 1970 test fisheries that peak catches at Flat Island (river kilometer 0) usually preceded peak catches at Ohogamiut (river kilometer 298) by 4 days; resulting in a third estimated migration rate of 74 km per day. Several biases, which possess the tendency to either overestimate or underestimate average chinook salmon migration rate were introduced into the above cited studies. The upriver location of the sampling site, size selection of sampling gear, seasonal timing of tagging, and differences in location of upriver recoveries are potential sources of bias.

Effott is defined as the proportion of a calendar day that was open to commercial harvest (either 0.025 [6 hours], 0.75 [18 hours], or 1.00 [24 hours]). The number of boats fishing during each interval of time is not considered in our analysis. The proportion of each calendar day that was open to commercial harvest used as a measurement of fishing effort was deemed adequate for the analysis and forecasts of test fishery catch fluctuations by Clark (1983). However a more refined unit of effort may be required in order to achieve an accurate assessment of the percent reduction in abundance of the proportion of the total population vulnerable to the commercial fleet. The number of fishing units can vary from 1 to more than 400 boats for a given period of fishing. The effect of relatively small numbers of fishing vessels participating in the fishery during the first few days of the"king season" on total abundance forecasts is evident, since estimates of

total annual abundance are generally low early in the season and increase later in the season when additional units of gear participate in the fishery (Tables 16-29). Total abundance estimates and estimated exploitation rates are presented in Table 33. These estimates of total annual abundance and estimated exploitation rates should be considered as preliminary in the opinion of the authors. Nonetheless, these preliminary estimates provide the only continium of estimates available for the Yukon River chinook salmon resources from 1968 to 1981 available to resource management scientists at this time. In addition to providing the only continium of estimates of annual run strength for the Yukon River chinook salmon resource, the authors believe that this study makes a significant contribution in terms of providing a statistical methodology applicable to other fisheries resource assessment problems. Resource problems which could be addressed by this methodology include annual run assessment of Yukon River summer and fall chum salmon runs, Yukon River coho salmon runs, and Kuskokwim River chinook, chum, and coho salmon runs.

The following modifications in methods and supporting data acquisitions are recommended as fruitful areas of future research of run strength of Yukon River chinook salmon.

1. Number of boat-hours recorded for subdistrict 334-12 (the subdistrict in which the Flat Island test fishery was located) should replace proportion of day open to the commercial fishery for years 1968 to 1978. Likewise, number of boat-hours recorded for subdistrict 334-12 and 334-13 (the subdistricts which are located downriver and surround the Big Eddy test fishery) and subdistrict 334-15 (the subdistrict which surrounds the Middle Mouth test fishery) should replace the present unit of effort used in this study for Big Eddy and Middle Mouth test fishery catch analysis, respectively. The reduction in daily abundance of chinook

Table 33. The estimated total run strength, the total recorded catch (commercial and subsistence) and the resulting exploitation rate.

Year	Estimated Abundance	Total Recorded Catch	Exploitation Rate
1968	213,860	123,744	.579
1969	301,862	106,863	.354
1970	298,987	98,854	.331
1971	806,708	142,169	.176
1972	196,733	116,521	.592
1973	205,114	103,657	.505
1974	385,678	123,476	.320
1975	134,697	82,785	.615
1976	225,265	111,477	.495
1977	432,879	121,422	.281
1978	167,733	130,874	.780
1979	302,759	170,436	.563
1980	282,739	222,812	.788
1981	240,066	204,734	.853

salmon, measured by test fishing catch, as a function of effort (number of boat-hours) can easily be related, quantitatively, to the total daily commercial catch and effort of District 1. It is anticipated that, due to the proportionally large number of boats in subdistrict 334-12 (historically over 1/4 of the commercial fleet has been concentrated in 334-12) compared to other subdistricts, recalculated total abundance estimates would be larger than those of Table 30.

2. Accurate measurement of residence time (or conversely, speed of migration) and its interseasonal and intraseasonal variation is of critical importance for accurate total abundance estimates. The value assumed for residence time has been shown to be of increasing importance as the true value of residence time decreases. However, estimates of residence time in District 1 varies from 3 days (Brady 1982) to 1.4 days (101 river kilometer at 74 kilometer per day). Remote sensing studies designed to specifically measure the speed of migration are needed.

3. An understanding of the relationship between abundance of the chinook salmon resource, its migratory behavior, removal of that resource by the commercial fleet, and the concomitant changes in test fishery cathces is fundamental to the improvement of these total abundance estimation methods. Sonar techniques may provide a means of studying the dynamics of migration, its relationship to commercial harvest, and the ability of test fish studies to accurately measure the relative abundance of chinook salmon in the surrounding waters.

LITERATURE CITED

Brannian, L.K. 1982. The stimation of daily escapement and total abundance from catch per unit effort of the sockeye salmon fishery in Togiak Bay, Alaska. M.S. Thesis, University of Washington, Seattle, WA. 173 pp.

Clark, J.E. 1983. Parameter estimation for a class of models describing the migratory timing of chinook salmon in the lower Yukon River, Alaska. PhD Dissertation. Old Dominion University. Norfolk, VA.

Dahlberg, M.L. 1968. Analysis of the dynamics of sockeye salmon returns to the Chignik Lakes, Alaska. Ph.D. Dissertation, University of Washington, Seattle. 337 pp.

Hornberger, M.L., P.R. Mundy, and O.A. Mathisen. 1979. Nushagak Bay salmon fishery model. Final Report, Fisheries Research Institute, University of Washington, Seattle, WA 74 pp.

Hornberger, M.L. and O.A. Mathisen. 1980. Nushagak Bay salmon fishery model. Final Report, Fisheries Research Institute, University of Washington, Seattle, WA 76 pp.

Hornberger, M.L. and O.A. Mathisen. 1981. Nushagak Bay salmon fishery model. Final Report, Fisheries Research Institute, University of Washington, Seattle, WA 63 pp.

LITERATURE CITED (Continued)

Geiger, M.F., R. Regnart, R. Baxter, and C. Yanagawa. 1969. Arctic-Yukon-Kuskokwim Area Anadromous Fish Investigations. 1968. Annual Technical Report. Anadromous Fish Project. Juneau, AK. 113 pp.

Lebida, R.C. 1970. Arctic-Yukon-Kuskokwim Area Anadromous Fish Investigations. 1969. Annual Technical Report. Anadromous Fish Project. Juneau, AK. 77 pp.

Lebida, R.C. 1971. Arctic-Yukon-Kuskokwim Area Anadromous Fish Investigations. 1979. Annual Technical Report. Anadromous Fish Project. Juneau, AK 41 pp.

McBride, D.N. and J. Wilcock. 1983. Alaska Chinook Salmon *(Oncorhynchus tschwytscha* Walbaum) with Age, Size, and Sex Composition Estimates. Informational Leaflet No. 212. Alaska Dept. Fish and Game, Juneau, AK. 181 pp.

Mundy, P.R. 1979. Aquantitative measureof migratory timing illustrated by application to the management of commercial salmon fisheries. Ph.D. Dissertation, University of Washington, Seattle. 85 pp.

Mundy, P.R. 1982a. Migratory timing of adult chinook salmon *(Oncorhynchus tshawytscha)* in the lower Yukon, Alaska with respect to fisheries management. Department of Oceanography, Old Dominion University, Norfolk, VA. 23508. Technical Report No. 82-1.

Mundy, P.R. 1982b. Computation of migratory timing statistics for adult chinook salmon in the Yukon River, Alaska, and their relevance to fisheries management. North American Journal of Fisheries Management 4: 359-370.

Mundy, P.R., J.E. Clark, H. Schaller, and J. Hollowed. 1981a. The Yukon data base, May 1981, Vol. I: Commercial catch. Department of Oceanography, Old Dominion University, Norfolk, VA-

Mundy, P.R., J.E. Clark, H. Schaller, and J. Hollowed. 1981b. The Yukon data base, May 1981, Vol. II: Test fishing, 1963-1979. Department of Oceanography. Old Dominion University, Norfolk, VA.

Preson, F.W. 1966. The mathematical representation of migration. Ecology 47: 375-392.

Royce, W.F. 1965. Almanac of Bristol Bay sockeye salmon. University of Washington. Fish. Res. Circ. 235. 48 pp.

Trasky, L. 1973. Yukon River salmon tagging studies 1970-1972. Arctic-Yukon-Kuskokwim Region. Yukon stock separation report No. 8, Alaska Department of Fish and Game. Anchorage, Alaska.

Vaughan, E. 1954. The use of catch statistics for estimating parameters of the pink salmon migration pattern in Icy Strait. In: Science in Alaska 1952. Proceedings of the Third Alaska Academic Conference at Mt. McKinely National Park 1952. Alaska Div. AAAS.

Walters, C.J. and Buckingham. 1975. A control system for intraseason salmon management. Proceedings of a workshop on salmon management. International Institute for Applied Systems Analysis, Scholoss Laxenburg, 2361 Laxenburg, Austria.