

APPENDIX A

Analysis of the Species Selectivity of Fishwheels for the Capture of
Adult Salmon in the Susitna River.

APPENDIX A

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INTRODUCTION

In Alaska, fishwheels have been utilized for commercial and subsistence fishing since before the turn of the century. They are used primarily in glacial, turbid rivers such as the Yukon, Kuskokwim, Copper and Susitna rivers. In the early 1950's fisheries scientists began using fishwheels to monitor salmon escapement timing, abundance and to obtain salmon age, length, weight and sex composition samples. Fishwheels are still used for these purposes today.

One of the early recognized limitations of fishwheels in fisheries management and research programs was species selectivity. Meehan (1961) reported that chinook and coho salmon in the Taku River were least susceptible to recapture by fishwheel while pink salmon were more susceptible to recapture. He also noted fishwheel selectivity within a species; the smaller "jack" chinook salmon were more readily captured than the larger, older chinook salmon. He felt that fishwheel selectivity was manageable when the data were used as a relative index of the escapement and not as a definitive measure of the escapement.

It is the purpose of this report to address the question of whether fishwheels used in the Susitna River are in fact species selective and if so, to what extent.

The Alaska Department of Fish and Game (ADF&G) Su Hydro, Adult Anadromous staff deployed fishwheels for tag/ recapture programs at several locations on the Susitna River mainstem including Sunshine,

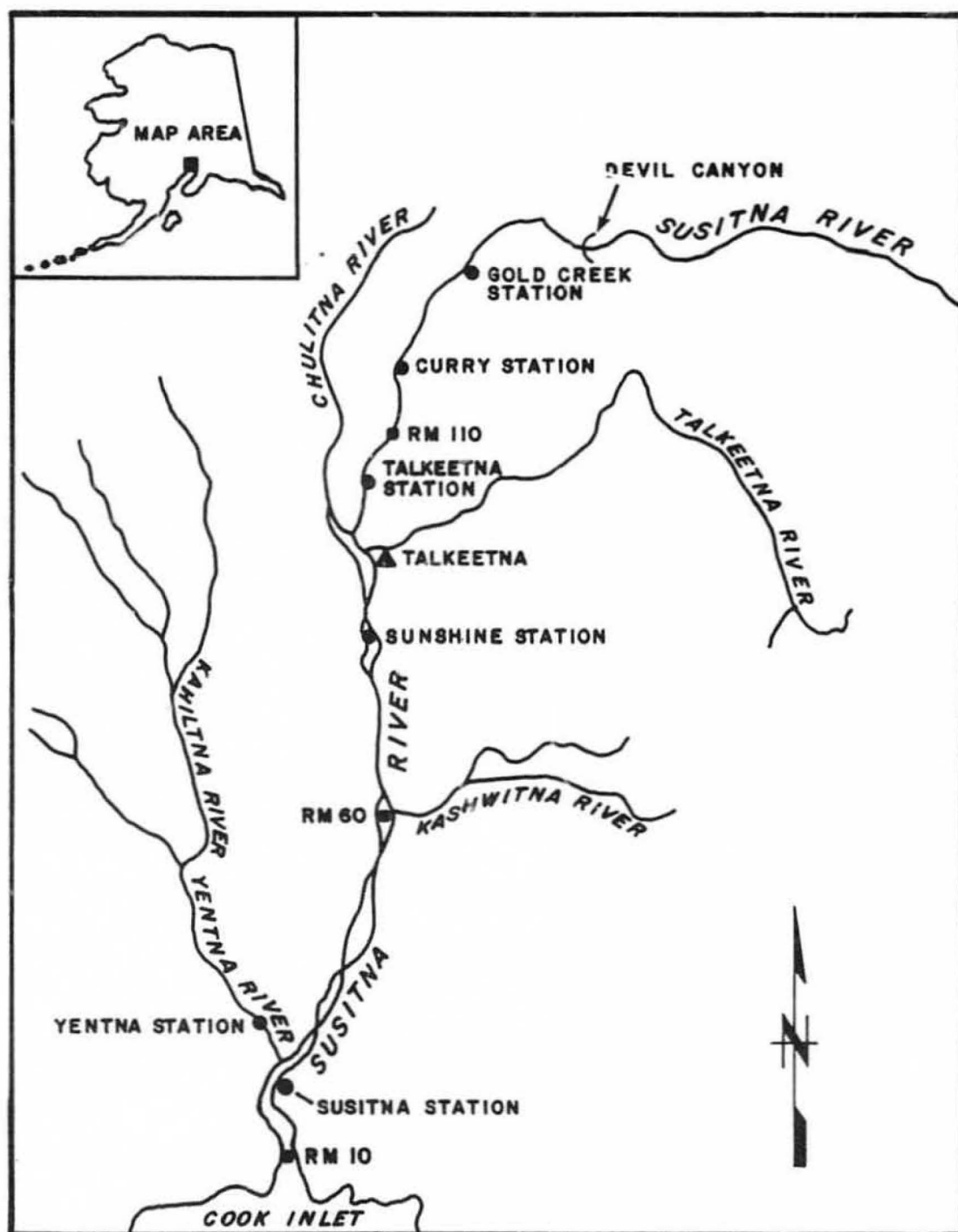
Talkeetna and Curry stations. Side scan sonar units were operated at Susitna, Yentna, Sunshine and Talkeetna stations with species apportionment of sonar counts provided by fishwheel catch data (Appendix Figure A-1). The equipment located at Susitna Station was managed by ADF&G, Commercial Fisheries Division, Soldotna.

METHODS

Tagging Process

Fishwheels, designed and built by ADF&G/Su Hydro, Adult Anadromous staff, were used to intercept salmon for tag application at Sunshine, Talkeetna and Curry stations in 1981 and 1982. Four fishwheels were located at Sunshine and Talkeetna stations and two at Curry Station. Fishwheel site locations and specifications may be obtained by consulting the Phase I, ADF&G/Su Hydro, Adult Anadromous Report (ADF&G 1981).

Rotating baskets of the fishwheels trapped adult salmon and exited them via a padded chute into a water filled live box. Individual captures were then dipnetted from the live box and placed on a padded platform. The fish were next tagged with a floy FT-4 spaghetti tag or a Petersen disc secured beneath the dorsal fin and released. Both tag types were color coded to identify capture station. Total time of the tagging process, from dipnetting to release, was 10 to 15 seconds.



Appendix Figure A-1. Susitna River basin map showing field stations and major tributaries.

Tag Recovery

Marked salmon were recovered during surveys of salmon spawning streams and sloughs above the tagging sites. Streams and sloughs were surveyed repetitively throughout the season at seven to ten day intervals. Surveyors recorded the number of tagged live salmon by tag type, color and species and the number of live untagged salmon by species. Results of the repetitive surveys were summed and provided the total number of salmon observed that had tags (r) and the total number of salmon examined for tags (c), by species and station. Only those surveys with good to excellent visibility conditions were used in computing the seasonal r/c proportions.

Tag Loss

The percent tag loss was used to adjust the number of tags recovered (r) for each species tagged at stations with reported tag loss. The adjustment was made as follows with the results presented in Appendix Table A-1:

$$r_{\text{adjusted}} = (1 + \text{percent tag loss}) \times r_{\text{observed}}$$

Data Analysis

Determination and quantification of fishwheel selectivity required two procedures. The first procedure statistically addresses the question of fishwheel selectivity and the second procedure is used to quantify fishwheel selectivity.

Appendix Table A-1 Percent tag loss based on surveys conducted between
Talkeetna Station and Devil Canyon in 1981 and 1982

<u>Tag Type</u>	<u>Tagging Station</u>	<u>Year</u>	<u>No. tagged fish examined</u>	<u>No. shed tags</u>	<u>Percent tag loss</u>
FT-4/Spaghetti	Talkeetna	1981	397	27	7.5
FT-4/Spaghetti	Talkeetna	1982	386	26	6.3
Petersen disc	Curry	1982	325	3	0.9

Step 1: Determination of fishwheel selectivity

If fishwheels were non-species selective in capture it would follow that the number of salmon caught and tagged would be proportionally the same for each species. This can be tested by using the tag recovery data accumulated from surveys of streams and sloughs. Again, if fishwheels were non-species selective in capture the number of tagged salmon observed during tag recovery surveys should be proportionally the same for each species. A chi-square test of association was used to test the null hypothesis that the proportion of tagged salmon of each species observed during the tag recovery surveys was equal or:

$$H_0: r_1/c_1 = r_2/c_2 = \dots r_i/c_i$$

where: r_i = total number of tagged adult salmon observed
during tag recovery surveys for the i^{th} species

c_i = total number of the i^{th} species of adult
salmon examined for tags during tag recovery
surveys

This test incorporated the following assumptions:

- 1) Fishwheels were not selective for stocks within a species. Chinook salmon less than 351 millimeters in fork length were not tagged and therefore not considered in the analysis.

- 2) Tagged salmon mixed randomly with untagged salmon and exhibited essentially no behavioral differences.
- 3) Reported tag loss, by station and tag type, occurred at the same rate for all species.
- 4) Tagged and untagged salmon had no differential mortality.
- 5) Fishwheel efficiency and operation remained constant throughout the season.

Determination of fishwheel selectivity proceeded as follows:

- 1) The expected frequency of r for each species was calculated by:

$$r_i \text{ expected} = \frac{\sum r_i}{\sum c_i} \times c_i$$

It should be noted that r_i expected values are weighted by sample size.

- 2) A chi-square contingency table was calculated in the following form (Summer et al. 1981):

	Species 1	Species 2	Species 3	Species 4
r	cell χ^2	cell χ^2	cell χ^2	cell χ^2
r-c	cell χ^2	cell χ^2	cell χ^2	cell χ^2

The individual cell chi-square values are summed and with the appropriate degrees of freedom compared to a tabled value to determine if observed values differed significantly from expected values.

Step 2: Quantification of fishwheel selectivity

The second procedure was to quantify species selectivity if present. To accomplish this an expected value for r (E_r) not weighted by sample size was derived for each species. This expected value is not the same and should not be confused with the expected values used for the chi-square contingency table. These E_r values were determined by using the arithmetic mean of the observed r_i/c_i proportions (both r_i and c_i continue to be the observed number of tagged salmon (r_i) and the number of salmon observed (c_i) for the i^{th} species during tag recovery surveys) for all species at each station and multiplying this value by the total number of each species (c_i) examined for marks

during tag recovery surveys. The resultant expected value for r (E_r) and the observed value for r (O_r) for each species were expressed as the ratio $O_r:E_r$. Setting E_r equal to one to define a base for comparison O_r then becomes a function of fishwheel selectivity herein referred to as the coefficient of selectivity (CS). CS values less than one indicate fewer tagged salmon of that species were observed during surveys than expected and conversely CS values greater than one indicate more tagged salmon of that species were observed during surveys than expected.

The percent deviation between observed r values (O_r) and expected r values (E_r) were determined for each species at each station. These values were derived by subtracting O_r from E_r and expressing this value as a percent of E_r . Observed r values that were greater than expected r values resulted in a negative percent deviation (-) and observed r values less than expected r values resulted in positive percent deviations (+). Percent deviations, regardless of sign, were divided into three categories:

- 1) $< 15\%$ low deviation from expected value
- 2) 15% to 30% moderate deviation from expected value
- 3) $> 30\%$ high deviation from expected value

RESULTS

Fishwheel Selectivity

All survey results and fishwheel catch data were provided in previous reports (ADF&G 1981; ADF&G 1983).

The null hypothesis, that proportion of tagged salmon of each species observed during tag recovery surveys was equal, was tested for salmon tagged at Talkeetna and Curry stations in 1981 and 1982. Salmon tagged at Sunshine Station were not included in the test as fishwheels there did not operate continuously and therefore had a disproportionate amount of capture effort expended for each species.

Results of the chi-square test indicated a highly significant ($1-P < .001$) difference between observed and expected values of r for sockeye, pink, chum and coho salmon tagged at Talkeetna and Curry stations in 1981 (Appendix Table A-2). Similarly, the results of the chi-square test for data collected in 1982 also indicated a highly significant ($1-P < .001$) difference between observed and expected values of r for chinook, sockeye, pink, chum and coho tagged at Talkeetna Station and chinook, sockeye, chum and coho salmon tagged at Curry Station (Appendix Table A-3). Fifty percent of the pink salmon captured at Curry Station in 1982 were tagged and subsequently they were not included in the analysis. Based on the chi-square test results, fishwheels operated at Talkeetna and Curry stations in 1981 and 1982 were species selective in capturing adult salmon.

Appendix Table A-2 Chi-square test results of observed versus expected number of tag recoveries during stream and slough surveys for salmon tagged at Talkeetna and Curry stations in 1981.

TALKEETNA STATION					
Species	<u>c^{1/}</u>	Observed ^{2/} <u>r</u>	Expected <u>r</u>	Cell χ^2 ^{3/}	Significance ^{4/} DF=3
Sockeye	4,167	286	296	.37	N.S.
Pink	724	82	51	11.36	**
Chum	5,944	346	423	16.98	***
Coho	852	117	61	27.21	***
Total	11,687	831	831	91.39 ^{5/}	***

CURRY STATION					
Species	<u>c</u>	Observed <u>r</u>	Expected <u>r</u>	Cell χ^2	Significance DF=3
Sockeye	3,040	403	324	15.55	***
Pink	69	12	7	1.80	N.S.
Chum	4,033	345	430	20.76	***
Coho	105	12	11	.05	N.S.
Total	7,247	772	772	43.67	***

^{1/} c = Total number of fish examined for marks during stream and slough surveys

^{2/} r = Total number of tags (adjusted) recovered during stream and slough surveys

^{3/} χ^2 = Chi-square

^{4/} Significance denotes 1-P values represented at: * < 0.05, ** < 0.01, *** < .001, N.S. $\geq$ 0.05.

^{5/} Total cell χ^2 includes all cells of chi-square table (that is including the χ^2 associated with observed and expected c-r cells).

Appendix Table A-3 Chi-square test results of observed versus expected number of tag recoveries during stream and slough surveys for salmon tagged at Talkeetna and Curry stations in 1982.

TALKEETNA STATION					
Species	c ¹	Observed ^{2/} r	Expected r	Cell χ^2 ^{3/}	Significance ^{4/} DF=4
Chinook	1,436	88	183	49.52	***
Sockeye	2,128	287	272	.88	N.S.
Pink	13,936	2,597	1,779	376.61	***
Chum	9,588	503	1,223	424.42	***
Coho	1,065	118	136	2.36	N.S.
Total	28,153	3,593	3,593	978.70 ^{5/}	***

CURRY STATION					
Species	c	Observed r	Expected r	Cell χ^2	Significance DF=3
Chinook	642	35	35	.00	N.S.
Sockeye	1,970	171	108	36.67	***
Chum	7,802	361	428	10.46	*
Coho	398	26	22	.80	N.S.
Total	10,812	593	593	50.72	***

^{1/} c = Total number of fish examined for marks during stream and slough surveys

^{2/} r = Total number of tags (adjusted) recovered during stream and slough surveys

^{3/} χ^2 = Chi-square

^{4/} Significance denotes 1- α values represented as: * < 0.005, ** < 0.01, *** < 0.001, N.S. $\geq$ 0.05.

^{5/} Total cell χ^2 includes all cells of chi-square table (that is including the χ^2 associated with observed and expected c-r cells).

Quantification of Fishwheel Selectivity

The unweighted mean value of the r/c proportions and subsequently derived expected r values provided a quantitative method to assess the species selectivity of fishwheels located at Talkeetna and Curry stations. The deviation of the observed number of tag recoveries from stream and slough surveys and the calculated expected number of tag recoveries, provided the assumptions previously described are true, reflects the selectivity or non-selectivity of fishwheel captures for each species. Results for each species are summarized below:

Chinook salmon

Chinook salmon were tagged at Talkeetna and Curry stations in 1982 only. Chinook salmon less than 351 mm were not tagged. The coefficients of selectivity were 0.56 at Talkeetna Station and 0.61 at Curry Station. The percent deviation between the number of tag recoveries observed and the number expected was high, +44.0 percent at Talkeetna Station and +34.0 percent at Curry Station (Appendix Table A-4).

Sockeye salmon

Between year comparisons for sockeye, pink, chum and coho percent deviations and coefficients of selectivity required an analysis without chinook salmon, which were tagged in 1982 only. The results are provided in Appendix Table A-5 and A-6. Fishwheels were not selective toward

Appendix Table A-4 Coefficient of selectivity and percent deviation for chinook, sockeye, pink, chum and coho salmon tagged at Talkeetna and Curry stations in 1982.

TALKEETNA STATION							
Species	Observed ^{1/} Values			Expected ^{2/} Values		Coeffi- cient of Select- ivity	Percent Devia- tion
	c	r	r/c	r/c	r		
Chinook	1,436	88	.06	.11	157	.56	+44.0
Sockeye	2,126	284	.13	.11	233	1.22	-21.9
Pink	13,936	2,596	.19	.11	1,473	1.76	-76.2
Chum	9,588	502	.05	.11	1,054	.48	+47.6
Coho	1,065	117	.11	.11	117	1.0	0.0

CURRY STATION							
Species	Observed Values			Expected Values		Coefficient of Selectivity	Percent Deviation
	c	r	r/c	r/c	r		
Chinook	642	35	.06	.09	57	.66	+34.0
Sockeye	1970	171	.09	.09	177	1.05	- 4.9
Pink	4,470	726	.16	.09	371	1.96	-95.7
Chum	7,802	359	.05	.09	647	.55	+44.5
Coho	398	26	.07	.09	33	.79	+21.2

^{1/} c = total number of fish examined for marks during stream and slough surveys
 r = total number of tags (adjusted) recovered during stream and slough surveys

^{2/} Expected values calculated by multiplying the non-weighted arithmetic mean of the observed r_i/c_i ratio for all species by the individual species observed c_i value.

Appendix Table A-5 Coefficient of selectivity and percent deviation for sockeye, pink, chum and coho salmon tagged at Talkeetna Station in 1981 and 1982.

Species	1981						Coefficient of Selectivity	Percent Deviation
	Observed ^{1/} Values			Expected ^{2/} Values				
	c	r	r/c	r/c	r			
Sockeye	4,167	299	.07	.10	416	.72	+28.1	
Pink	724	86	.12	.10	72	1.19	-19.4	
Chum	5,944	357	.06	.10	594	.60	+39.9	
Coho	852	125	.15	.10	85	1.47	-47.1	

1982							
Species	Observed Values			Expected Values		Coefficient of Selectivity	Percent Deviation
	c	r	r/c	r/c	r		
Sockeye	2,126	284	.13	.12	257	1.11	-10.5
Pink	13,936	2,596	.19	.12	1,686	1.54	-54.0
Chum	9,588	502	.05	.12	1,160	.43	+56.7
Coho	1,065	117	.11	.12	128	.91	+8.6

^{1/} c = total number of fish examined for marks during stream and slough surveys
r = total number of tags (adjusted) recovered during stream and slough surveys

^{2/} Expected values calculated by multiplying the non-weighted arithmetic mean of the observed r_i/c_i ratio for all species by the individual species observed c_i value.

Appendix Table A-6 Coefficient of selectivity and percent deviation for sockeye, pink, chum and coho salmon tagged at Curry Station in 1981 and 1982.

1981							
Species	Observed ^{1/} Values			Expected ^{2/} Values		Coeffi- cient of Select- ivity	Percent Devia- tion
	c	r	r/c	r/c	r		
Sockeye	3,040	386	.13	.13	380	1.02	- 1.6
Pink	69	12	.17	.13	8	1.50	-50.0
Chum	4,033	333	.08	.13	504	.66	+33.9
Coho	105	12	.11	.13	13	.92	+ 7.7

1982							
Species	Observed Values			Expected Values		Coeffi- cient of Select- ivity	Percent Devia- tion
	c	r	r/c	r/c	r		
Sockeye	1,970	172	.09	.09	177	.97	+ 2.8
Pink	4,470	732	.16	.09	402	1.82	-82.1
Chum	7,802	362	.04	.09	702	.52	+48.4
Coho	398	26	.07	.09	35	.74	+27.7

^{1/} c = total number of fish examined for marks during stream and slough surveys
r = total number of tags (adjusted) recovered during stream and slough surveys

^{2/} Expected values calculated by multiplying the non-weighted arithmetic mean of the observed r_i/c_i ratio for all species by the individual species observed c_i value.

sockeye salmon in 1982 at either Talkeetna or Curry stations. The coefficients of selectivity in 1981 were 0.72 and 1.02 at Talkeetna and Curry stations and 1.11 and 0.97 in 1982. The percent deviation between observed and expected tag recoveries was -10.5 percent at Talkeetna Station and +2.8 percent at Curry Station, both low values. In 1981 sockeye salmon were caught at less than the expected rate (moderate percent deviation of +28.1 percent) at Talkeetna Station while fishwheels at Curry Station did not appear to be selective in capture (low percent deviation of -1.6 percent) (Appendix Table A-5 and A-6).

Pink salmon

Pink salmon tended to have consistently higher observed r values than expected. The coefficients of selectivity in 1981 were 1.19 and 1.50 at Talkeetna and Curry stations, respectively (Appendix Table A-5 and A-6). The CS values increased in 1982, the dominant pink salmon year in a two year cycle, to 1.54 and 1.82 at Talkeetna and Curry stations. In 1982, due to the large number of pink salmon in the Susitna River drainage and manpower constraints 50 percent of the pink salmon intercepted at Curry Station were tagged and in deriving the E_r values all tag recoveries were increased by a factor of two.

The percent deviation in 1981 was -19.4 and -50.0 percents at Talkeetna and Curry stations and increased to -54.0 and -82.1 percents in 1982 (Appendix Table A-5 and A-6). Pink salmon were captured by fishwheels at a rate that exceeded expectations regardless of the location.

Chum salmon

The number of chum salmon tag recoveries were lower than expected for fish tagged at Talkeetna and Curry stations in both 1981 and 1982. In 1981 the coefficients of selectivity were 0.60 and 0.66 at Talkeetna and Curry stations, respectively. In 1982 the coefficients of selectivity were lower, 0.43 and 0.52 in the above station order. The percent deviation remained high, greater than +30 percent at both Talkeetna and Curry stations in 1981 and 1982 (Appendix Table A-5 and A-6).

Coho salmon

Coho salmon tag recoveries and expected tag recoveries varied considerably between years and between sites. The coefficients of selectivity were 1.47 and 0.92 at Talkeetna and Curry stations in 1981 and 0.91 and 0.74 in 1982. In 1981 the percent deviation at Talkeetna and Curry stations were -47.1 and +7.7 percents, respectively. In 1982 for the same stations the percent deviations were +8.6 and +27.7 percents (Appendix Table A-5 and A-6).

DISCUSSION

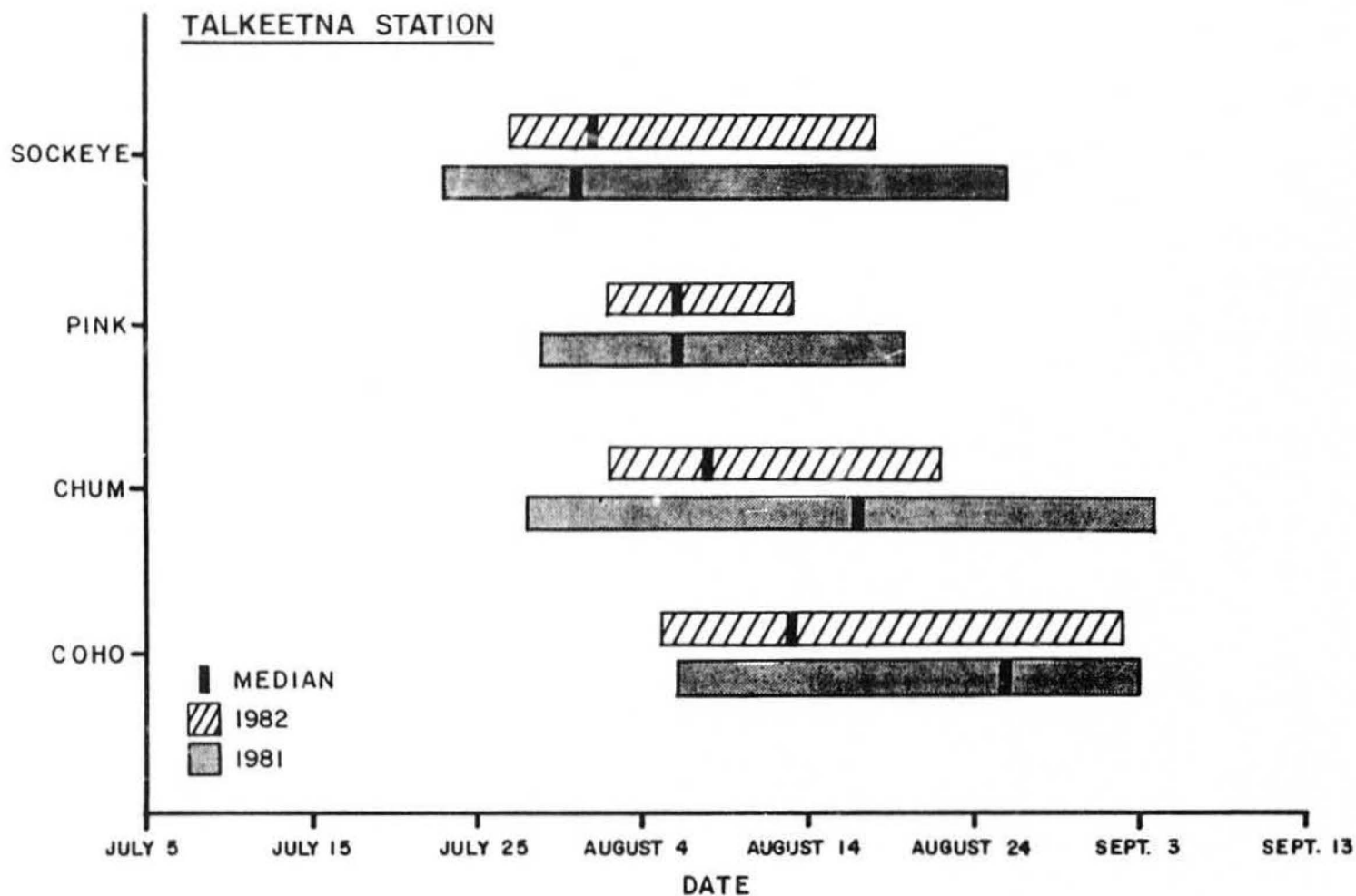
It has been determined that fishwheels are species selective at two sites on the Susitna River. Selectivity can be a function of many parameters such as fishwheel site, channel configuration, water velocity, fish size and behavioral traits. These parameters have been considered intuitively by fisheries biologists but were difficult to

quantify. The large number of fish tagged and the extensive random surveys pursuant to goals of this project provided a means for quantifying fishwheel selectivity. For reasons yet to be defined chinook and chum salmon are under-caught by fishwheels at Talkeetna and Curry stations while pink salmon are over-caught. Sockeye and coho salmon were caught at rates that deviated from expected catch rates but were not consistently under- or over- caught by fishwheels at Talkeetna and Curry stations.

Having established fishwheel selectivity, it becomes apparent that using fishwheels to apportion sonar counts in the Susitna River would bias the counts based on the selectivity of the fishwheels at that site. This bias can change constantly, from no bias (one species present) to bias which severely impacts daily sonar estimates of the number of each species present (when two or more species temporally overlap). This is graphically portrayed in Appendix Figure A-2 where as many as four species overlapped in migrational timing in 1981 and 1982 at Talkeetna Station.

It may be possible, in the future, to formulate reasonable escapement estimates based on fishwheel catch statistics. Analysis indicates that fishwheels intercept a near constant proportion of the escapement (Talkeetna and Curry stations). Based on r/c proportions, fishwheel catches between years usually vary 5 percent or less for an individual species.

Additional data would be required to assess the feasibility of using fishwheel catch data as a method of determining escapement size.



Appendix Figure A-2. Migrational timing of sockeye, pink, chum and coho salmon at Talkeetna station in 1981 and 1982.

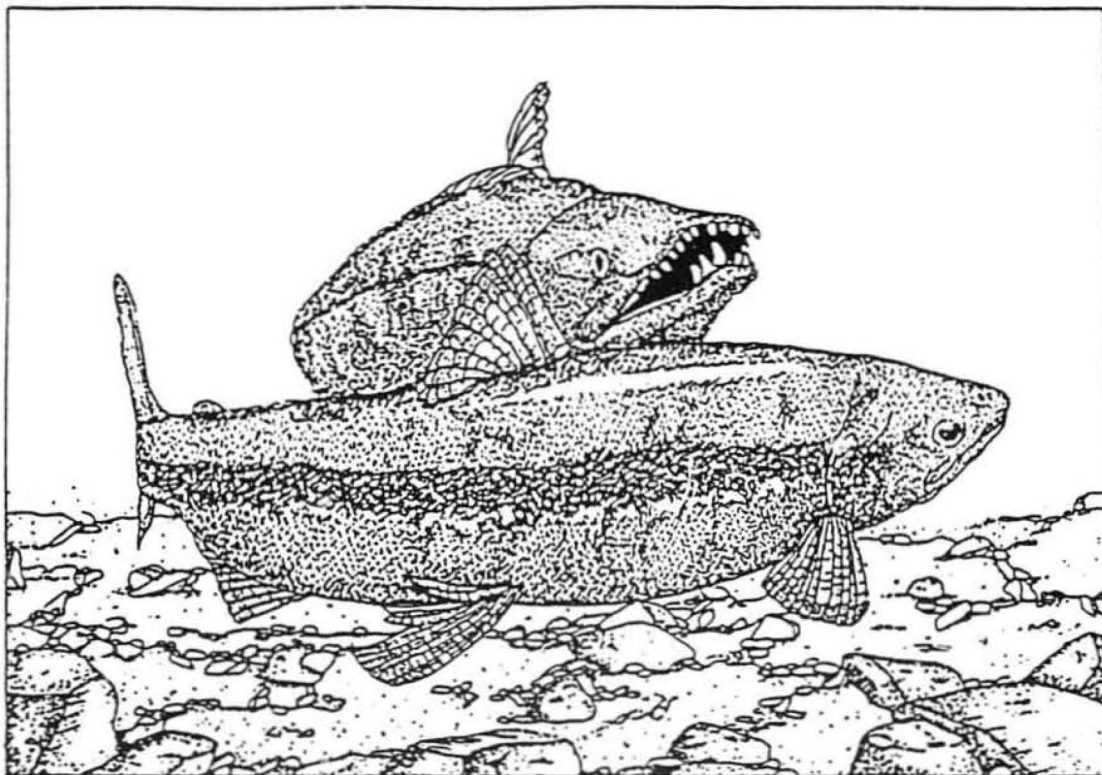
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SUSITNA HYDRO AQUATIC STUDIES
PHASE II REPORT

Synopsis of the 1982
Aquatic Studies and Analysis of
Fish and Habitat Relationships

— APPENDICES —

by

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1983

