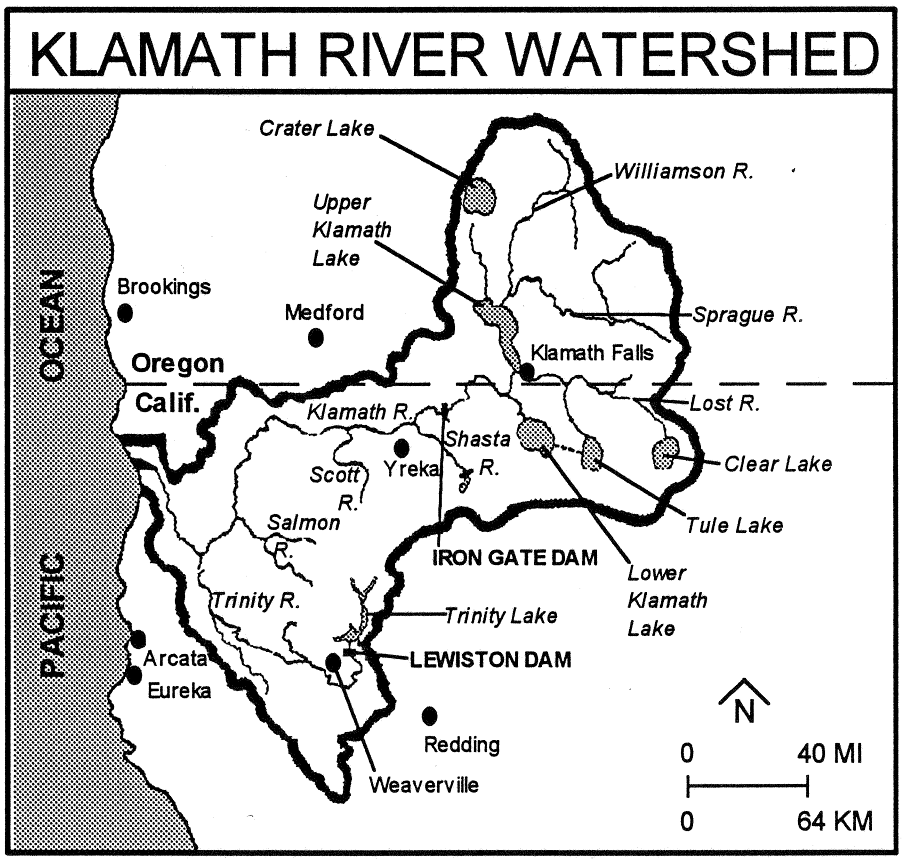
TECHNICAL APPENDIX

TO THE
KLAMATH RIVER FALL CHINOOK
REVIEW TEAM REPORT



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ACKNOWLEDGEMENTS

This compilation of technical papers documents much of the basis for the conclusions and recommendations developed by the Klamath River Fall Chinook Review Team. During its assessment of the Klamath River fall chinook stock, the review team and other report contributors were divided into several sections to consider specific topics and report back to the entire team. The individual appendices in this document were drafted by the members of the various sections listed below as part of the review process (section leaders are noted by an asterisk).

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LIST OF ACRONYMS AND ABBREVIATIONS

AD–clip	adipose fin–clipped
CCRFO	Coastal California Fishery Resource Office (U.S. Fish and Wildlife Service)
CDFG	California Department of Fish and Game
CDWR	California Department of Water Resources
CPUE	catch per unit of effort
CWT	coded–wire tag
FMP	fishery management plan
HRM	Harvest Rate Model
IGH	Iron Gate Hatchery
IHNV	infectious hematopoietic necrosis
KMZ	Klamath Management Zone
KOHM	Klamath Ocean Harvest Model
KRTAT	Klamath River Technical Advisory Team
NMFS	National Marine Fisheries Service
OHR	ocean harvest rate
RKM	river kilometer
RM	river mile
TRH	Trinity River Hatchery
USFWS	U. S. Fish and Wildlife Service
YIR	Yurok Indian Reservation

APPENDIX A
OCEAN SURVIVAL RATES AND PRODUCTIVITY OF KLAMATH RIVER FALL CHINOOK SALMON

OBJECTIVES

Poor stock productivity in recent years must be at least in part responsible for having precipitated this "overfishing" review for Klamath River fall chinook salmon. In 1992, for example, the preseason abundance estimate was so low that the minimum allowable spawning escapement floor of 35,000 adult natural spawners could not have been met even if there had been no ocean or river fishing in that year. In this section we attempt to determine the extent to which poor production of recent broods can be attributed to poor ocean survival conditions. We also reexamine existing stock–recruitment data for naturally spawning Klamath River chinook salmon in light of our findings regarding ocean survival conditions. In particular, we wish to determine whether the poor production resulting from the large 1986 and 1987 natural escapements (in excess of 100,000 adults) was more likely attributable to "overescapement" in those years or to poor ocean survival conditions.

METHODS

We explored two alternative measures of ocean survival conditions. First, based on coded–wire tag (CWT) recovery data, we calculated indices of survival rates from release to age–2 for 1979–1988 brood fall and spring chinook salmon released as subyearlings ("yearlings" in California hatchery jargon) in October from the Klamath and Rogue rivers, and as subyearlings (fingerlings) in June from the Sacramento River delta. We believed that survival rates of these juveniles would be influenced primarily by ocean rather than freshwater conditions because downstream migration is known to be rapid (Klamath and Rogue October releases) or because of the close proximity of the marine environment (Sacramento delta releases). Second, we used the CWT analysis methods of Hankin and Mohr (1993) to calculate estimates of "overwinter" ocean survival rates for adults from the Klamath River system.

Using our proxies for ocean survival conditions, we then "adjusted" observed stock–recruitment data for 1979–1988 broods of naturally spawning Klamath River chinook salmon. Adjustments consisted of scaling observed recruitments upward or downward according to whether brood year ocean survival indices were low or high, respectively, when compared to the average index for the period. We then compared these adjusted stock–recruitment data with the unadjusted data to determine whether it appeared more likely that poor ocean survival conditions or "overescapement" of spawners was responsible for the poor productivity of recent broods, in particular those originating from escapements in 1986 and 1987.

RESULTS

Results of our analyses suggest the following conclusions.

Overwinter Adult Survival Rates

Based on application of the methods of Hankin and Mohr (1993), overwinter ocean survival rates of age–2 and older Klamath River fall chinook salmon varied substantially but apparently "randomly" from 1981–1982 through 1989–1990. Model 2 estimates of survival rates were extremely low (less than 15 percent) for both Iron Gate Hatchery (IGH) and Trinity River Hatchery (TRH) races during the peak of the 1982–1983 El Niño event and also during 1985–1986 (Figure A–1). Model 4 estimates of overwinter survival rates were also highly variable and were lowest during the 1982–1983 El Niño–influenced period. Estimated survival rates for recent years (1987–1989) ranged from about 25 to 70 percent for both models (Table A–1). Although average estimated overwinter survival rates were considerably lower than the 80 percent value assumed in Klamath River management modeling, there was no evidence that these survival rates were markedly lower in the most recent years as compared to earlier years. Therefore, we concluded that recent poor productivity was probably not caused by extremely poor overwinter survival of age–2 and older fish.

TABLE A–1. Estimated overwinter ocean survival rates (fall of year i through spring of year i+1) for age–2 and older Klamath River fall chinook salmon based on applications of methods presented in Hankin and Mohr (1993) to CWT recovery data for 1978–1985 brood years.[a/]

	Model 2		Model 4	
Season	IGH	TRH	IGH	TRH
1981–82	1.000	0.338	0.415	0.370
1982–83	0.108	0.100	0.226	0.226
1983–84	1.000	1.000	0.383	0.218
1984–85	0.773	1.000	0.470	0.599
1985–86	0.077	0.153	0.526	0.469
1986–87	0.445	0.346	0.399	0.326
1987–88	0.236	0.702	0.312	0.778
1988–89	0.686	0.594	0.738	0.639
1989–90	0.247	0.496	0.266	0.450

a/ Model 4 structure assumes that overwinter survival rates of age–2 and older fish fluctuate together with ocean survival rates of juveniles released in October of the same year. Model 2 structure does not assume that survival rates of adults and juveniles fluctuate together, but note that this model produces estimates of overwinter survival rates that are equal to 100 percent (model constraint) in some years. Note that errors of estimation for the Hankin and Mohr methods are relatively small when overwinter mortality is large, but are relatively large when overwinter mortality is low. Thus, low overwinter survival rates are more accurately estimated than high overwinter survival rates.

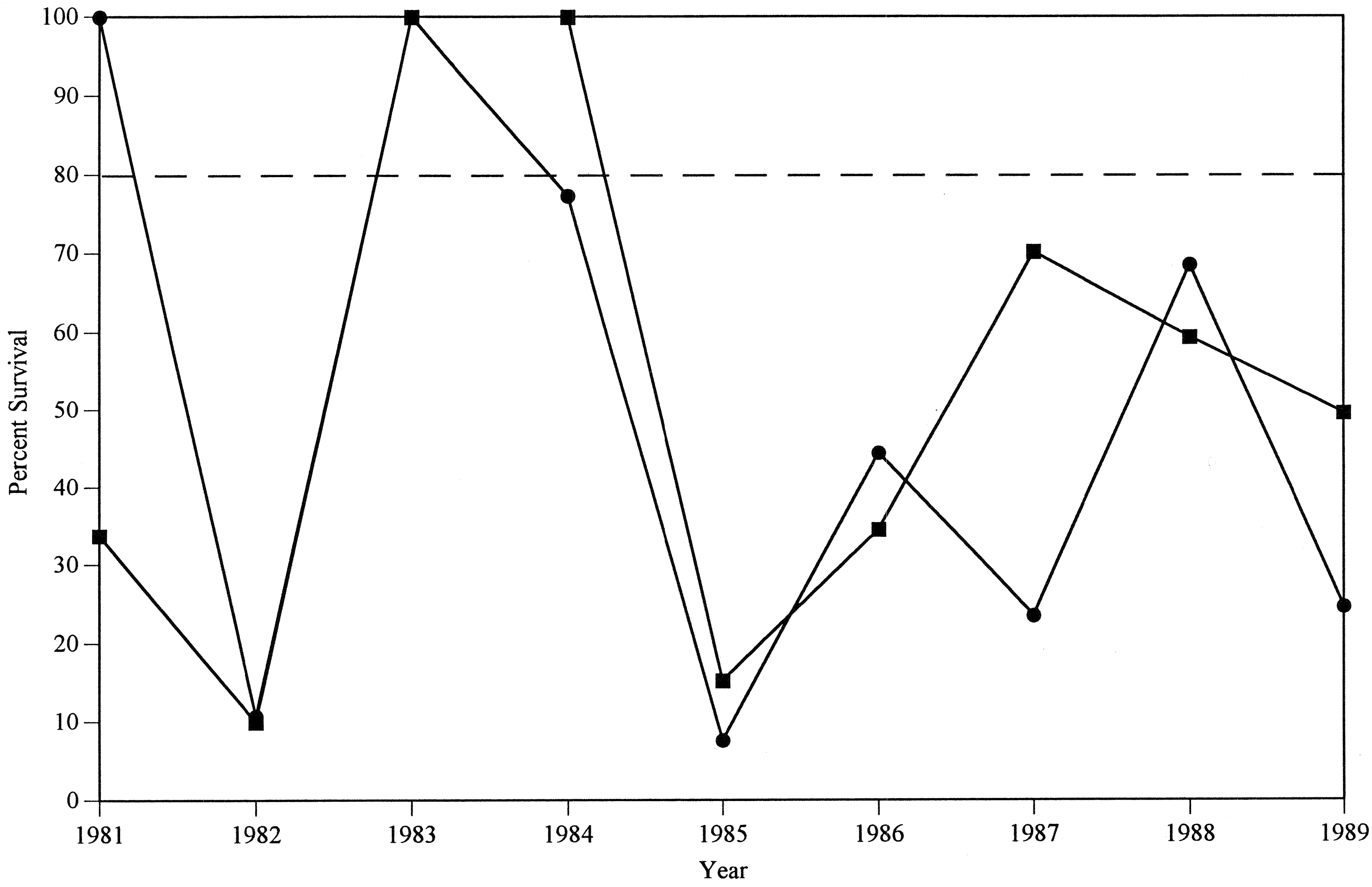

FIGURE A-1. Estimated overwinter survival rates for IGH (circles) and TRH (squares) fall chinook salmon based on Hankin and Mohr's (1993) Model CWT analysis methods. Horizontal line shows survival rate assumed for age-3 and older fish in Klamath management models.

Juvenile Survival Rates

CWT tag recovery data for Klamath River fall chinook salmon released as subyearlings in October showed remarkably strong agreement between IGH and TRH indices of juvenile survival rates across brood years (r_s=0.90, n=10; Figure A–2), and these indices were positively correlated ($0.48 < r_s < 0.59$, $0.15 > p > 0.08$) with survival indices for Rogue spring chinook released as subyearlings in October. Survival indices for Klamath and Rogue October releases were very poorly correlated with similar indices for releases of fall chinook salmon from the Sacramento delta ($-0.006 < r_s < +0.05$), however. Nevertheless, survival indices for all stocks were much lower than average for the 1981 brood year (released during the peak of the 1982–1983 El Niño event) and for the 1988 brood year (fall 1989), which had comparably poor survival. Survival indices for all stocks were substantially above average for the 1983 brood year (Table A–2).

TABLE A–2. Comparative survival rate indices of Sacramento fall, Klamath River fall (TRH fall and IGH fall), and Rogue River spring chinook salmon based on CWT release and recovery data believed to primarily reflect ocean survival conditions. Numbers in parentheses indicate number of CWT groups. When CWT groups exceeded one, reported numbers are simple averages between groups. Note that there are no adjustments for ocean natural mortalities for any stocks.

Brood Year	Sacramento Fall b/		Rogue Spring c/		TRH Fall d/	IGH Fall c/
1979	0.0322	(2)	0.0123	(4)	0.0336	0.0247
1980	0.0443	(1)	0.0066	(2)	0.0293	0.0146
1981	0.0132	(2)	0.0132	(8)	0.0085	0.0067
1982	0.0060	(1)	0.0484	(12)	0.0202	0.0225
1983	0.0211	(1)	0.0606	(10)	0.1289	0.0379
1984	0.0130	(2)	0.0195	(9)	0.0673	0.0388
1985	0.0413	(2)	0.0370	(3)	0.0658	0.0243
1986	0.0046 e/	(1)	0.0098	(3)	0.0684	0.0319
1987	0.0239	(1)	0.0064	(3)	0.0094	0.0090
1988	0.0097	(1)	0.0025	(3)	0.0104	0.0008

b/ Sacramento fall indices are based on recovery data for Feather River fish released at Port Chicago in June. Survival indices are equal to: (estimated ocean catches divided by CVI harvest rate index at age–3) divided by the number released.

c/ Rogue spring indices are based on fish released as subyearlings in October at sizes from 60–80 g. Survival indices are equal to: (total estimated ocean recoveries plus hatchery returns) divided by the number released.

d/ Klamath River indices are based on fish released as subyearlings during October from Iron Gate and Trinity River hatcheries. Survival indices are equal to: total estimated recoveries in all areas and hatcheries divided by number released. Combined TRH and IGH indices were calculated as simple averages.

e/ There was no Port Chicago release for the 1986 brood year; reported value is for a single San Francisco Bay release which may not be comparable.

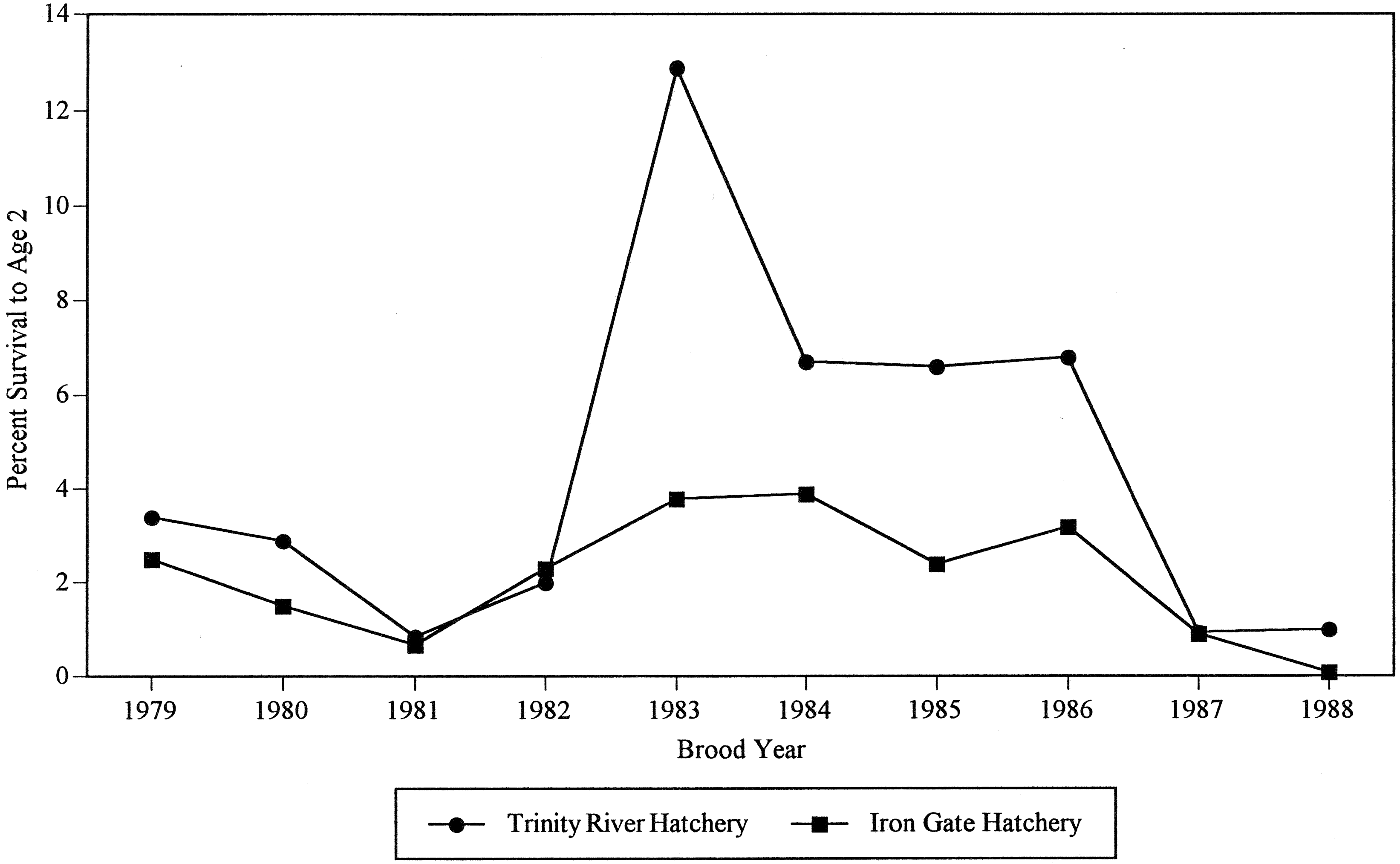

FIGURE A-2. Survival rates from release to age 2 for yearling fall chinook salmon released from the Trinity River Hatchery and the Iron Gate Hatchery in the Klamath River system. Survival rates are equal to total estimated recoveries divided by release group size, but include no adjustment for ocean natural mortality.

Tag recovery data from the Klamath and Rogue rivers indicate that yearlings released during October head straight for the ocean and do not engage in long-term freshwater rearing. If one therefore concludes that survival rates for October releases of subyearling fall chinook salmon reflect primarily ocean survival conditions, then CWT recovery data for both Klamath River hatcheries suggest that juvenile ocean survival rates were extremely poor for both 1987 and 1988 broods. Thus, poor ocean survival conditions for juveniles may have played a significant role in reduced productivity of Klamath River fall chinook salmon for those two brood years which should have made major contributions to recruitment in 1990, 1991 and 1992.

Adjusted Stock-Recruitment Data

We adjusted existing stock-recruitment data for naturally spawning Klamath River fall chinook salmon for three alternative sequences of juvenile ocean survival rates for the 1979-1988 brood years: (1) Sacramento delta releases of fall chinook fingerlings during June; (2) combined Klamath River (TRH and IGH) releases of fall chinook subyearlings during October; and (3) Rogue River releases of subyearlings during October (Table A-3). In each case, juvenile survival indices were reexpressed as a proportion of the mean annual survival index so as to generate comparable "relative survival" values across stocks. Existing brood year recruitment estimates for naturally spawning fall chinook were adjusted upward or downward by division by these "relative survivals." Including the unadjusted stock-recruitment data set, we thus examined our alternative data sets (Table A-4).

TABLE A-3. Scaled relative survival rate indices for chinook salmon released from the Sacramento, Rogue and Klamath rivers, 1979-1988 brood years. Scaled survival indices are equal to the survival rate indices reported in Table A-2 divided by the average annual survival index for individual stocks. See Table A-2 footnotes for details regarding data.

Brood Year	Sacramento Fall	Rogue Spring	Combined Klamath (TRH+IGH)/2
1979	1.469	0.572	0.966
1980	2.021	0.307	0.677
1981	0.603	0.611	0.255
1982	0.271	2.235	0.761
1983	1.472	2.799	2.356
1984	0.593	0.903	1.680
1985	1.884	1.707	1.320
1986	0.209	0.452	1.529
1987	1.090	0.298	0.319
1988	0.442	0.117	0.137

TABLE A–4. Unadjusted and adjusted recruitment data for naturally spawning Klamath River fall chinook salmon. Adjusted recruitments are equal to unadjusted cohort size divided by relative survival rate indices for Sacramento, Rogue and Klamath (TRH+IGH) stocks presented in Table A–3. Natural cohort size estimates at age–2 are from Klamath River Technical Advisory Team files.

		Age–2 Cohort Size			
Brood	Adults	Unadjusted	TRH+IGH	Sacramento	Rogue
1979	30,000	557,000	576,000	379,000	974,000
1980	21,000	144,000	213,000	71,300	469,000
1981	34,000	151,000	592,000	250,000	247,000
1982	32,000	171,000	225,000	631,000	77,000
1983	31,000	658,000	279,000	447,000	235,000
1984	16,000	575,000	342,000	970,000	637,000
1985	26,000	809,000	613,000	429,000	474,000
1986	113,000	255,000	167,000	1,220,000	564,000
1987	102,000	224,000	702,000	206,000	752,000
1988	79,000	56,000	409,000	127,000	478,000

Figure A–3 contrasts the unadjusted stock–recruitment data sets with adjusted recruitments based on relative ocean survival indices. For the unadjusted data set, all three highest spawning levels produced low or very low recruitments, prompting speculation of "overescapement" in those years. Adjusted recruitments for these large escapements, however, were highly variable and not always small. Indeed, for TRH–IGH and Sacramento River adjustments, the largest escapements produced the largest and nearly the smallest adjusted recruitments.

We conclude from these adjusted stock–recruitment data that:

1. Given a small range of adult spawning stock (e.g., 20,000 to 40,000, 100,000 to 120,000), variation in recruitment of Klamath River fall chinook salmon has been extremely large.

2. The poor recruitment that resulted from the large escapements of 1986 and 1987 appears attributable in part to poor juvenile ocean survival rates for those brood years.

3. Variability in recruitment at all levels of stock size has been so large that it is impossible to conclude that recent poor production of Klamath fall chinook is caused primarily by "overescapement."

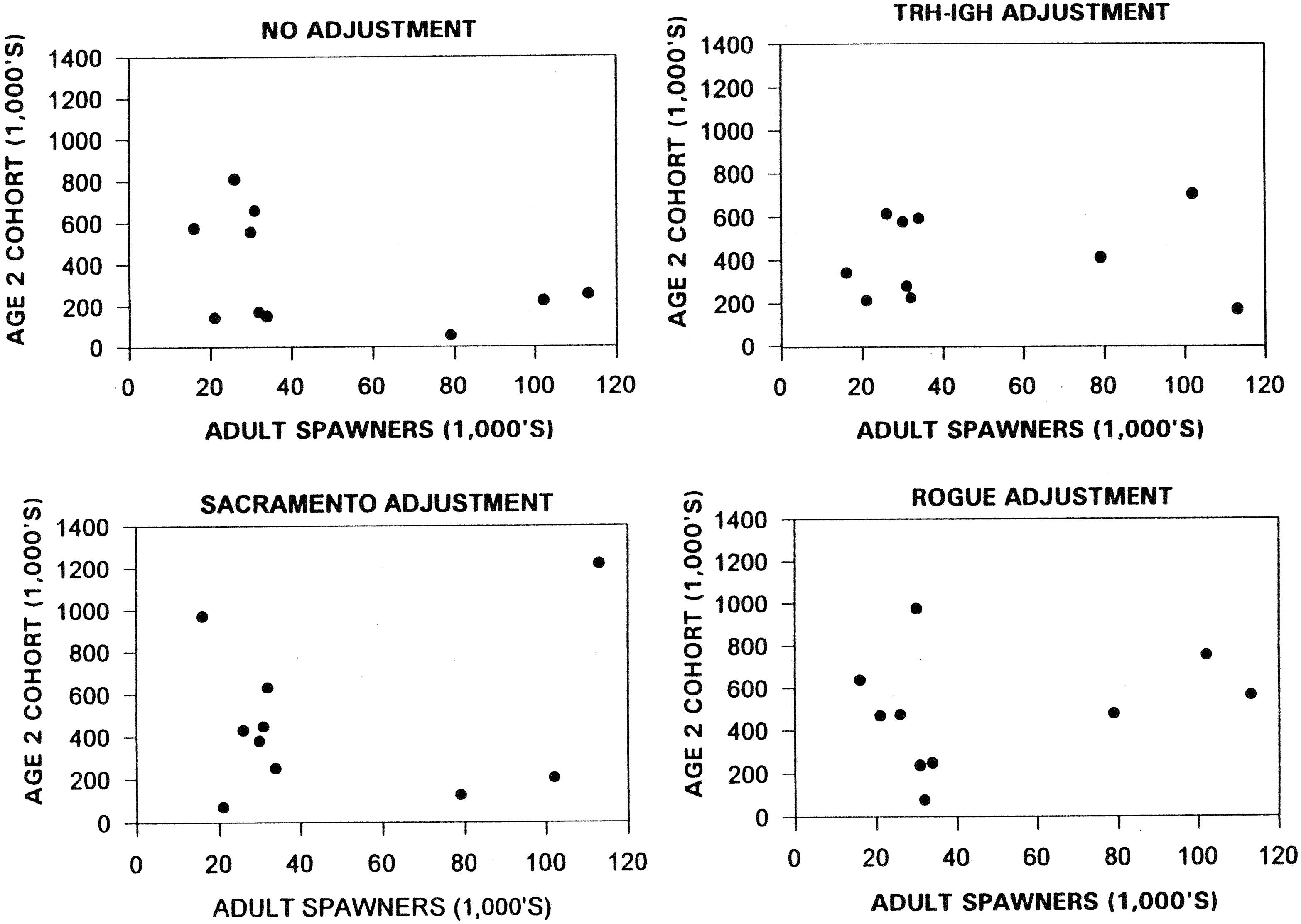

FIGURE A-3. Klamath River natural stocks spawner–recruit data adjusted for ocean survival.

SUMMARY

Poor stock productivity in recent years must be at least in part responsible for having precipitated this "overfishing" review for Klamath River fall chinook salmon. We attempted to determine the probable effect of ocean survival conditions on stock productivity by (1) calculating estimates of ocean survival rates of adults and juveniles from the 1979–1988 brood years, and (2) adjusting existing stock–recruitment data for naturally spawning adults to "average" ocean survival conditions for juveniles. Our results and conclusions are summarized below.

1. Application of the methods of Hankin and Mohr (1993) to CWT recovery data for fall chinook salmon released from Iron Gate and Trinity River hatcheries, 1979–1988 brood years, produced estimates of adult "overwinter" (approximately September through May) ocean survival rates that were extremely variable across years and, on average, considerably below the average survival rates assumed in management models for chinook salmon. Estimated ocean survival rates were especially low (about 10 percent) during the 1982–1983 El Niño event and also during 1985–1986, but they were not "unusually low" during the most recent years which might have affected recent levels of stock productivity. We therefore concluded that poor ocean survival rates for adults were probably not a primary factor contributing to recent poor productivity of Klamath River fall chinook salmon.

2. Based on CWT recovery data, we calculated indices of survival rates from release to age–2 for subyearling fall chinook salmon released in October from Iron Gate and Trinity River hatcheries, for subyearling spring chinook salmon released from Cole Rivers Hatchery on Oregon's Rogue River, and for "trucked" (San Francisco Bay area) releases of Feather River fall chinook salmon in the Sacramento River. River sampling in the Klamath and Rogue rivers suggests that when chinook salmon are released during October at a large size, their freshwater outmigration is extremely rapid. Thus, it is reasonable to assume that survival rates of these releases depend primarily on ocean environmental conditions. We found that survival rates of IGH, TRH and Cole Rivers fish were very highly correlated across years and that survival rates were unusually low (comparable to poor 1981 El Niño–affected broods) for the 1987 and 1988 brood years. We therefore concluded that poor ocean survival conditions for juveniles have probably made a substantial contribution to poor stock productivity in recent years.

3. Adjustment of existing stock–recruitment data to "average ocean survival conditions" based on estimated juvenile survival rates (see 2, above) failed to reduce variation in recruitment given stock size. Indeed, adjusted data merely emphasized the enormous variation in recruitment that has been associated with all stock sizes. We found no evidence in support of a contention that the stock was "overescaped" in 1986 and 1987.

REFERENCES

Data Sources

Sacramento coded–wire tag release/recovery data:

U.S. Fish and Wildlife Service. 1992. Abundance and survival of juvenile chinook salmon in the Sacramento San Joaquin estuary. 1991 Annual Progress Report. Fishery Resource Office, Stockton, CA.

Rogue coded–wire tag release/recovery data:

Oregon Department of Fish and Wildlife compilation provided by S. Jacobs.

Trinity River Hatchery and Iron Gate Hatchery coded–wire tag release/recovery data:

Klamath River Technical Advisory Team.

Estimation Methods

Hankin, D.G., and Mohr, M.S. 1993. New methods for analysis of coded–wire tag recovery data. Final Report, California Cooperative Fishery Research Unit Agreement Number 14–16–0009–1547, Research Work Order Number 32.

APPENDIX B
KLAMATH AND TRINITY RIVERS NATURAL FALL CHINOOK STOCK–RECRUIT RELATIONSHIP

Klamath River fall chinook are managed as an aggregate hatchery and natural stock with harvest rates set at levels that are believed to be sustainable by the natural stocks. Cohort reconstruction used to develop the stock–recruit data base for Klamath fall chinook is based primarily on data collected from hatchery produced fall chinook. Natural stock data is derived by subtracting the number of fall chinook attributable to hatchery production from total stock size estimates of both hatchery and natural chinook.

Data on Klamath River natural fall chinook stocks are insufficient to reconstruct cohorts necessary to develop a stock–recruit relationship specific to the natural stocks of each sub–basin. Age composition data, age specific maturity rates and harvest rates necessary to attempt cohort reconstruction are not available for natural stocks. Because of the lack of data specific to natural stocks and insufficient time to develop a data base using hatchery data as a surrogate for natural stocks, the development of a natural stock–recruit data base was not pursued.

APPENDIX C
SPAWNING ABUNDANCE AND DISTRIBUTION, AND BROOD ESCAPEMENT RATE OF KLAMATH RIVER FALL CHINOOK SALMON

SPAWNING ABUNDANCE AND DISTRIBUTION

Recent subfloor natural spawning escapements and severe harvest restrictions suggest that the 1986, 1987 and 1988 broods experienced poor recruitment or survival. This has led some to contend that the poor performance (measured in harvest and escapement) was caused by large spawner escapements in these years.

Although the fall chinook spawning escapements in 1986, 1987 and 1988 were the largest observed since 1978 (averaging 129,700 adults), there was a disproportionate distribution of spawners throughout the basin (Table C–1). The average fall chinook adult spawning escapement in the Klamath Basin for 1978–1985 and 1989–1992 was 41,200 and 19,800, respectively. From 1986–1988, the majority of the adult fall chinook (including hatchery escapement) spawned in the Trinity River Basin: 108,300 in 1986 (74 percent of basin total), 85,800 in 1987 (66 percent) and 62,000 in 1988 (55 percent) (Tables C–1 and C–2). Adult fall chinook escapement into Iron Gate Hatchery (IGH) and Bogus Creek, adjacent to IGH, averaged 16,100 (13 percent of basin total) and 10,700 (9 percent), respectively, during these years. During the same period, the adult spawning escapement in the Shasta, Scott and Salmon rivers averaged 3,400 (3 percent of the basin total), 5,200 (4 percent) and 3,300 (3 percent), respectively.

The average fall chinook spawning escapement for 1986–1988 to Trinity River Hatchery (TRH) and the mainstem Trinity River were 480 percent and 538 percent of the 1978–1985 average (Table C–3). Fall chinook escapements to IGH and Bogus Creek were 232 percent and 280 percent of the 1978–1985 average, respectively. During the three years of higher escapements, two of the three primary natural spawning tributaries on the Klamath River, the Scott and Salmon rivers, also experienced increases in adult fall chinook spawning, 163 percent and 242 percent of the 1978–1985 average, respectively. The Shasta River did not experience an increase in fall chinook spawning escapements, averaging only 66 percent of the 1978–1985 average.

In 1985, biologists familiar with the Klamath Basin determined, to the best of their ability, low and high optimum fall chinook spawning escapement levels for the major spawning areas (Table C–4). Various methods were employed to assess optimum spawning escapements. Based on these data, the optimum escapement for the Trinity River and its major tributaries ranges from 19,000 to 25,000 adult fall chinook. The spawning escapements that occurred during 1986–1988, and also in 1989, exceeded the high optimum escapement level (Figure C–1). Based on the optimum spawning escapement assessment of the biologists familiar with the system, it appears that there was excessive spawner escapement into the Trinity River during the 1986–1988 which may have decreased the production of this component of the Klamath Basin fall chinook population.

TABLE C-1. Klamath Basin adult fall chinook spawning escapement in thousands of fish (from 1992 "Megatable," CDFG).

Subunit	Return Year																1990–92 Avg.	1986–88 Avg.	1978–85 Avg.
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	Avg.			
Iron Gate Hatchery	6.9	2.3	2.4	2.1	8.4	8.4	5.3	20.0	17.1	15.2	16.1	10.9	6.7	4.0	3.6	8.6	4.8	16.1	7.0
Trinity River Hatchery	6.0	1.3	4.1	2.4	2.1	5.5	2.2	2.6	15.8	13.9	17.4	11.1	1.3	2.5	3.7	6.1	2.5	15.7	3.3
Trinity River Basin	31.1	8.0	7.7	15.3	9.3	17.3	5.7	9.2	92.5	71.9	44.6	29.4	7.7	4.9	6.5	24.1	6.4	69.7	12.9
Salmon River	2.6	1.0	0.8	0.8	1.0	1.2	1.2	2.3	2.7	3.8	3.3	2.9	4.1	1.3	0.9	2.0	2.1	3.3	1.4
Scott River	3.4	3.4	2.0	3.1	5.8	3.4	1.4	3.1	3.2	7.8	4.7	3.0	1.4	2.0	1.7	3.3	1.7	5.2	3.2
Shasta River	12.0	7.1	3.8	7.9	6.5	3.1	2.4	2.9	3.3	4.3	2.6	1.4	0.4	0.7	0.5	3.9	0.5	3.4	5.7
Bogus Creek	4.9	5.4	3.3	2.7	4.8	2.7	3.1	3.5	6.1	9.7	16.2	2.2	0.7	1.3	0.6	4.5	0.9	10.7	3.8
Main Stem Klamath	1.7	4.2	2.5	3.0	3.0	1.8	1.4	0.5	0.6	0.9	3.0	1.0	0.5	0.6	0.4	1.7	0.5	1.5	2.2
Misc. Klamath Tribs.	2.8	1.1	1.0	1.0	1.5	1.3	1.0	4.2	4.9	3.3	4.2	3.2	0.7	0.5	0.4	2.1	0.5	4.1	1.7
Total Adults	71.5	33.9	27.6	38.3	42.4	44.6	23.6	48.1	146.3	130.8	112.0	65.3	23.5	17.8	18.2	56.3	19.8	129.7	41.2
Natural Adults	58.5	30.2	21.1	33.9	32.0	30.8	16.1	25.6	113.4	101.7	78.6	43.3	15.5	11.3	11.0				
Percent Natural	82	89	76	88	75	69	68	53	78	78	70	66	66	63	60				

TABLE C-2. Klamath Basin adult fall chinook (percent) spawning escapement (from 1992 "Megatable," CDFG).

Subunit	Return Year																1990–92 Avg.	1986–88 Avg.	1978–85 Avg.
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	Avg.			
Iron Gate Hatchery	10	7	9	5	20	19	23	41	12	12	14	17	28	23	20	17	24	13	17
Trinity River Hatchery	8	4	15	6	5	12	9	5	11	11	15	17	6	14	20	11	13	12	8
Trinity River Basin	43	24	28	40	22	39	24	19	63	55	40	45	33	27	36	36	32	53	30
Salmon River	4	3	3	2	2	3	5	5	2	3	3	4	17	8	5	5	10	3	3
Scott River	5	10	7	8	14	8	6	6	2	6	4	5	6	11	9	7	9	4	8
Shasta River	17	21	14	21	15	7	10	6	2	3	2	2	2	4	3	9	3	3	14
Bogus Creek	7	16	12	7	11	6	13	7	4	7	14	3	3	7	3	8	4	9	10
Main Stem Klamath	2	12	9	8	7	4	6	1	0	1	3	2	2	3	2	4	2	1	6
Misc. Klamath Tribs.	4	3	4	3	4	3	4	9	3	3	4	5	3	3	2	4	3	3	4

TABLE C–3. Adult fall chinook spawning escapement as a percentage of 1978–1985 average.

Subunit	1990–1992	1986–1988
Iron Gate Hatchery	68%	232%
Trinity River Hatchery	76%	480%
Trinity River Basin	49%	538%
Salmon River	155%	242%
Scott River	53%	163%
Shasta River	9%	59%
Bogus Creek	23%	280%
Main Stem Klamath	21%	66%
Misc. Klamath Tributaries	30%	239%

TABLE C–4. Low and high assessment of optimum adult fall chinook spawning escapement levels in the Klamath Basin, June 1985.

	Number		Percentage	
Subunit	Low	High	Low	High
Trinity River	19,490	25,040	30	19
Shasta River	5,600	18,220	9	14
Scott River	6,000	9,260	9	7
Salmon River	3,000	26,000	5	20
Balance of Klamath River	6,520	27,330	10	21
Subtotal of Natural Components	40,610	105,850	63	82
Trinity River Hatchery	12,000	12,000	19	9
Iron Gate Hatchery	12,000	12,000	19	9
Subtotal of Hatchery Components	24,000	24,000	37	18
Basin Total	64,610	129,850		

Source: Recommended spawning escapement policy for Klamath River fall chinook. Klamath River Technical Team, February 1986.

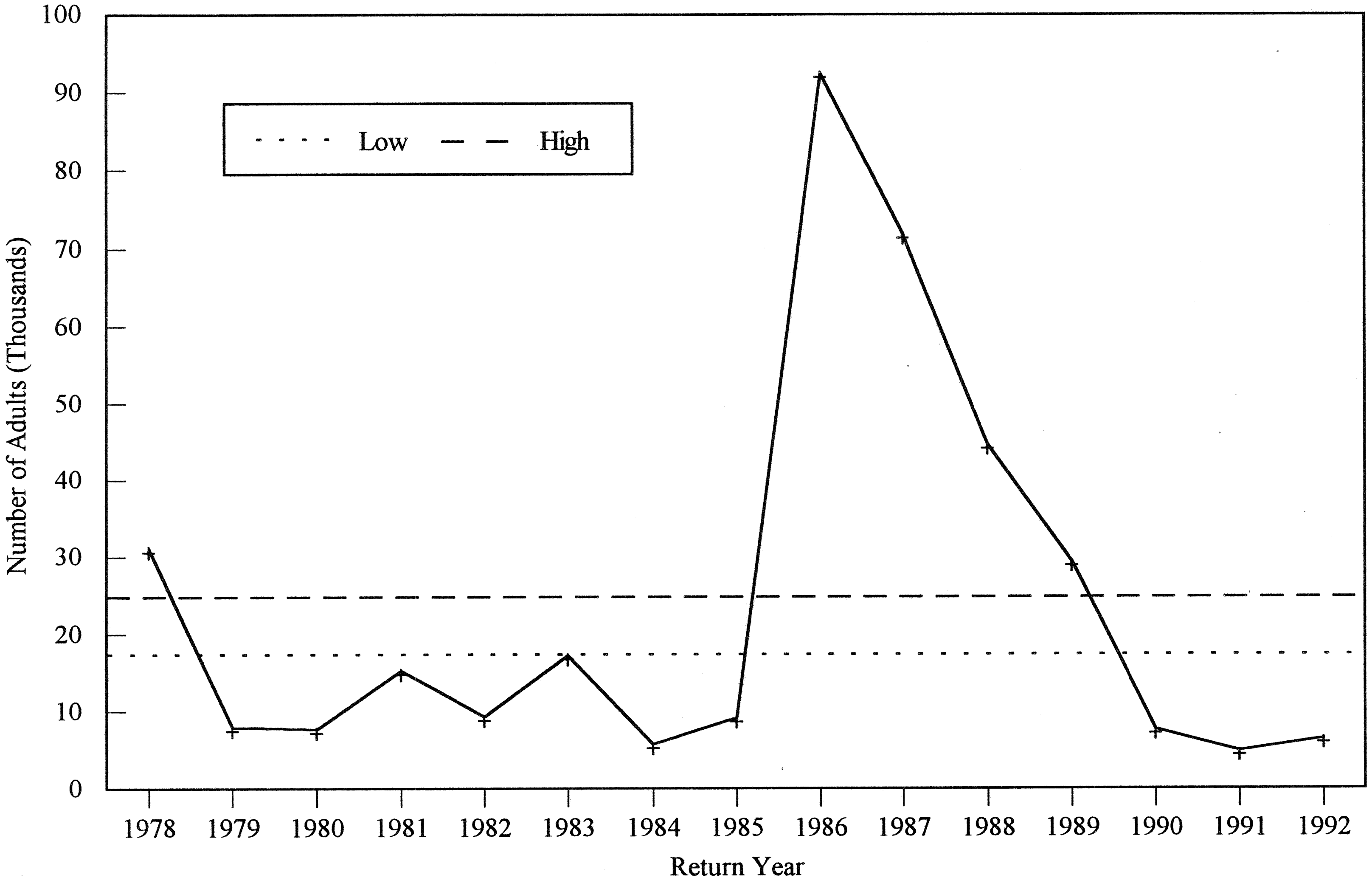

FIGURE C-1. Trinity River natural adult fall chinook spawning escapement with high and low optimum spawning escapement levels, 1978-1992.

While the spawning escapements in the Trinity River surpassed what biologists believed to be optimum levels, the combined spawning escapements of the Shasta, Scott and Salmon rivers have been below the lower level optimum escapement level in all but two years, 1978 and 1987 (Figure C–2). Combined escapements into these major natural spawning tributaries have not approached the higher optimum escapement level. The Shasta River has not met its lower optimum escapement level since 1982 (Figure C–3).

BROOD ESCAPEMENT RATE

Because there are no data specific to Trinity River and Klamath River natural stocks, brood escapement rates of hatchery fall chinook must be used to represent the natural stocks from each sub–basin. Data from fingerling release groups are used as a surrogate for natural stocks because the majority of the natural production emigrates from natal streams as fingerlings. The brood escapement rates for fingerling releases from IGH consistently have been less than the escapement rates for TRH fingerlings (Table C–5). The escapement rates for IGH fingerling releases have averaged 20 percent (1984–1987 broods) and have met the escapement rate set for natural stocks (33 to 34 percent) in only one year (1987) since harvest rate management was implemented (Figure C–4). The escapement rates of TRH fingerling releases have averaged 43 percent and exceeded 33 percent in three of the four years under harvest rate management.

TABLE C–5. Klamath River adult fall chinook brood year escapement rates 1979–1988 broods.

		Escapement Rate in Percent by Brood									
		1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
IGH:	Yearling	14	27	52	31	19	21	12	19	30	65
	Fingerling	14	23	46	33	22	16	12	18	35	70
TRH:	Yearling	28	69	60	47	51	61	57	51	47	67
	Fingerling	33	69	63	41	40	31	47	46	46	64
	Yearling +	49	–	–	–	70	66	–	77	–	–

Yearling releases show a similar trend, with escapement rates for IGH yearlings being less than TRH releases (Table C–5, Figure C–5). The escapement rates for IGH yearling releases have averaged 21 percent and have not exceeded 33 percent under harvest rate management, while escapement rates for TRH yearling releases have averaged 54 percent and have exceeded the 33 percent escapement level in all years.

Unequal escapement rates experienced by Klamath and Trinity fall chinook subpopulations have contributed to the disproportionate spawning escapements that have occurred. Because of their older average age of maturity, Klamath sub–basin fall chinook are subjected to higher harvest rates by all fisheries, resulting in lower escapement rates. The disproportionate escapement rates of fall chinook for the Klamath and Trinity sub–basins, based on hatchery fingerling releases, will continue until harvest methods are employed that will balance the impacts on the two sub–basin stocks. Until harvest methods are employed to minimize the difference in escapement rates, Trinity River sub–basin stocks will continue to escape at a rate higher than what is believed necessary, while Klamath River sub–basin stocks will escape at a lower rate.

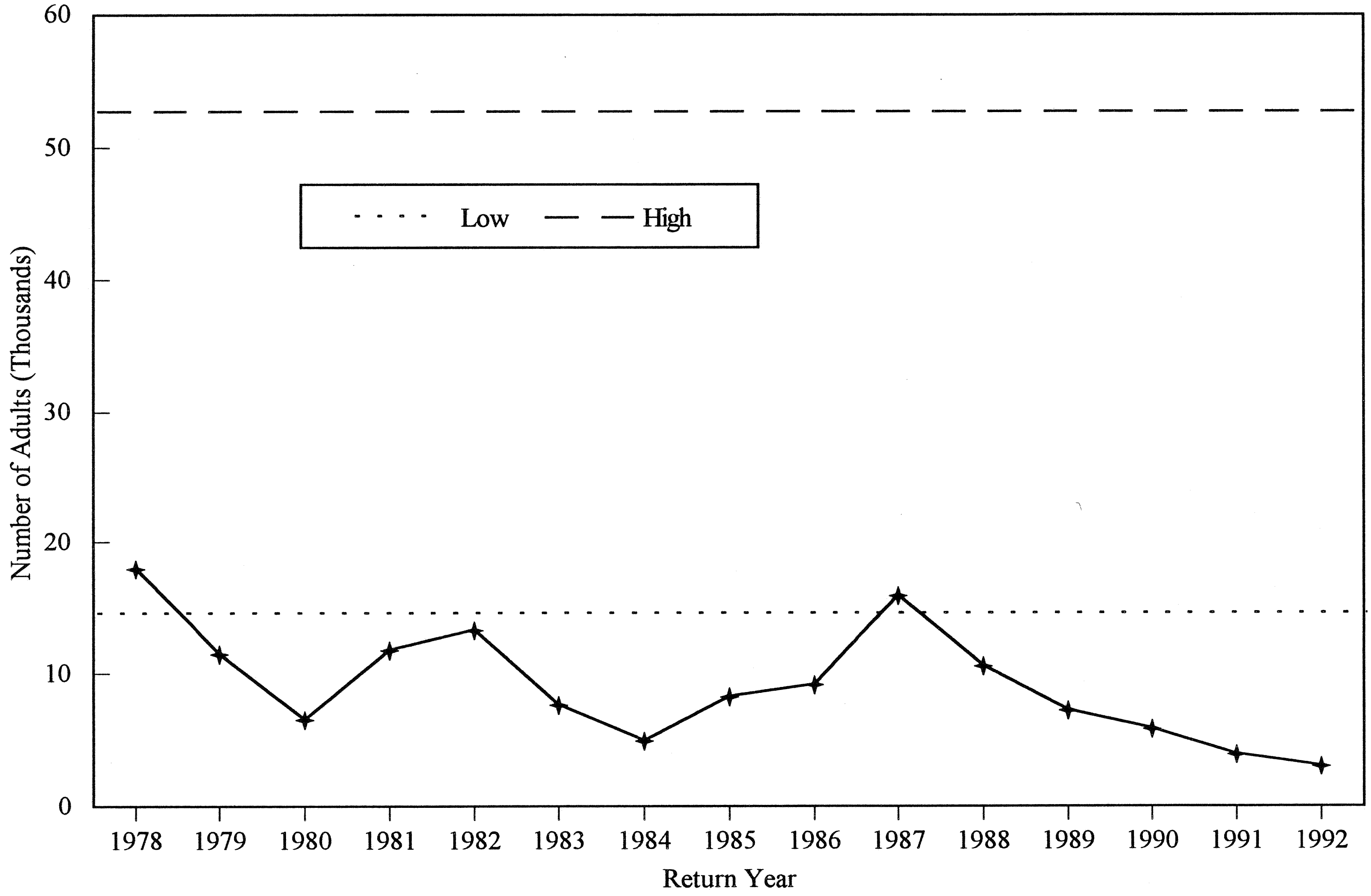

FIGURE C-2. Shasta, Scott and Salmon rivers adult fall chinook spawning escapement with high and low spawning escapement levels, 1978-1992.

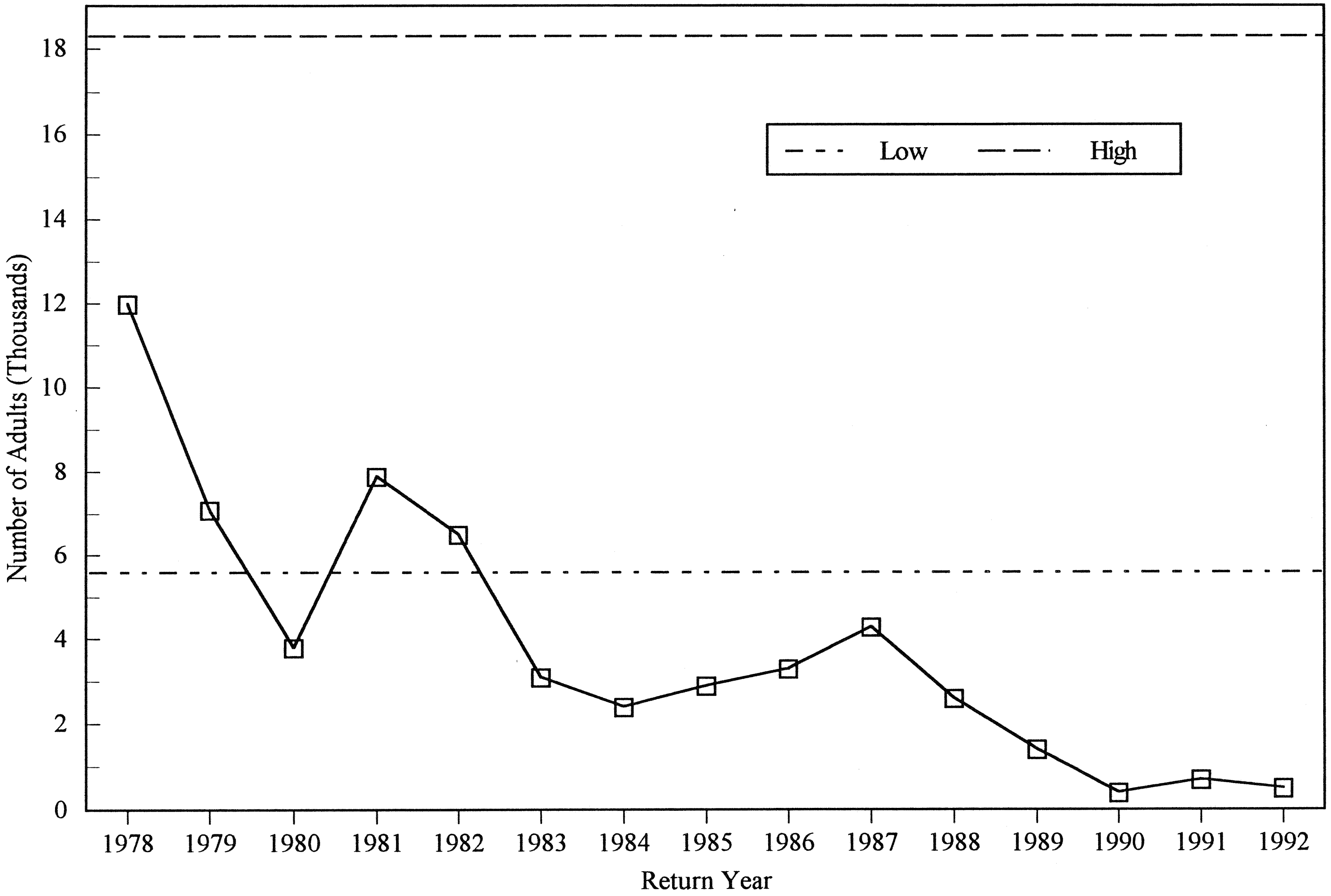

FIGURE C-3. Shasta River adult fall chinook spawning escapement with high and low spawning escapement levels, 1978-1992.

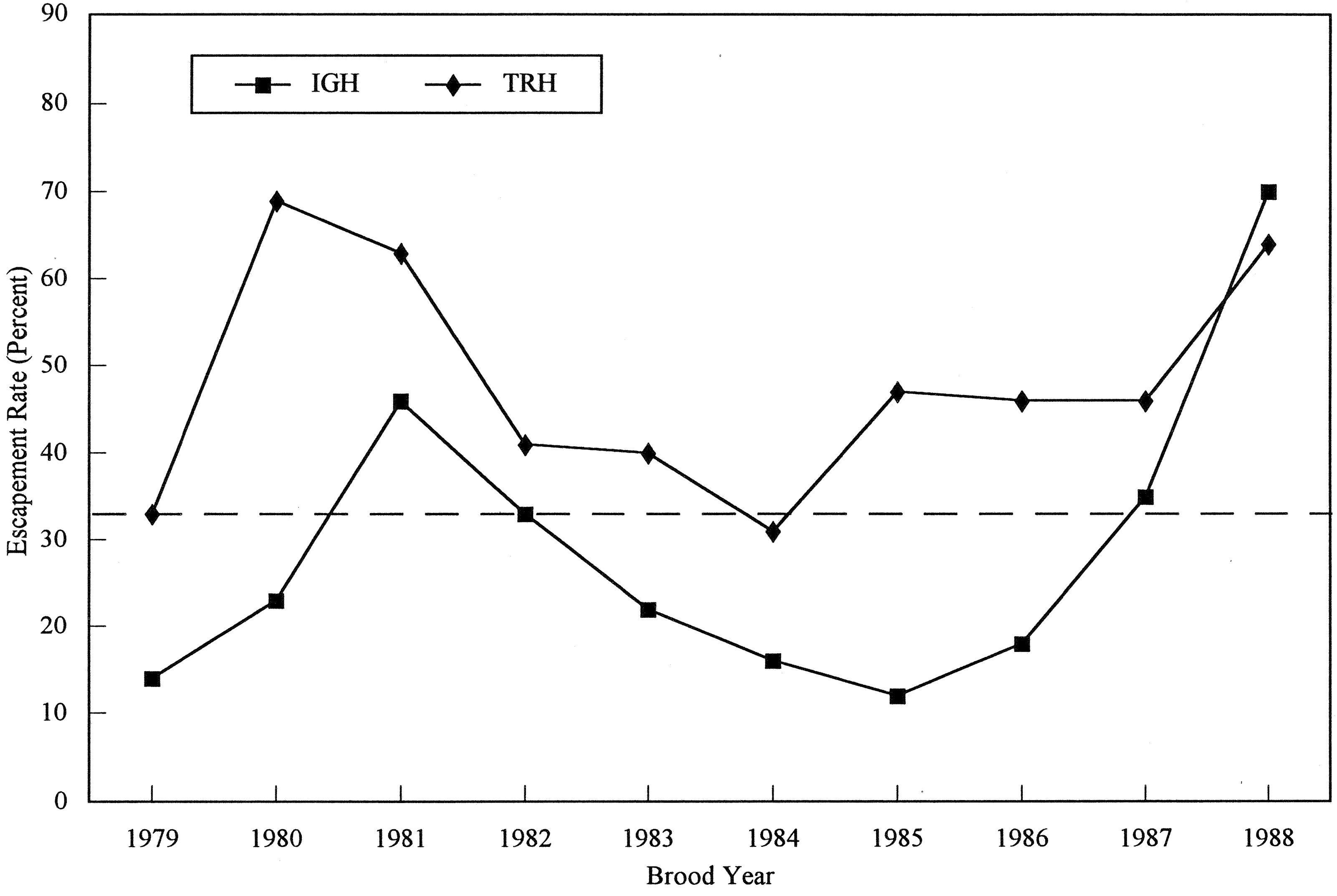

FIGURE C-4. Brood year escapement rate for Iron Gate Hatchery (IGH) and Trinity River Hatchery (TRH) fingerling fall chinook releases (horizontal line represents 33 percent escapement rate).

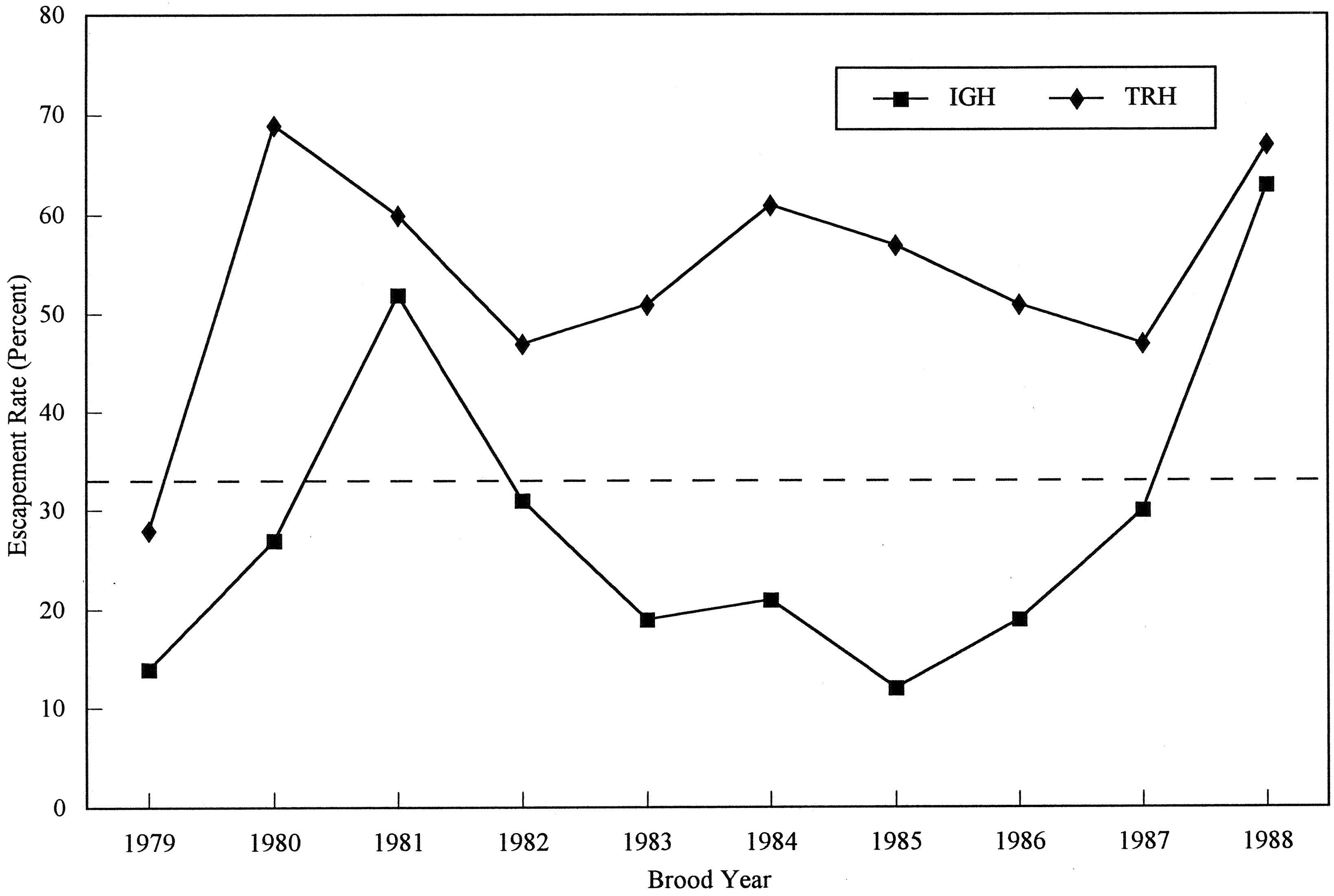

FIGURE C-5. Brood year escapement rate for Iron Gate Hatchery (IGH) and Trinity River Hatchery (TRH) yearling fall chinook releases (horizontal line represents 33 percent escapement rate).

SUMMARY

Spawning Abundance and Distribution, and Brood Escapement Rate of Klamath River Fall Chinook Salmon

Although the recruitment of the fall chinook spawning escapements in 1986, 1987 and 1988 was poor, it does not appear that spawning capacity of many parts of the basin was exceeded . The high optimum escapement level was exceeded in these years, but there was a disproportionate distribution of spawners throughout the basin. During 1986–1989, the majority of the spawning escapement occurred in the Trinity River basin (53 percent), the two basin hatcheries (25 percent), and in Bogus Creek (9 percent); accounting for 87 percent of the total spawners. The combined spawning escapement into the Shasta, Scott and Salmon rivers comprised only 10 percent of the spawning population during the same period, and exceeded the lower level of optimum escapement only in 1987. Although density dependent factors may have affected the spawning success in the Trinity River and Bogus Creek, they should not have been a factor in the rest of the Klamath Basin natural spawning areas. The escapements into major Klamath River natural spawning areas (Shasta, Scott and Salmon rivers) that are minimally affected by hatchery strays appear to be suffering from chronic underescapement.

Based on hatchery fingerling escapement rates, Iron Gate Hatchery and presumably Klamath River natural stocks have experienced low escapement rates (averaging 20 percent for the 1984–1987 broods). Trinity River Hatchery and presumably Trinity River natural stocks have experienced higher escapement rates (averaging 43 percent for the 1984–1987 broods).

Unequal brood escapement rates experienced by Klamath and Trinity fall chinook subpopulations have contributed to the disproportionate spawning escapements that have occurred. Because of the older average age of maturity, Klamath sub–basin fall chinook are subjected to higher harvest rates by all fisheries, resulting in lower escapement rates. The disproportionate brood escapement rates of fall chinook for the Klamath and Trinity sub–basins, based on hatchery fingerling releases, will continue until harvest methods are employed that will equalize the impacts on the two sub–basin stocks.

APPENDIX D
CONTRIBUTION OF METHODOLOGY PROBLEMS TO OVERFISHING STATUS OF KLAMATH RIVER FALL CHINOOK SALMON

There are several technical analyses performed each year that form the basis for the annual harvest management cycle for Klamath fall chinook salmon. First, the current year's stock size is predicted using linear regression relationships. Next, a model called the Harvest Rate Model (HRM) determines allowable catches and resultant escapements based on allocations to the ocean and river fisheries and escapement targets. Finally, a model called the Klamath Ocean Harvest Model (KOHM) is used to structure ocean fishing seasons, some of which are managed by quotas and some of which are managed on a time/area basis, to achieve the target ocean harvest impact. This section briefly describes each of these methodologies and discusses how they may have contributed to failure in meeting the spawning escapement target during the past three years.

STOCK ABUNDANCE PREDICTOR

Klamath River fall chinook salmon contribute to ocean and river fisheries primarily as age–3 and age–4 fish. Preseason stock abundance predictions for these two age classes are derived from estimates of completed cohorts from past brood years. Cohorts from past brood years are reconstructed from postseason estimates of ocean and river fishery landings, noncatch fishery related mortality, coded–wire tag recoveries, hatchery returns and natural spawning escapement. Separate predictions are made for each age class. Linear regression is used to relate past ocean population abundance estimates of age–3 and age–4 fish to inriver run size estimates of age–2 and age–3 fish, from the previous year, respectively. Ocean abundance is forecasted by substituting the most recent run estimate into these regression equations.

In order to provide reliable predictions for harvest management the following conditions should occur:

1. **Accounting and cohort reconstruction methods yield reasonably accurate postseason estimates of ocean abundance and inriver run size.** There are numerous assumptions associated with the cohort reconstruction method used for Klamath fall chinook. Although some of these assumptions probably have been violated, we believe that violation of conditions #2 and #3 (below) have been the principle causes of unreliability in stock abundance predictions.

2. **Large variation in maturity rates and natural marine mortality rates do not occur among or within cohorts.** This condition appears to be violated. Large variation in the maturity rate for age–2 Klamath fall chinook does appear to occur. The maturity rate at age 2 for Klamath fall chinook salmon has ranged from 1.5 to 15.9 percent during the 1979–1988 brood years. However, this is largely indistinguishable from variability in overwinter survival.

3. **Least–squares linear regression adequately describes the relationship between run size and subsequent ocean abundance.** Both the method itself, and violation of some of its assumptions by the data, tend to impart a positive bias at low abundance to forecasts made using linear regression.

For the eight seasons that predictions have been made (1985–1992), preseason predictions have ranged from 31 to 210 percent of postseason estimates and 56 to 183 percent of postseason estimates for age–3 and age–4 fish, respectively (Table D–1). Because the forecast of age–3 fish is based on a smaller fraction of the total cohort, variability in maturation or survival rates leads to higher error in the forecasts. Thus, the method used to forecast Klamath fall chinook abundance can be expected to have wide variability, especially for the age–3 component. Although in the mid–1980s forecasts were made based on very few data points, and sometimes forecasts were made outside the range of available data, it is unlikely that the addition of new data points will resolve the inherent variability of this projection method in the foreseeable future.

TABLE D–1. Comparisons of preseason and postseason ocean abundance estimates for age–3 and age–4 Klamath River fall chinook.

Age	Season	Preseason Estimate	Postseason Estimate	Pre/Postseason
3	1985	56,500	138,400	0.41
	1986	213,000[a/]	607,800	0.35
	1987	255,900	415,000	0.62
	1988	185,400	605,400	0.31
	1989	225,300	133,200	1.69
	1990	239,500	114,200	2.10
	1991	88,100	41,900[b/]	2.10
	1992	25,000	20,100[b/]	1.24
4	1985	45,500	46,300	0.98
	1986	53,000	56,400	0.94
	1987	164,900	194,300	0.85
	1988	149,100	108,400	1.38
	1989	172,400	185,900	0.93
	1990	40,100	71,000	0.56
	1991	35,700	26,600	1.34
	1992	35,800	19,600[b/]	1.83

a/ A 75 percent jack count adjustment was applied because most of the jacks were in the Trinity River. Also, the Klamath River Basin jack count was outside the data base.

b/ Very preliminary estimate as the cohort has not completed its life cycle.

FISHERY ALLOCATION

The HRM treats the management of Klamath fall chinook as two fisheries: an ocean fishery that impacts immature and mature chinook, and the inriver fishery (tribal and sport) that impacts only mature fish. Age specific ocean stock size estimates, projected ocean fishery impacts, average maturity rates and projected inriver fishery impacts are used to determine appropriate harvest levels to achieve resultant spawning escapement targets. Ocean and inriver harvest rates are based on the projected harvest of age-4 and age-5 chinook, which are considered fully vulnerable to the ocean and river fisheries.

Impacts of the ocean fishery based on an allocated ocean harvest rate are determined using the preseason, age specific ocean stock size estimates for Klamath fall chinook combined with factors that are used to account for the vulnerability of the stock to the offshore fisheries and the noncatch mortality of sublegal sized fish.

The Klamath River fall chinook inriver run (ocean escapement) is determined by subtracting projected age specific ocean fishery impacts from the preseason ocean stock size projection and applying age specific maturity rates to the remaining population. Initially, maturity rates were set at 0.135 for age-2, 0.43 for age-3, 0.89 for age-4 and 1.0 for age-5. In 1992, based on updated information from the Klamath River fall chinook cohort reconstruction, the maturity rates for age-2 through age-4 were revised to 0.05 for age-2, 0.37 for age-3 and 0.94 for age-4.

The impacts of the inriver tribal and sport fisheries, based on an allocated harvest rate, are determined using the projected inriver run (by age class) combined with the river contact rate and noncatch mortality factors specific to the two fisheries. The river contact rate, or vulnerability factor, accounts for the selectivity of the inriver fisheries, primarily the gillnet fishery, for larger and presumably older fish. This vulnerability factor is used to adjust inriver fishery quotas according to the expected ratio of age-3 fish to older fall chinook in the run. Originally, the vulnerability factor was set at 0.67 but this was revised in 1992 to 0.57 based on updated data from the inriver fisheries.

The preseason spawning escapement estimate of Klamath River fall chinook (natural and hatchery) is determined by subtracting the projected impacts of the inriver fisheries from the estimated inriver run. The naturally spawning component of the fall chinook run is determined by applying the average observed proportion of natural spawners in the total spawning escapement (0.74) in past years.

In order to adequately perform, the HRM is dependent upon the following conditions:

1. **Preseason ocean abundance estimates are accurate.** As discussed in the previous section, preseason ocean abundance projections have not been accurate. This condition has had a major impact on the reliability of the HRM.

2. **Preseason ocean harvest impacts are met (or not exceeded).** As discussed in the subsequent section, preseason ocean harvest impacts have generally been exceeded. This condition has also had a major impact on the performance of the HRM.

3. **Maturity rates do not vary.** Variation from expected maturity rates results in errors in model river run size forecasts. River run forecasts are most effected by variation in the age–3 maturity rate because the age–4 and age–5 maturity rates appear to be relatively constant. It appears that the age–3 maturity rate has varied considerably during the period the HRM has been in use. This variation has caused errors in river run forecasts.

4. **Preseason inriver harvest impacts are met (or not exceeded).** Since the establishment of harvest rate management for Klamath fall chinook in 1986, actual harvest rates of the inriver fishery have exceeded the preseason target in five of the seven years that this program has been implemented (Table D–2). Preseason target inriver harvest rates on age–4 Klamath fall chinook (tribal and sport fisheries combined) have ranged from 0.53 in 1987 and 1988 to 0.15 in 1992. The actual estimated inriver harvest rates have ranged from 0.84 in 1988 to 0.27 in 1992.

   The majority of the inriver harvest is operated under a quota based on a sharing allocation agreement between sport and tribal fisheries. During the period of 1986–1992, the inriver sport fisheries quota was exceeded in five of the seven years. For the same period, the tribal inriver fishery quota was exceeded in one of the seven years, 1992 (Table D–3).

   A variety of factors potentially contributed to exceeding inriver target harvest rates for age–4 Klamath fall chinook, including errors in ocean escapement estimates, underestimates of the selectivity of the inriver fisheries (particularly the lower river gillnet fishery), and underestimates of the projected sport harvest in time–managed areas. Exceeding the tribal harvest quota did not contribute to exceeding the target harvest rate in any year except 1992.

5. **Proportion of adult chinook spawning in natural areas does not vary.** Natural spawning escapement of Klamath fall chinook has ranged from 113,360 in 1986 (248 percent of the preseason projection) to 11,120 in 1992 (41 percent of the preseason projection, Table D–3). For the 4–year period of 1989–1992, actual natural spawning escapements have averaged 59 percent of preseason projections. Of particular concern is that natural spawning escapement has averaged 12,700 adults during the past 3 years (1990–1992). During these 3 years natural spawners accounted for 64 percent of the total spawning escapement into the Klamath Basin. This lower than anticipated proportion of spawning escapement as natural spawners (compared to an assumed 74 percent) has contributed to the subfloor natural spawning escapements during these years.

TABLE D–2. Inriver age–4 Klamath River fall chinook preseason target harvest rate and postseason estimate, 1986–1992 (Council 1993).

	Inriver fishery harvest rates		
Return Year	Preseason Target	Postseason Estimate	Percent of target
1986	0.50	0.74	148
1987	0.53	0.57	109
1988	0.53	0.84	160
1989	0.49	0.46	94
1990	0.49	0.30	61
1991	0.28	0.47	168
1992	0.15	0.27	180

TABLE D-3. Inriver preseason projections, postseason estimates and percent of preseason projection for Klamath River adult fall chinook escapement and harvest, 1986-1992.

	Return Year						
	1986	1987	1988	1989	1990	1991	1992
				Inriver Harvest			
Tribal							
Preseason	28,250	59,000	51,725	52,000	24,500	10,300	4,920
Postseason	25,127	53,096	51,651	45,565	7,906	10,198	5,585
(Post/Pre)%	89%	90%	100%	88%	32%	99%	114%
Sport							
Preseason	7,800	17,900	15,575	15,600	6,500	2,600	800
Postseason	21,027	20,169	22,203	8,775	3,553	3,383	1,002
(Post/Pre)%	270%	113%	143%	56%	55%	130%	125%
				Spawning Escapement			
Natural							
Preseason	45,700	62,500	50,700	76,700	49,200	35,000	27,000
Postseason	113,360	101,717	79,386	43,868	15,596	11,649	12,028
(Post/Pre)%	248%	163%	157%	57%	32%	33%	45%
Hatchery							
Preseason	16,000	40,000	14,300	21,600	15,600	12,300	9,500
Postseason	32,891	29,123	33,458	21,991	8,052	6,484	7,360
(Post/Pre)%	206%	73%	234%	102%	52%	53%	77%
				Inriver Run			
Total							
Preseason	97,750	179,600	132,300	165,900	95,800	60,200	42,220
Postseason	192,405	204,105	186,698	120,199	35,107	31,714	26,175
(Post/Pre)%	197%	114%	141%	73%	37%	53%	62%

OCEAN SEASON STRUCTURE AND MANAGEMENT

Once the current year's Klamath stock size has been projected and the appropriate level of ocean harvest has been projected, ocean fisheries are structured using the KOHM. The KOHM attempts to distribute ocean impact rates on Klamath chinook by modifying time/area fisheries or by setting quotas, measuring the overall impact rate on age-4 fish.

The KOHM uses the average ocean harvest distribution pattern of Klamath chinook observed in fisheries from 1986–1990 as the base condition. Contribution rates of Klamath fish in each of 24 model cells (six areas over four months) are scaled to current population projections for Central Valley (Sacramento), Klamath and Rogue River chinook, compared to those in the 1986–1990 base period. These other stock size projections are needed to set appropriate quota levels but do not influence the exploitation of Klamath fall chinook in time/area fisheries.

During the actual KOHM modeling process, the modeler attempts to anticipate how fishers will react to a modification in any particular month and area. For instance, closure of an area for all or part of a month would reduce Klamath exploitation in that area by some amount, but would increase it in an adjacent area that remained open (resulting from effort shifts by a portion of the fishing fleet to the open area). The modeler must use his best judgment to quantify these fishery responses, often with no actual experience to draw from.

Modeling of ocean impact rates on Klamath fall chinook has consistently failed to accurately assess actual impacts on an overall ocean basis in every year it has been used. Actual ocean fishery impact rates have exceeded preseason targets modeled by the KOHM in every year of its use except 1992, a year of exceedingly restrictive ocean fisheries (Table D–4).

TABLE D–4. Preseason targets of impact of ocean salmon fisheries on age–4 fish compared to postseason estimates, 1988–1992.

Year	Preseason target	Postseason estimate
1988	39.0%	45.0%
1989	37.5%	43.0%
1990	37.5%	61.0%
1991	16.0%	22.0%
1992	8.0%	4.0%

Because the KOHM is composed of six areas, the actual performance in predicting fishery responses was analyzed by area to determine where modelling efforts need to be improved.

In general, the following conclusions were reached:

1. No improvement in the ability to determine appropriate quota fisheries could be expected because changes in abundance, stock mix and stock distribution (compared to that in the base period) cannot be reliably predicted.
2. Angler response to changes in bag limits or days–per–week available to fishing cannot be predicted. Normal impacts should be anticipated preseason.

3. Model factors used for effort shift to the areas south of Point Arena and north of Florence appear to have been estimated reasonably well. Low Klamath abundance in these areas allows considerable leeway without major errors in predicting overall ocean harvest rate. On average since 1988, KOHM impacts predicted in these areas have been slightly higher than those actually observed.

4. Model factors used preseason in time/area fisheries in the Fort Bragg and Coos Bay areas have, on average, underpredicted actual impact rates. Short closures, coupled with partial area closures, have been ineffective in reducing fishery impacts.

5. Efforts to reduce impacts early in the season are ineffective. Early impact reductions can be negated by later open time frames or areas.

6. Attempts to reduce impacts sequentially in areas (i.e., June in Fort Bragg and August in Coos Bay) has allowed effort shifts between areas that were larger than anticipated.

Given these conclusions, it appears that the resolution of the model is beyond the reliability of the data and insufficient for structuring ocean fishing seasons. Furthermore, it is unreasonable to expect major improvements in the performance of the model in the foreseeable future.

DISCUSSION

Various methodological errors have contributed to the subfloor escapements of Klamath fall chinook during the last three years (Table D–5). During 1990, errors in accurately modeling time and area ocean fisheries were the principal cause of the escapement shortfall. This occurrence is evidenced by an actual ocean fishery harvest rate of 61 percent that exceeded the target (37.5 percent) by 63 percent (Table D–4). This occurred primarily as a result of underestimating Klamath impacts in the Coos Bay ocean catch area. Errors in stock projection and river fishery management methodologies also contributed to the escapement shortfall in 1990.

In 1991, escapement shortfalls were primarily attributed to overpredicting the ocean abundance of age–3 and age–4 Klamath fall chinook. For both age classes combined, the preseason projection was 80 percent greater than the postseason abundance estimate, allowing fishery harvest rates that were too high to attain the escapement floor. Underestimating ocean impacts in time and area fisheries, and overestimating the proportion of natural spawners in the inriver run, also contributed to the escapement shortfall in 1991.

In 1992, problems with river fishery management methodology contributed to failure to clear the escapement floor. However, the primary cause of the escapement shortfall resulted not from errors in fishery management methodology but from extremely poor natural production of Klamath fall chinook from the 1987–1989 brood years. Preseason abundance projections identified that the escapement floor would not be met even in the complete absence of ocean and river fisheries.

TABLE D–5. Summary of contribution of methodology problems to failure in obtaining escapement floor of Klamath fall chinook salmon, 1990–1992. Large impact = '++', moderate to minor impact = '+', no impact '–', and unknown impact = '?'.

Management Methodology	1990	1991	1992
Stock Abundance Prediction			
Age–3	+	++	–
Age–4	+	++	–
Ocean Harvest Management			
Time & Area Fisheries	++	+	–
River Harvest Management			
Maturity Rate	+	–	?
Proportion of Natural Spawners	+	+	+
Quotas (exceeding)	–	–	+

CONCLUSION

Various methodological errors have contributed to the subfloor escapements of Klamath fall chinook during the last three years. During 1990, errors in accurately modeling time and area ocean fisheries were the principal cause of the escapement shortfall. In 1991, escapement shortfalls were attributed primarily to overpredicting the ocean abundance of age–3 and age–4 Klamath fall chinook. In 1992, although problems with river fishery management methodology contributed to not clearing the escapement floor, the primary cause of the escapement shortfall did not result from errors in fishery management methodology but from extremely poor production of Klamath fall chinook from the 1987–1989 brood years.

Although some improvement in harvest management methodology may be realized in the future, we believe that natural variability and measurement uncertainty will always plague the performance of this process. The presently perceived needs of harvest management are beyond the reliability of the management methodology. If minimizing the risk of escapement shortfalls continues to be a management objective in the future, we recommend adopting a more conservative management structure.

APPENDIX E
REPORT OF THE SUBCOMMITTEE ON SOCIOPOLITICAL FACTORS AND ALLOCATION CONFLICTS

CONFLICTS OVER FISHERIES ALLOCATIONS

Two types of events occurred to cause the three–year underescapement situation that led to this review:

1. In 1990, both abundance and, more critically, distribution of Klamath stocks were different than predicted. The distribution of stocks appears to have been such that an ocean season shaped to avoid those stocks [targeted at 0.375 ocean harvest rate (OHR)] instead functioned as though it had been shaped to target Klamath stocks, with the result that the most restrictive ocean season to date apparently produced a Klamath OHR (0.60) which approached what would be expected with full fisheries. Had ocean fisheries caught the target harvest rate, the floor would have been met, so this event was not an allocation problem.

2. In both 1991 and 1992, there were not enough fish to have met the floor even with all fishing closed. There was nothing fisheries managers could have done in these years that would have resulted in meeting the floor, so these events were not allocation problems.

The subcommittee noted that as long as allocation conflicts take place within the framework of the Pacific Fishery Management Council's harvest rate management plan, they will not of themselves contribute to underescapement events. With a few exceptions, these conflicts have occurred within that framework. The "extra" fish caught under the exceptions have not influenced whether or not the floor was met.

Two exceptions occurred in 1987 and 1988, before harvest rate management was incorporated in the Council's framework plan. In those years, the Council managed for about a 30 percent escapement rate by allowing a slightly higher ocean harvest rate than called for in the Klamath Allocation Agreement. In both years, the floor was exceeded.

The other exception occurred in 1992, when management entities chose (driven by socioeconomic factors) to allow some fishing in both the ocean and the river in spite of the expectation that underescapement would occur even with no fishing. Once the decision to allow some fishing was made, allocation disputes added several hundred fish to the total allowable harvest. The decision to allow fishing contributed significantly to the extent of the shortfall from the floor escapement, but not to the existence of the shortfall.

JURISDICTIONAL PROBLEMS

A potential obstacle to meeting future escapement goals is the lack of a single management entity for all fisheries on Klamath stocks. Currently, the Council sets escapement goals and manages ocean fisheries, the Bureau of Indian Affairs or the tribes themselves manage the fisheries of tribes with federally recognized fishing rights in the Klamath Basin, and California Department of Fish and Game manages other fisheries in the basin. The Klamath Fishery Management Council, charged with making allocation decisions, has so far failed to reconcile conflicts between fisheries. To date, those conflicts have led to some minor excesses over total allowable harvest. The potential for major excesses exists as long as these jurisdictional disputes are unresolved.

CONCLUSION

Underescapement would have occurred in 1990, 1991 and 1992, and this review would have taken place, regardless of the influence of sociopolitical factors and allocation disputes on harvest. Those factors and disputes contributed significantly to the degree of underescapement in 1992.

APPENDIX F
DESCRIPTION AND JUSTIFICATION OF SPAWNER DEFICIT ACCOUNTING

Pursuant to instructions received at the September 28–29, 1993 Klamath River Fall Chinook Review Team meeting in Eureka, the Hoopa Valley Tribal Fisheries Department has prepared the following description and justification for spawner deficit accounting.

The Pacific Fishery Management Council directed the review team to consider spawner deficit accounting as a procedure which seeks to reduce the risk of consistent and significant failures to clear the 35,000 floor for Klamath fall chinook natural spawners. While alternative methods for avoiding future "overfishing" events for the Klamath fall chinook have been proposed, deficit accounting is the only measure which provides a post–facto response to a subfloor escapement event. The Hoopa Valley Tribe has vigorously advocated deficit accounting because it specifically seeks to provide accountability to the chinook resource through the management process.

DESCRIPTION

A description and analysis of deficit accounting was developed in July 1993 by the Klamath River Technical Advisory Team (KRTAT). This report, evaluating spawner deficit accounting, was made available to the Pacific Fishery Management Council at its September 1993 meeting and to review team members at the Eureka review team meeting.

Modifications to the Original Proposal for Deficit Accounting

The Hoopa Valley Tribe has modified the originally proposed procedures for deficit accounting implementation in response to constructive discussions at recent meetings of the Klamath Fishery Management Council, KRTAT and the Pacific Fishery Management Council. The following summary reviews these modifications.

1. **Spawner deficit accounting should be implemented on a "cohort" basis as defined in the KRTAT report.** Accordingly, shortfalls in natural spawning escapement are compensated for in the year immediately following the shortfall. The spawner escapement floor of 35,000 natural area spawners, as called for in the Council salmon fishery management plan (FMP), is the standard against which escapement is compared in all years. For example, if in year i, the natural spawner escapement was 30,000 fish, a shortfall of 5,000 natural spawners would be added to the 35,000 fish standard in the following year (i + 1). Years in which emergency rule changes to the Council's salmon FMP justify lowering the base floor would not be exempt from this policy.

2. **Deficits are not cumulative.** Only one attempt to account for a deficit is made. If the "supplemented floor" (35,000 base floor plus the deficit from the previous year's shortfall) is not attained, a new deficit is not calculated. However, if in a supplemented year, the base floor of 35,000 is not cleared, the margin by which it is missed becomes the new deficit for the following year.

3. **A cap of 20,000 natural spawners applies to all supplemented years.** While estimates of optimal utilization of available habitat for Klamath natural fall chinook have ranged as high as 106,000 spawners (Hubbell and Boydstun 1985), concerns that unbounded spawner deficit accounting would lead to "overescapement" have been raised. The cap of 20,000 natural spawners provides that total natural escapement called for under deficit accounting would not exceed 55,000 (base floor plus a 20,000 supplement), approximately half of the high estimate for optimal utilization noted above. Without this cap in place, deficit accounting would call for a natural escapement as high as 70,000 natural spawners in a year following a 100 percent shortfall of the base floor level.

JUSTIFICATION FOR SPAWNER DEFICIT ACCOUNTING

The Hoopa Valley Tribe originally proposed spawner deficit accounting as a mechanism to introduce management accountability to the Klamath fall chinook resource. The proposal sought to embrace the 35,000 floor for natural spawners in all years. The 35,000 natural spawner escapement floor for adult Klamath fall chinook was introduced during consideration of Amendment 9 to the Council's salmon FMP in 1986. The floor was an absolute minimum "comfort" level agreed to by all parties, including biologists and industry representatives, below which escapement should not be allowed to fall. In 1993, after three years of consistent and significant failures to clear the 35,000 natural floor, the Hoopa Valley Tribe began to develop spawner deficit accounting as a proactive response to this disturbing trend.

The central assumption of deficit accounting has been that lost production, caused by shortfalls in the natural spawner escapement of chinook, may be compensated for by providing added spawning opportunity for members of the same cohort in future years. Whereas several thoughts have been expressed regarding ways to avoid future subfloor escapements, deficit accounting stands alone as a mechanism which would call for immediate action in the event that the floor is not cleared. For example, floor elevation, as recently proposed by the Salmon Technical Team, would result in an elevated probability that the floor would not be met. However, floor elevation would not call for corrective action once it was determined postseason that the floor had not been met. Similarly, modifications of predictive methodologies, while being well warranted, would provide no compensation to the resource in the event that the floor were not cleared.

Our recommendation to the review team would be to consider a synthesis approach including removal of bias in predictive methodologies and spawner deficit accounting. This complete package would greatly minimize the likelihood of three consecutive years of subfloor escapement. Moreover, with spawner deficit accounting in place, management would be compelled to be accountable to the chinook resource of the Klamath Basin by acknowledging the importance of the spawner floor in all years. We look forward to further development of these and other issues through our participation in the Klamath River Fall Chinook Review Team.

REFERENCES

Hubbell, P.M. and L.B. Boydstun. 1985. An assessment of the current carrying capacity of the Klamath River Basin for adult fall chinook salmon. California Department of Fish and Game. Inland Fisheries Division, Sacramento, California.

KRTAT. 1993. Klamath River Technical Advisory Team, analysis of spawner deficit accounting as proposed for amendment to the FMP. Informal report, KRTAT, July 1993.

APPENDIX G
RIVER FLOWS OF KLAMATH BASIN

INTRODUCTION

The Klamath River Fall Chinook Review Team concluded that there was insufficient time, data and resources to quantify the effects of flow on salmon production. The lack of juvenile survival data during the freshwater phase prohibits analysis of effects influencing survival within the river. Whereas recruitment at age-2 for Klamath fall chinook may be estimated through cohort reconstruction, these data reflect survival as a combined function of freshwater and early ocean life. Available data on river flow during the water years 1979–1990 are of interest.[1/] Intuitively, suitable habitat for juvenile salmonids in their freshwater phase of life is, to some degree, dependent on water availability.

The objective of this report is to present river discharge of the Klamath Basin during water years 1979–1990. While not offering quantitative analysis of impacts to chinook survival, the team believes that this exercise is of value as it reflects the environmental stress to which chinook were exposed. The series of relatively low flow years occurring between water years 1987–1990 may have influenced chinook survival during its juvenile freshwater phase.

METHODS

Daily mean river flow data (cubic feet/second) at Klamath River mouth (Klamath, California) were obtained from the National Water Data Exchange of the U.S. Geological Survey. These data were manipulated to obtain total annual discharge (acre–feet) at Klamath, California for the water years 1979–1990. Water years run from October of the preceding calendar year through September of the water year. For example, water year 1988 began in October 1987 and included the months in which the 1987 brood fall chinook were hatched and reared.

RESULTS

Annual flows in Klamath Basin have varied between 7.4 to 26.2 million acre–feet over the period examined (Figure G–1). The low discharge volumes seen for the 1987–1990 water years reflect the drought conditions which were prevalent in the region during those years.

CONCLUSION

The comparatively low discharge volumes occurring over the period of the 1988–1990 water years coincided with the freshwater phase of the 1987–1989 broods. These broods were the major contributors to the subfloor escapement years of 1990, 1991 and 1992. Quantifying the influence of flow on juvenile survival is problematic because of the lack of freshwater survival data.

1/ Water years run from October of the preceding calendar year through September of the water year.

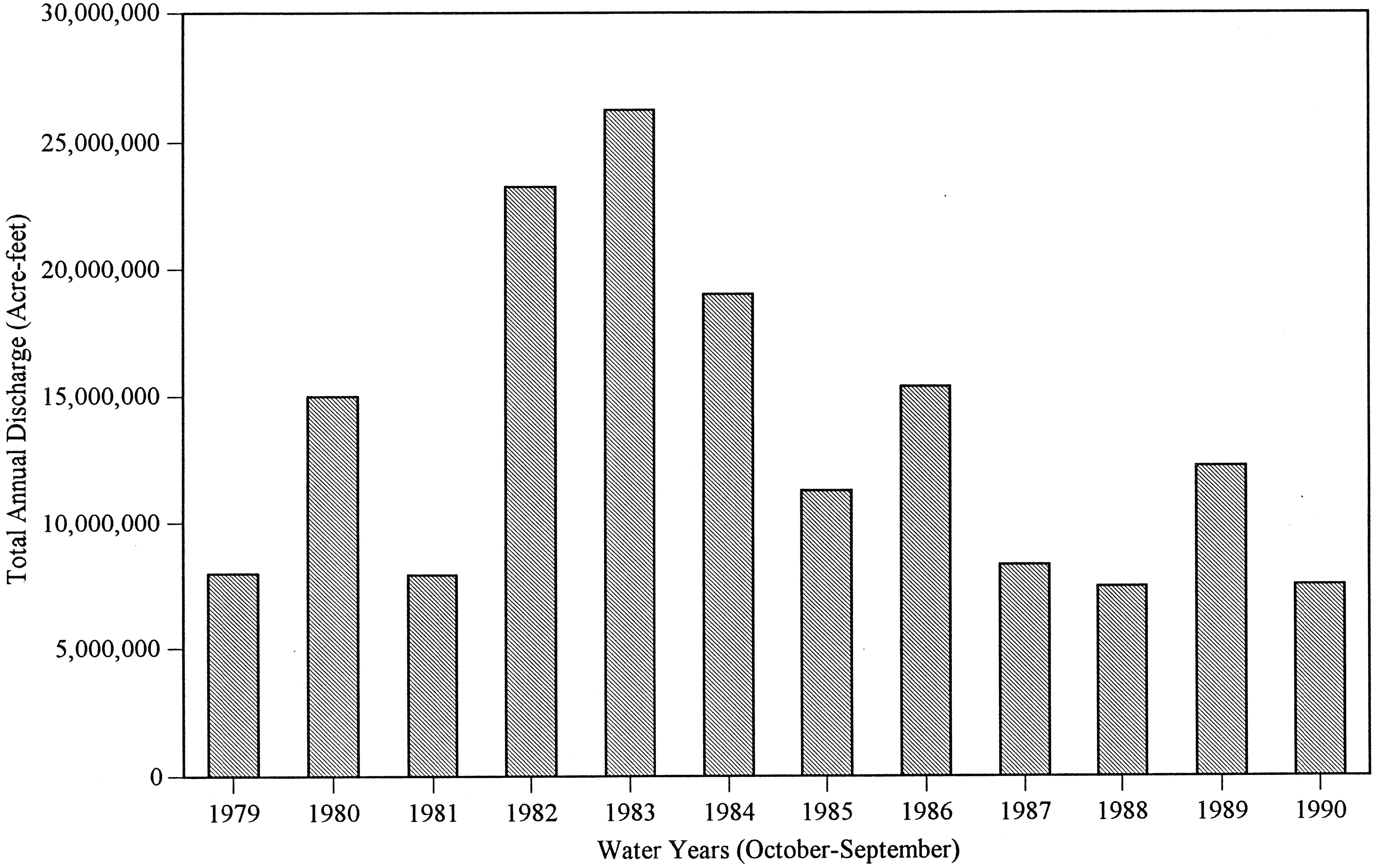

FIGURE G-1. Total annual discharge at Klamath gauge for water years 1979-1990. Brood years of 1987, 1988 and 1989 coincided with water years 1988-1990.

APPENDIX H
KLAMATH RIVER BASIN HABITAT CONDITIONS

MAIN STEM OF THE KLAMATH RIVER BELOW IRON GATE DAM

California Department of Water Resources (CDWR 1981) found that water quality problems in the main Klamath River below Iron Gate Dam occurred during drought years. Stream temperatures rose to well above chronic stress levels of 20°C (68°F) for prolonged periods during the day during summer low flow conditions. Any juvenile fall chinook salmon attempting to rear in the main stem of the Klamath River might seek refuge at the mouth of the cold water tributaries (U.S. Fish and Wildlife Service [USFWS] 1991). Intra-specific and inter-specific competition for food and space in these small habitat islands could lead to density dependent mortality in low flow years such as 1986–1989. The possibility exists that low survival of Type II fall chinook salmon juveniles, those that spend their first summer (or the first part of the summer) in the river environment (Sullivan 1989), may have contributed to low recruitment into adult fall chinook ocean populations in 1990–1992.

SHASTA RIVER

The Shasta River has acute problems with stream temperatures and low levels of dissolved oxygen. Gwynne (1993) found temperatures in the Shasta River to range as high as 30°C (86°F) at several sites. He recorded these temperatures from 1986–1992 and the maxima at all seven monitoring stations exceeded the stream temperature known to cause chronic stress for salmonids, as recognized by the North Coast Regional Water Quality Control Board. Gwynne also measured dissolved oxygen levels as low as 3.7 mg/l in the Shasta River, which is well below the level known to cause stress for salmonids.

While high stream temperatures and very depressed dissolved oxygen levels are not new phenomena on the Shasta River, problems related to these factors are known to be more severe during drought years (CDWR 1981). The drought and low flow conditions in the Shasta River that persisted during the 1986–1989 brood years may have had some bearing on decreased recruitment from those year classes. High stream temperatures during spawning migrations and difficulty of access may have restricted spawning success. Rearing for juvenile chinook in the river would also have been impacted by these water quality parameters.

SCOTT RIVER

The Scott River has both water quality and sediment problems that may reduce survival of fall chinook salmon, particularly in drought years. Substantial aggradation has taken place in the Scott Valley as a result of upland erosion on decomposed granitic terrain (USFWS 1991). Agricultural activities and flow depletion also contribute to temperature problems in the basin. The main Scott River may have extremely high temperatures in drought years. Low flows may also block access of spawning runs of fall chinook salmon to upper Scott River Basin tributaries such as the East Fork in drought years. The combination of flow depletion and aggradation may actually result in loss of surface flow in Scott Valley in drought years.

Fall chinook salmon are often forced to spawn in the canyon reach below Scott Valley in drought years (Sue Mauer, Klamath National Forest Fisheries Technician, personal communication). High levels of decomposed granitic sands in this reach may have some negative impact on survival to emergence of chinook salmon fry. Poor rearing conditions would also have prevailed during the brood years 1986–1989 which could have had some bearing on low recruitment of this stock contributing to low ocean abundance in 1990–1992.

SALMON RIVER

The Salmon River is an important contributor to the naturally spawning population of fall chinook in the Klamath River Basin. The watershed has been extensively disturbed by fire, logging and floods in this century, resulting in significant yields of sediment to the river and tributaries.

Intensive field surveys indicate that the spawning population of fall chinook in the Salmon River was well below the estimated capacity in 1991 and 1992. The redd count was only 26 per mile in 1992. Redd counts on other mid–Klamath River tributaries were much lower, ranging from 1 to 3.5 per mile.

High levels of fine sediment reduce the quality of salmon habitat by impacting food production, spawning success and volume of available habitat. Spawning gravel assessment in the South Fork Salmon River in 1990, an unusually dry year, found very low levels of fine sediment in redds. It was concluded that fine sediment had a very low potential to impact reproduction in the South Fork. Assessment of fine sediment content in riffle substrate indicated levels well below a standard proposed for stream habitat in the Columbia River Basin.

Frequent good quality pools are critical to providing essential rearing habitat for juvenile chinook salmon. In the Salmon River, field surveys show that two–thirds of the pool habitat attains a "good quality" standard.

Elevated water temperature impacts the growth and survival of juvenile salmon through rearing and smoltification. Available literature limits the optimum temperature for juvenile chinook at no more than 58°F, with one–day maximums at no more than 61°F. Maximum daily summer water temperatures in the Salmon River in 1991 and 1992 ranged from 64°F to 75°F. The Klamath River in this same period had maximums of 67°F to 77°F. The above data indicate that temperatures in the Salmon River very likely contribute to reduced growth and survival of juvenile fall chinook in the Salmon River.

In summary, assessment of habitat attributes in the Salmon River indicated low potential impacts upon chinook salmon production for spawning gravel amount and quality, fine sediment content of riffle habitat, and pool abundance and quality. Water temperatures in summer are sufficiently high to very likely reduce smolt production.

LOWER KLAMATH RIVER AND ESTUARY

The Klamath River below the Salmon River has no documented spawning activity for fall chinook. The river serves primarily as a migration and rearing area. Water temperatures can be quite warm, often exceeding 72°F in July and August. In 1991, the average daily river temperature during the primary natural smolt emigration period (June and July) at river-mile (RM) 80 ranged between 61°F and 76°F (USFWS 1993). This study reported the summer migration to be dominant for naturally produced smolts (63 percent of the total in 1991). It is of note that the overall hatchery contribution for the entire season was 76 percent.

Nine tributaries supporting low-level natural populations of fall chinook occur between the Salmon River and the mouth. Spawning habitat is rated moderate to high quality in most of the streams, but chinook returns are very low. The most important of these streams is Blue Creek, which has a minimum flow of 60 to 100 cfs. The spawning capacity for chinook has been estimated at 1,150 pair by USFWS (1990). The spawning escapement from 1988–1992 varied from 2 to 6 percent of the estimated capacity. All of these tributaries could support much higher populations of chinook salmon.

Lower Klamath tributaries have had catastrophic sediment inputs which have seriously diminished salmon habitat area and quality (USFWS 1990). Paine and Associates (1988) found that sedimentation was so severe in the mouths of these tributaries that streams flowed underground beneath deltas in drought years. This latter condition could have been responsible for both diminished spawning success for adult fall chinook salmon and decreased survival of juveniles in the drought years 1986–1989.

The habitat condition of the Klamath River estuary has not been thoroughly documented. Much of the information on the changes in the estuary is anecdotal. Indian fishers and resort owners have noted that the pools in the lower Klamath River and estuary have been considerably filled since 1970. An estuary is dynamic, reflecting highly variable erosion and deposition processes. The Klamath River Basin is noted for the extensive erosion from both man-caused and natural sources (primarily landslides). In 1931, Snyder commented on the easily visible, silt-laden flow of the river extending several miles to sea during spring run-off. A large island in the estuary depicted by Snyder no longer exists. At RM 1, the main channel has shifted 1,500 feet to the north since 1941 (California Department of Fish and Game [CDFG] 1992). Sedimentation may affect the volume of salt water intrusion which provides marine food organisms and a cool interface with the overlaying warmer fresh water. The "salt wedge" varies by tide and season, but generally extends about 3.5 miles into the estuary at high tide. The summer temperature varies from 54°F to 63°F, some 5 to 8 degrees less than the average temperature of the river.

An extended length of residence in the estuary has been identified by several workers as a major contributor to survival to adulthood of chinook salmon (Reimers 1971, Nicholas and Hankin 1989). Any reduction in the quality, volume or extent of the estuarine habitat can impact chinook salmon production. CDFG has recently begun a study of estuarine residence in the Klamath River. Significant numbers of juvenile chinook were found through August, with the peak in June and July.

MAINSTEM TRINITY RIVER AND TRIBUTARIES

The fall chinook habitat in the Trinity River is comprised of the 113 river-miles from Lewiston Dam to the mouth. The habitat has been heavily degraded since the construction of Trinity Dam in 1963. Flows have been reduced from 72 to 90 percent by diversion to the Central Valley

Project. The reduction of peak flows has caused deposition of millions of tons of sediment in the river, impacting both spawning and juvenile rearing habitat. Grass Valley Creek alone has an average annual sediment yield of almost 200,000 cubic yards. Restoration efforts have included construction of a sediment storage dam/reservoir on Grass Valley Creek, watershed stabilization, dredging of sediment, modification of river margin habitat and decreased water diversion. The total diversion is still a substantial 72 percent of the average annual flow.

USFWS (1994) has evaluated current habitat conditions in the mainstem. The evaluation determined that spawning activity for fall chinook occurs primarily in the upper 40 miles (80 percent) where deposited sediment has the most potential to affect the quality of spawning gravels. The study also estimated the spawning capacity of the entire Trinity River at 16,700 pairs of chinook salmon. The habitat capacity for juvenile chinook (spring and fall races) is estimated at 4.4 million in the upper 40 miles of the river. The conclusion is that rearing habitat is only 15 percent of spawning capacity and is the primary limiting factor to chinook production in the Trinity River. Comparatively minor numbers of fall chinook spawn in tributaries, exclusive of the South Fork, although the habitat quality is moderate to good. Intensive surveys of nine tributaries above and including the North Fork have found an average of only 100 redds in the past three years. In comparison, Horse Linto Creek, a lower river tributary and site of a small hatchery, had escapement of over 300 fall chinook in 1992. The capacity of the tributary streams for fall chinook is certainly much greater than the current escapement.

Summer water temperatures in the Trinity River are lower than during pre-dam conditions because of increased summer flow and colder water releases at Lewiston Dam. The water temperatures during the rearing and migration period of April through June are shown below in Table H-1 for 1992 and 1993. Water temperatures below 60°F are generally considered to have negligible effect upon the growth and behavior of juvenile salmonids.

TABLE H-1. Average monthly, mean daily temperatures at three stations in the Trinity River for three months in 1992 and 1993 in degrees Fahrenheit.

	1992			1993		
Location	April	May	June	April	May	June
Lewiston (RM 111)	51	51	51	47	51	55
North Fork (RM 74)	51	58	60	48	52	57
Weitchpec (RM 5)	54	64	67	50	55	60

SOUTH FORK TRINITY RIVER

The South Fork Trinity River suffers from over-supply of sediment as a result of erosion related to land management and past flood events (CDWR 1982). Hayfork Creek, a major South Fork tributary, has acute problems with high water temperatures related to agricultural activities in Hayfork Valley (USFWS 1991). The main stem of the South Fork has diminished greatly in depth and no longer stratifies sufficiently to provide rearing habitat for juvenile chinook salmon during summer. Water temperatures in both the main South Fork Trinity River and Hayfork Creek exceed levels that would lead to chronic stress or mortality during drought years (Pacific Watershed Associates 1994). For example, in 1991 the South Fork at Butter Creek was measured at 26°C (78°F) and the main stem of Hayfork Creek at Hyampom was 29.5°C (85°F).

High stream temperatures related to drought and low flows from 1986–1989 could have had some bearing on survival of juveniles reared in the South Fork Trinity River Basin. Low flows and high stream temperatures in early fall may have also inhibited spawning success for adult fall chinook salmon. Pre–spawn mortality rates in the basin for female fall chinook salmon were quite high in 1986 and 1990, which may have been related to adverse environmental conditions (Pacific Watershed Associates 1994).

CONCLUSION

It is not possible to segregate habitat causes from other environmental factors contributing to the recent decline of the natural population of Klamath River fall chinook. In consideration of the relatively sparse occupancy of spawning habitat and the lack of evidence of a decline of habitat quality affecting the subject brood years, it is probable that degraded non–flow habitat provides a chronic depression, but has not caused the current drastic decline.

REFERENCES

CDFG. 1992. Assessment of fish habitat types within the Klamath River Estuary, July 1991 – June 1992. Project Number F–51–R–4, Study Number 22, Job Number 1.

CDWR. 1981. Shasta River and Klamath River water quality investigations. CDWR, Northern District, Red Bluff, CA.

CDWR. 1982. South Fork Trinity River salmonid enhancement study. CDWR, Northern District, Red Bluff, CA.

Gwynne, B.A. 1993. Interim Report: Investigation of water quality conditions in the Shasta River, Siskiyou County. North Coast Regional Water Quality Control Board, Santa Rosa, CA.

Nicholas, J.W. and D. Hankin. 1988. Chinook salmon populations in Oregon coastal river basins; descriptions of life histories and assessment of recent trends in run strength. Oregon Department of Fish and Wildlife, Report Number EM 8402, 1989. Oregon State University Extension Service, Corvallis, OR.

Pacific Watershed Associates. 1994. South Fork Trinity River watershed and fisheries restoration action plan. Performed under contract for U.S. Department of the Interior Bureau of Reclamation, Weaverville, CA.

Paine, T.R. and Associates. 1989. Lower Klamath tributary delta study. Performed under contract for the U.S. Department of the Interior Bureau of Indian Affairs, Redding, CA.

Reimers, P.E. 1971. The length of residence of juvenile fall chinook salmon in Sixes River, Oregon. Ph.D. dissertation, Oregon State University, Corvallis, OR.

Snyder, J.O. 1931. Salmon of the Klamath River. California Department of Fish and Game Fisheries Bull. No. 34. 134p.

Sullivan, C.M. 1989. Juvenile life history of Klamath River Basin fall chinook salmon as determined by adult scale samples. M.S. thesis, Humboldt State University, Arcata, CA.

USFWS. 1990. Investigations on the lower tributaries to the Klamath River, annual progress report, fiscal year 1989. Fisheries Assistance Office, Arcata, CA.

USFWS. 1991. Long range plan for the Klamath River Basin conservation area fishery restoration program. Prepared by Wm. M. Kier Assoc. for the Klamath Task Force. USFWS Field Office, Yreka, CA.

USFWS. 1993. Juvenile salmonid monitoring on the Trinity and Klamath Rivers, 1991. Report Number AFF-1-FRO-93-14, Coastal California Fishery Resource Office. Arcata, CA.

USFWS. 1994. Restoration of the mainstem Trinity River background Report. Trinity River Fishery Resource Office, Weaverville, CA.

APPENDIX I
MIGRATION RATES, MIGRATION DURATION AND MAGNITUDE OF RELEASES OF JUVENILE CHINOOK FROM IRON GATE AND TRINITY RIVER HATCHERIES

MIGRATION RATE AND DURATION

The potential for intra-specific competition between natural and hatchery produced chinook salmon from the Klamath River basin arises when fingerling and yearling releases from the hatcheries occur, typically in June and October, respectively. The timing of fingerling and yearling releases is intended to mimic the natural migration patterns of chinook salmon and thereby reduce competition between hatchery and naturally produced chinook for rearing habitat.

The U.S. Fish and Wildlife Service Coastal California Fishery Resource Office (CCFRO) in Arcata, California has conducted juvenile salmonid monitoring programs since 1988. These programs have focused on monitoring the magnitude and duration of the juvenile salmonid emigration of the Klamath and Trinity rivers as well as collecting biological data. Trapping on the Klamath River was conducted with a rotary screw trap at Big Bar river access (river-kilometer [RKM] 81). On the Trinity River, a rotary screw trap was operated downstream of Willow Creek (RKM 38). During the juvenile monitoring program, adipose fin-clipped (AD-clip) chinook were captured and sacrificed for coded-wire tag (CWT) recovery. From the CWT data, migration rates and duration were determined for each CWT release group. Migration rates were calculated using the time from release to the median recovery for each CWT group. Migration duration was calculated from CWT recovery data, excluding the first and last 10 percent of the recoveries.

Migration rates ranged from 2.7 km/d (06-63-27) to 34.6 km/d (06-56-34) (Table I-1). There was a general relationship between migration rate and size at release, with smaller fish migrating at slower rates (Figure I-1).

Migration rates for CWT fall chinook released from Iron Gate Hatchery (IGH) ranged from 4.0 km/d for the presmolt release in 1989 (B-Series) to 10.7 km/d for the fingerling release in 1989 (6-Series) (Table I-1). The two yearling offsite releases, Indian and Elk creeks, had the lowest migration rates for any release group. The fingerling release in 1989 had a higher than expected migration rate, 10.7 km/d. Excluding the offsite releases, the larger a chinook at time of release, the greater its migration rate (Figure I-2). The duration of the IGH chinook migration ranged from two to five weeks, and was typically two to three weeks. This short time frame indicates that if any impact on natural stocks were to occur, it would do so in a short period of time. Based on mean migration rates for onsite releases , the time required for chinook released at IGH to reach the estuary ranged from 28 days (6-Series) to 75 days (B-Series) (Table I-1).

Migration rates for CWT spring and fall chinook released from Trinity River Hatchery (TRH) ranged from 5.8 km/d for the fingerling spring chinook release in 1989 (06-61-49) to 34.6 km/d for the yearling fall chinook release in 1990 (06-56-34) (Table I-1). Chinook released from TRH followed the same general trend of larger chinook having greater migration rates (Figure I-3). TRH chinook, especially yearling releases, exhibited more variability. The duration

TABLE I-1. Migration rates and duration for CWT chinook captured at Willow Creek and Big Bar trapping sites.

Hatchery	Code	Race	Type	Date	Size #/lb.	Number	Rate km/d	Duration (d)	Days to Estuary	Comments
IGH	B-series	fall	f	04/24/89	289	9	4.0	14	75	
IGH	6-series	fall	f	06/02/89	122	34	10.7	19	28	
IGH	6-1-2-1-4	fall	f	05/21/90	233	5	5.5	22	55	
IGH	6-1-2-1-5	fall	f	05/28/91	150	43	6.0	15	50	
IGH	6-1-2-1-6	fall	f	05/28/91	150	33	6.6	15	45	
IGH	06-63-24	fall	y-off	10/21/91	7	29	2.8	35		Offsite release
IGH	06-63-27	fall	y-off	10/21/91	7	73	2.7	29		Offsite release
IGH	06-57-03	fall	y	11/15/91	8	63	9.8	22	31	
TRH	06-61-49	spring	f	05/26/89	83	685	5.8	30	37	
TRH	06-56-35	fall	f	06/12/89	73	712	14.0	18	15	
TRH	6-1-4-1-2	spring	f	05/18/90	86	65	16.3	12	13	
TRH	6-1-4-1-1	fall	f	05/18/90	156	11	6.1	52	35	
TRH	06-56-39	spring	y	10/01/90	11.5	44	16.9	17	13	
TRH	06-56-34	fall	y	10/15/90	13	66	34.6	7	6	
TRH	6-1-4-1-3	spring	f	05/28/91	72	505	7.8	51	28	
TRH	06-56-36	spring	y	10/08/91	10	40	24.7	6	9	
TRH	06-56-38	fall	y	10/09/91	11	117	24.1	12	9	
TRH	06-56-40	spring	y	10/08/91	10	52	30.2	13	7	

NOTES: Hatchery: IGH = Iron Gate Hatchery; TRH = Trinity River Hatchery.
Release Type: f = fingerling; y = yearling.
Duration: number of days the code was recovered, excluding the first and last 10 percent of the tags.
Data source: USFWS-CCFRO juvenile salmonid monitoring reports.

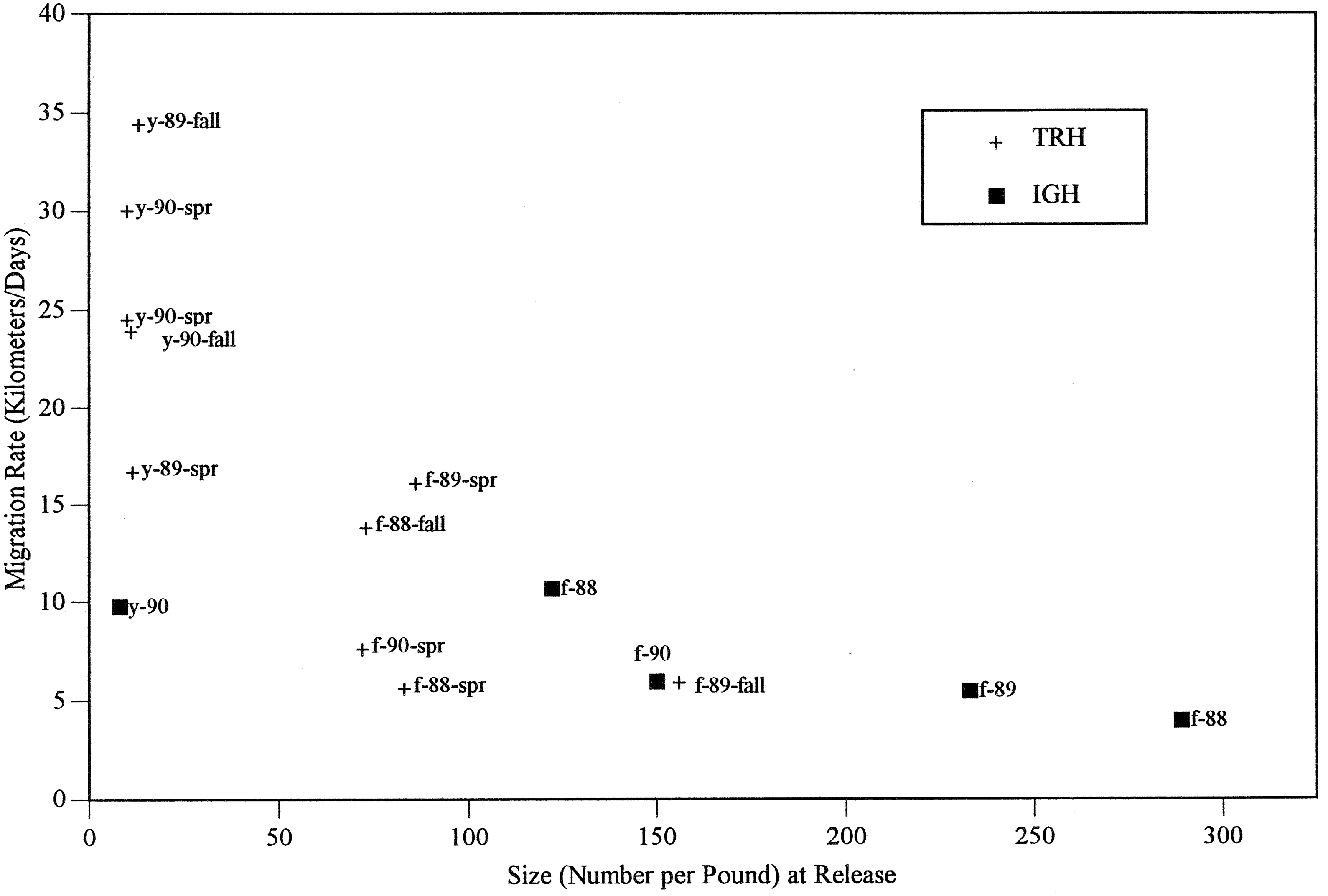

FIGURE I-1. Migration rates of Iron Gate Hatchery (IGH) and Trinity River Hatchery (TRH) juvenile chinook (release type-brood year-race; y = yearling, f = fingerling).

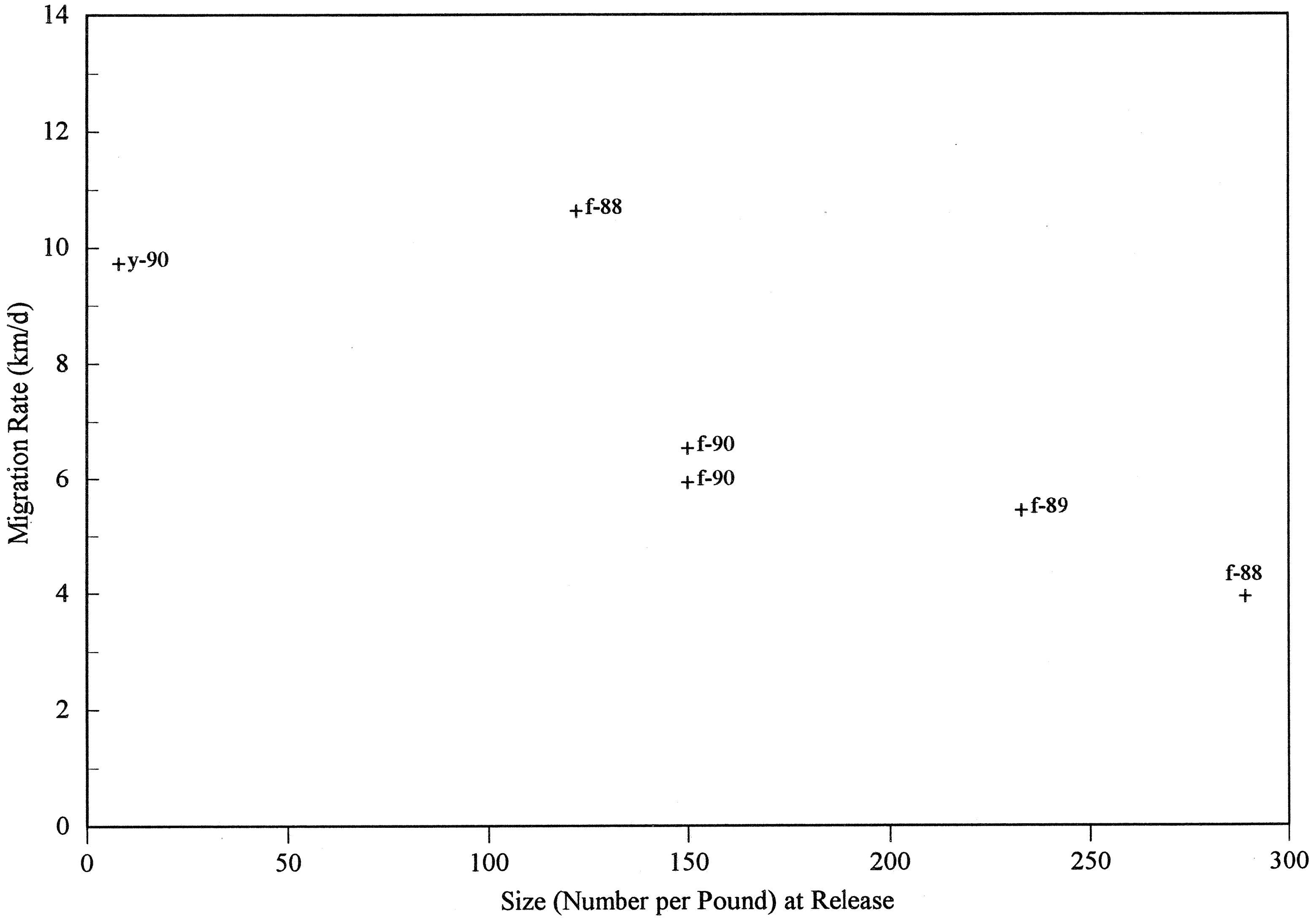

FIGURE I-2. Migration rates of Iron Gate Hatchery juvenile chinook (release type-brood year).

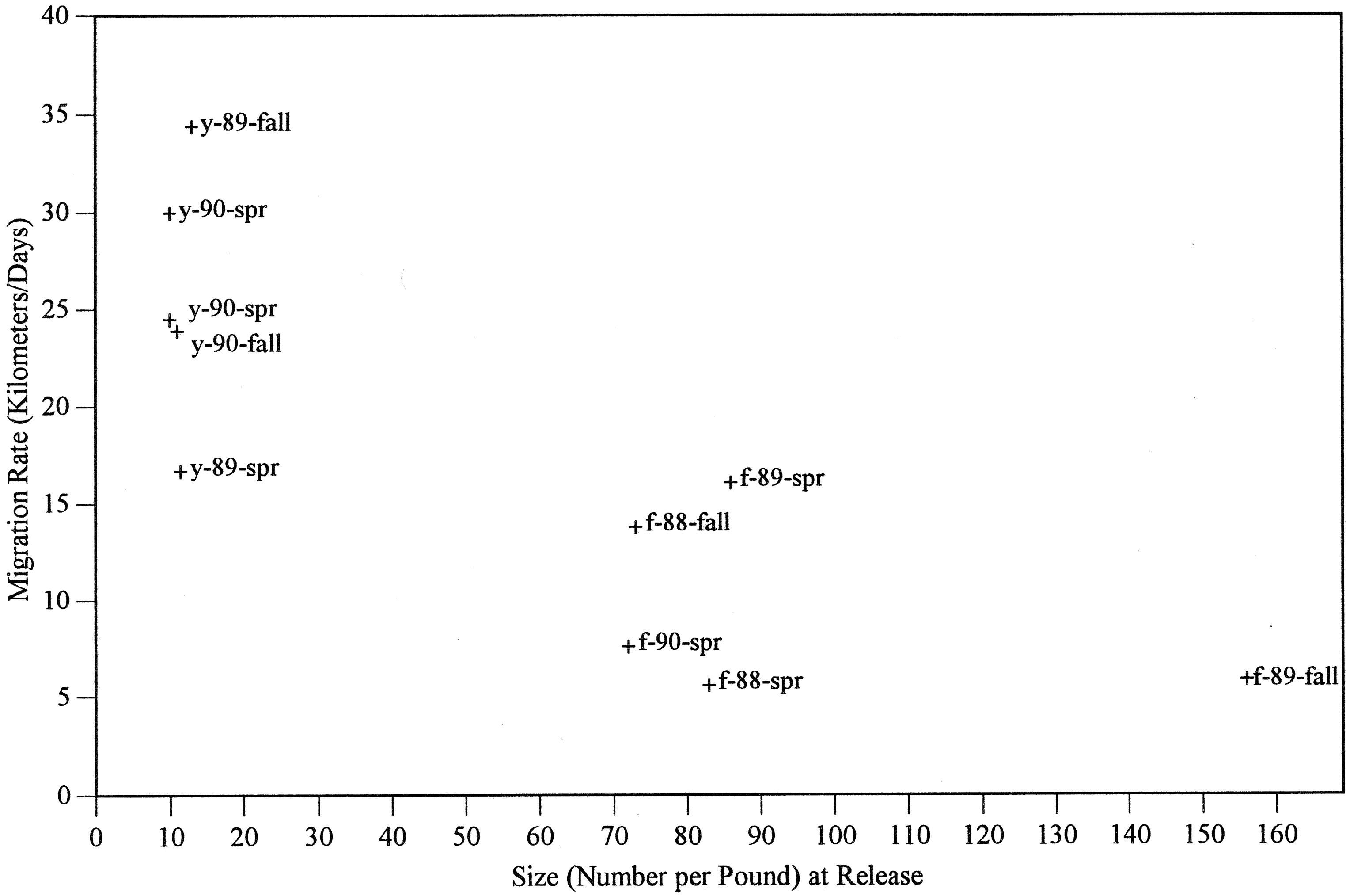

FIGURE I-3. Migration rates of Trinity River Hatchery juvenile chinook (release type-brood year-race).

of the TRH chinook migration ranged from one to seven weeks, and was typically one to two weeks. Any impact on natural stocks is probably minimal because of the short duration of these migrations. The time required for TRH chinook to reach the estuary ranged from 6 to 37 days (06–56–34 and 06–61–49, respectively) (Table I–1).

Based on CWT data, it appears that yearling chinook from IGH and TRH migrate from the system rapidly, while fingerling releases migrate through the system at a slower rate. The short duration of emigration for the yearling hatchery releases, one to three weeks, should cause minimal impacts on natural stocks because the hatchery fish do not appear to be rearing in the river for a prolonged period of time. Based on catch data collected at both trapping sites, virtually all naturally produced chinook have emigrated from the system before typical yearling releases occur. Fingerling releases tend to remain in the river longer, increasing the potential for intra–specific competition with natural stocks. It appears that it would be advantageous to rear fish to as large a size as possible while still maintaining fingerling and yearling release strategies. The larger size at release and the associated higher migration rate would serve to minimize the amount of time that hatchery fish are present in the river and, therefore, would reduce competition with natural stocks (Figure I–4).

However, using migration rates to determine if intra–specific competition occurs between hatchery and natural juvenile chinook ignores any impacts that may arise when the hatchery chinook migrate through natural rearing areas. When hatchery fish migrate through natural rearing areas, natural stocks may be displaced to less suitable rearing habitat or they may initiate their emigration prematurely.

MAGNITUDE OF HATCHERY RELEASES

In conjunction with migration rate and duration data, the magnitude of releases may provide information concerning the potential impact of hatchery releases on naturally produced chinook. These data were collected from IGH and TRH hatchery reports. Fingerlings that were moved to offsite pond rearing projects to be reared to yearlings were not included in the hatchery release numbers.

Prior to 1985, IGH fingerling and yearling releases of fall chinook averaged 1.9 million and 1.0 million, respectively (Table I–2). Fingerling production for the 1985–1989 broods greatly exceeded previous releases, ranging from 5.1 million (1989 brood) to 12.2 million (1985 brood), and averaged 9.6 million (Figure I–5). Prior to 1985, the average fingerling and yearling spring and fall chinook releases from TRH were 1.8 million and 1.3 million, respectively (Table I–2). For the 1985–1989 broods, fingerling production from TRH averaged 5.30 million (Figure I–6). During the 1985–1989 broods, fingerling production, primarily at IGH but also at TRH, was greatly increased. The combined fingerling production from both basin hatcheries averaged 14.8 million during this period, exceeding the 3.7 million average for prior years.

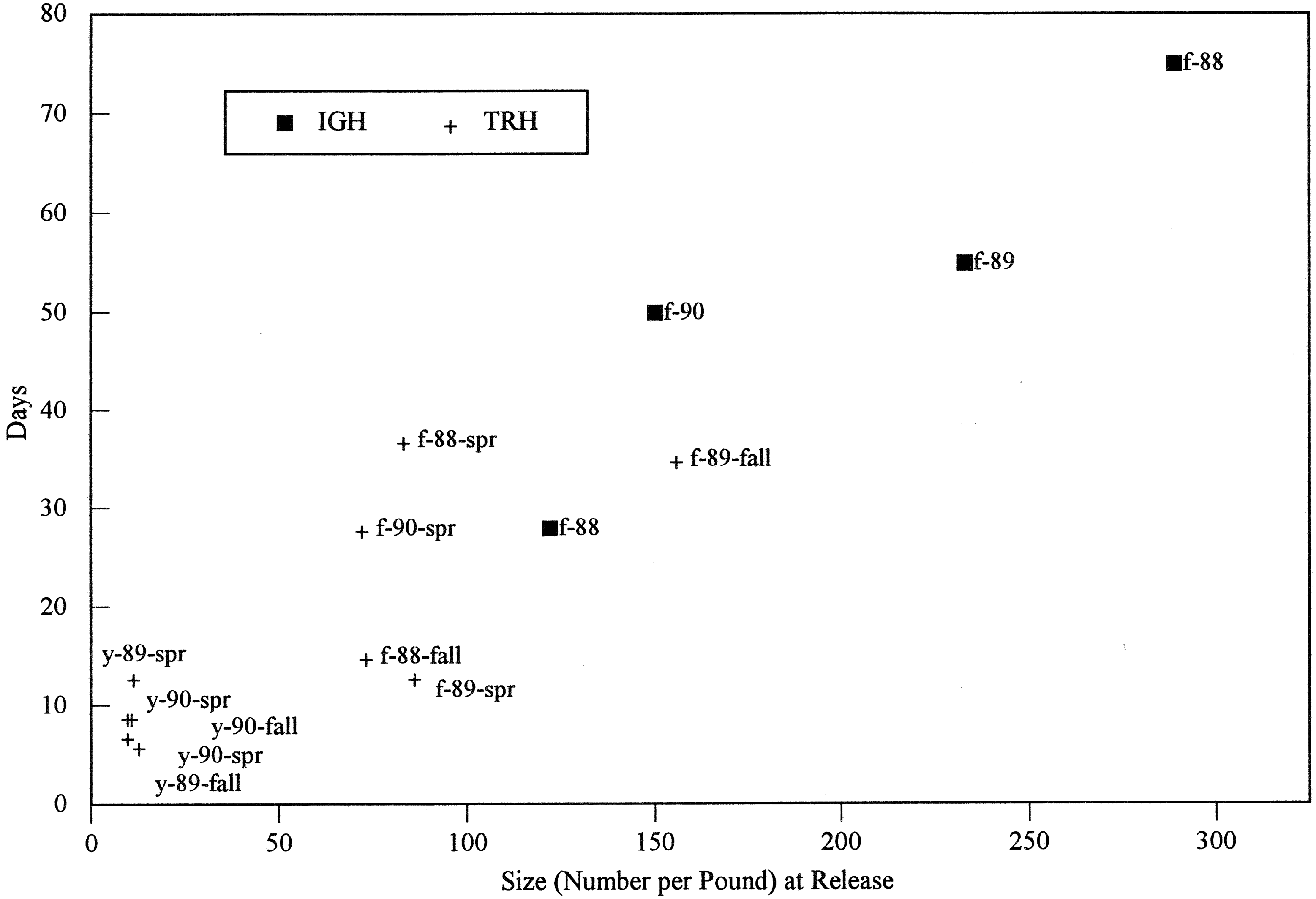

FIGURE I-4. Size at release (number per pound) and estimated number of days required to reach the estuary for hatchery reared chinook (release type-brood year-race; y = yearling, f = fingerling).

TABLE I–2. Fingerling and yearling chinook releases (in millions) for Iron Gate Hatchery (IGH) and Trinity River Hatchery (TRH), 1978–1989 broods.

	IGH		TRH		IGH & TRH	
Brood Year	Fingerling	Yearling	Fingerling	Yearling	Fingerling	Yearling
1978	3.4	1.0	4.4	1.2	7.8	2.2
1979	1.3	1.0	0.8	0.8	2.2	1.9
1980	1.5	1.0	1.5	1.0	3.0	2.0
1981	0.9	1.0	2.2	1.5	3.1	2.5
1982	0.6	0.9	0.6	1.2	1.2	2.1
1983	2.9	1.3	2.6	1.6	5.5	2.9
1984	2.8	0.9	0.5	1.7	3.3	2.6
1985	12.2	1.1	5.4	1.5	17.6	2.6
1986	9.3	1.1	5.8	1.5	15.1	2.5
1987	11.4	1.1	5.2	0.1	16.5	1.2
1988	10.2	1.0	4.9	1.7	15.0	2.7
1989	5.1	N/A	4.5	N/A	9.6	N/A

NOTES: Fingerling = May through June release; Yearling = October through November release.
IGH releases are fall chinook only.
TRH releases are fall and spring chinook.

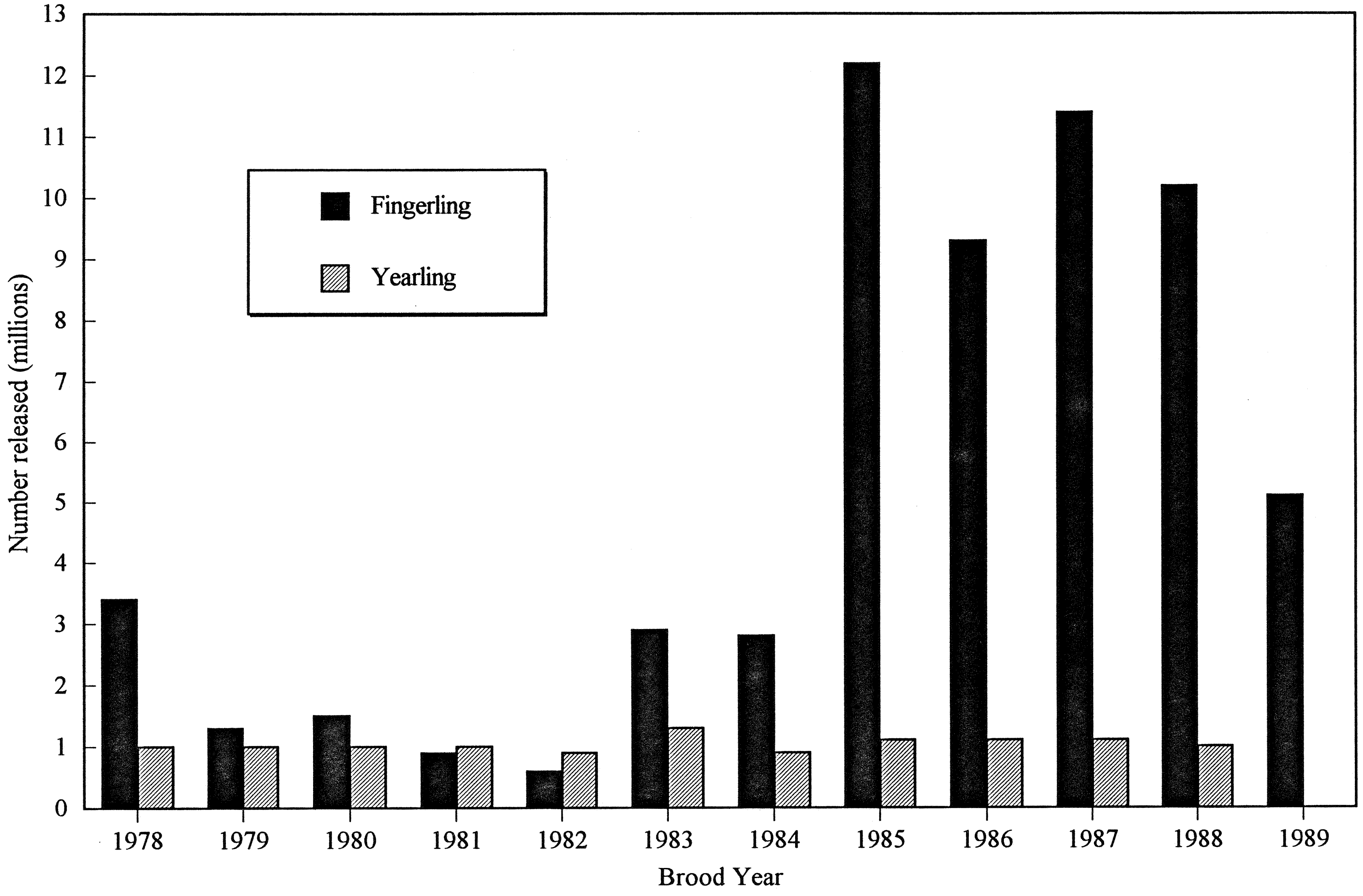

FIGURE I-5. Fingerling and yearling releases of fall chinook from Iron Gate Hatchery, 1978-1989 broods.

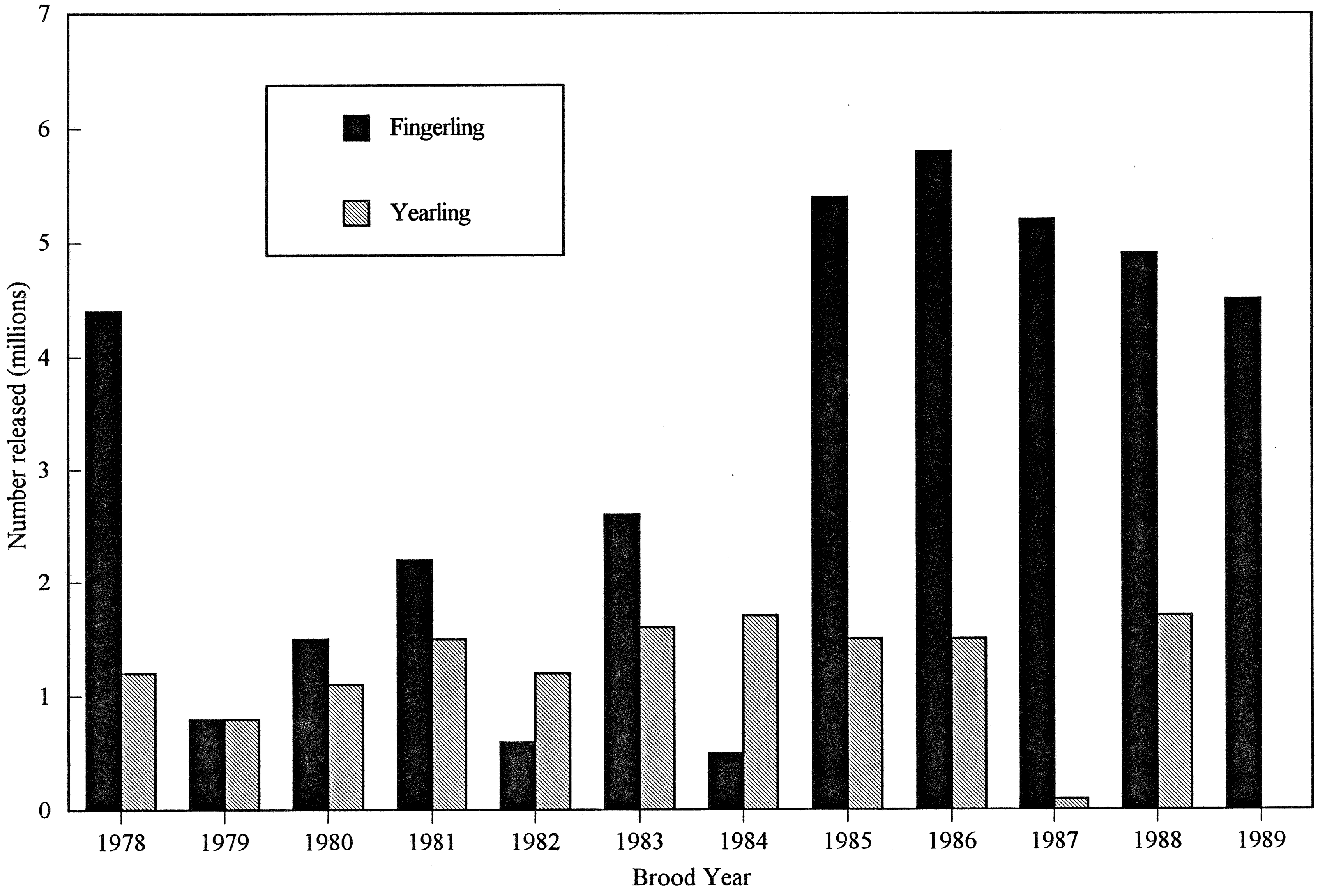

FIGURE I-6. Fingerling and yearling releases of spring and fall chinook from Trinity River Hatchery, 1978-1989 broods.

SIZE OF FISH

For the IGH fingerling chinook releases of the 1986–1989 broods, the number of fish per pound was 87, 162, 149, and 233, respectively (Table I–3). The unweighted average number of fish per pound for 1978–1985 broods fingerling releases was 88.

For the TRH fall chinook fingerling releases of the 1986–1989 broods, the number of fish per pound was 94, 117, 83 and 121, respectively (Table I–3). The unweighted average number of fish per pound for fingerling releases of the 1978–1985 broods was 87. The number of spring chinook per pound for the TRH fingerling releases for the 1986–1989 broods was 101, 85, 82 and 78, respectively. The unweighted average number of fish per pound for 1978–1985 broods spring chinook fingerling releases was 72.

1986–1989 BROODS

No direct information exists on the impact of hatchery chinook released from IGH and TRH on the natural stock juvenile chinook from the broods that have caused overfishing review (1986–1989 broods). Migration rate and duration data collected in 1989 (1988 brood year production) and 1990 (1989 brood year), in conjunction with the data on the magnitude of the releases, are the only information that can be used to infer if the hatchery releases may have impacted the natural stocks.

The 1989 (1988 brood year) presmolt (B–Series) released from IGH exhibited the slowest migration rate observed and had the greatest potential for impacting natural stocks. Although the migration duration for this release was relatively short (14d), the slow rate at which they moved through the system indicates that there was an increased period for competition with natural stocks to occur. Conversely, the migration rate of the 1989 fingerling release from IGH (6–Series) was more rapid, which should have minimized the impact on natural stocks. The fingerling release group in 1990 (1989 brood year) exhibited a slower migration rate which may have increased the competition with natural stocks.

Fingerling spring chinook (1988 brood year) and fall chinook (1989 brood year) releases from TRH exhibited relatively slow migration rates, (5.8 km/d and 6.1 km/d, respectively). These releases would have an increased potential for interactions with natural stocks. Conversely, TRH releases of fingerling fall chinook in 1989 (1988 brood year) and spring chinook in 1990 (1989 brood year) had relatively high migration rates for fingerling releases, presumably reducing impacts on natural stocks. The yearling spring chinook release in 1990 had the slowest migration rate (16.9 km/d) for all yearling release groups, but the potential for competition with natural chinook stocks is probably minimized because the majority of natural juvenile chinook have emigrated from the system before the yearling releases. The yearling fall chinook release in 1990 had the greatest migration rate for TRH yearling releases (34.6 km/d) and presumably did not compete for rearing habitat with any natural stock chinook that remained in the system.

TABLE I–3. Size at release (#/lb.) for fingerling and yearling chinook releases for IGH and TRH, 1979–1989 broods.

	IGH		TRH – Fall		TRH – Spring	
Brood Year	Fingerling	Yearling	Fingerling	Yearling	Fingerling	Yearling
1978	87	9	93	13	69	9
1979	77	11	105	13	69	11
1980	70	9	95	14		10
1981	88	10	94	15	67	13
1982	78	9	113	14	81	13
1983	75	9	66	10		10
1984	117	9	53	11		13
1985	113	8	79	13	74	12
1986	87	12	94	16	101	17
1987	162	8	117	9	85	
1988	149	8	83	15	82	13
1989	233	N/A	121	N/A	78	N/A

NOTES: Fingerling = May through June release; Yearling = October through November release.

SUMMARY

Juvenile chinook migration rate and duration data, based on CWT recoveries, indicate that the migration rates for fingerling releases are related to the size of fish at release. Smaller fish tend to migrate slower, thus increasing the potential for intra–specific competition with naturally produced chinook.

The small size at release for the 1987, 1988 and especially the 1989 brood IGH fingerlings, coupled with the magnitude of these releases (5.1 million in 1989 to 11.4 million in 1987), may have had an adverse impact on natural stocks. The fingerling releases of TRH fall chinook for the 1987 and 1989 brood years were smaller than average, 117 per pound and 121 per pound, respectively. During these years, there was increased potential for intra–specific competition with natural stock chinook. In addition to the smaller size of the fingerlings released, the magnitude of the TRH fingerling releases for the 1986–1989 broods was greatly increased over pre–1985 release levels.

Yearling chinook generally exhibited higher migration rates than fingerling releases. Yearling releases migrate through the system quickly and probably do not pose a significant threat to naturally produced chinook. Also, the majority of naturally produced chinook emigrate prior to yearling releases, reducing the potential for intra–specific competition.

The information presented here does not address the potential for exceeding the rearing capacity of the system. The magnitude of the chinook fingerling releases from the 1986–1989 broods, averaging 14.1 million, and the size of the fish at release (for some of the broods) may have negatively affected the production of juvenile chinook from the Klamath basin.

APPENDIX J
GENERAL IMPACTS OF HATCHERY/NATURAL STOCK INTERACTION AND POSSIBLE CONTRIBUTIONS TO KLAMATH FALL CHINOOK SALMON UNDERESCAPEMENT FROM 1990–1992

A combination of factors led to record low escapements of natural stocks of Klamath River Basin fall chinook salmon in 1990, 1991 and 1992. The escapement levels fell far below the 35,000 natural spawners required by Amendment 9 to the Pacific Fishery Management Council's salmon fishery management plan and led to this investigation of the causes of the shortfall. Recommendations for assuring future productivity of the stock are also to be a product of this report. Several possible contributions of hatchery operations at Trinity River and Iron Gate hatcheries to the low levels of natural escapement are explored below.

RELATIONSHIP OF HATCHERY PRODUCTION TO ADULT SURVIVAL

In 1986–1988, the large hatcheries in the Klamath River Basin increased their production of chinook salmon sharply, as noted in Appendix I. Average planting levels of fingerling and yearling fall and spring chinook salmon combined rose from an average of just over 6 million from 1978–1984 to 18.3 million from 1985–1988 (Figures I–5 and I–6, Appendix I).

Stempel (1988) pointed out the potential for competition between wild and hatchery fish in the Trinity and Klamath rivers, particularly in limited cold water rearing habitats late in summer, such as the mouths of cold water tributaries. As reported in Appendix I, migration rates were related to size at release of fingerling chinook salmon, with smaller fish moving downstream more slowly. Yearling releases migrate at a much higher rate and therefore pose less threat of competition with wild stocks. The high densities of fish reared at Iron Gate Hatchery led to a small average release size in the 1986, 1987 and 1988 brood years. The 1988 brood release had the smallest average size and exhibited the slowest migration rate (Appendix I). Trinity River spring and fall chinook fingerling releases in 1988 and 1989 (1987 and 1988 broods) also had slow downstream migration rates.

As reported in Appendix H, summer water temperatures in the main stem of the Klamath River exceeded 75°F during the 1986–1988 brood years. This temperature is above those considered lethal for salmonids (Reiser and Bjornn 1979). Mills (as cited in USFWS 1991) found that juvenile chinook bearing hatchery fin clips were often seen lingering at the mouths of cold tributaries. The drought conditions that prevailed during 1987–1989 resulted in lower than usual stream flows and higher than usual temperatures resulting in very restricted amounts of suitable habitat for both hatchery and wild chinook juveniles remaining in the river during these periods.

Reimers (1973) discovered that high densities of juvenile chinook salmon in Oregon coastal stream estuaries led to premature ocean entry and low survival to adulthood. Nicholas and Hankin (1988) also suggested that estuarine rearing capacity might serve as a limiting factor for chinook salmon juvenile survival in some Oregon coastal rivers if hatchery supplementation was increased. In background information offered for this report entitled Klamath River Mouth and Estuary Issues, it was noted that areas of the estuary had diminished greatly in depth as a result of sedimentation over the last several decades. It seems that the carrying capacity of the estuary has been decreased by sedimentation. Therefore, high levels of supplementation could have lead to competition in the estuary, resulting in lowered survival rates of chinook juveniles entering the ocean at a small size.

Numerous examples have been documented where hatchery supplementation led to low survival rates of both hatchery and wild juvenile salmonids (Smith et al. 1985; Solazzi et al. 1983; Steward and Bjornn 1990). **The combination of decreased carrying capacity related to the drought in main river environments, a shallow Klamath River estuary, extremely high hatchery releases and the slow migration rate of release groups may have acted together to cause very low survival rates for both hatchery and natural chinook salmon juveniles from brood years 1986–1988.**

During the summer of 1992, the chairpersons of the Klamath River Task Force, the Klamath Fisheries Management Council (KFMC) and the Trinity River Task Force requested a review of production at Iron Gate Hatchery (IGH) and Trinity River Hatchery (TRH) (California Department of Fish and Game [CDFG] 1992). Participants were concerned that "potential competition between hatchery and naturally produced juvenile fish for limited rearing habitat in the river system may depress the survival of naturally produced salmon and steelhead," and that genetic variability of wild stocks might be decreased because of increasing reliance on hatchery fish (CDFG 1992).

Review team members thought that a shift should be made to releasing only yearlings and no fingerlings. CDFG felt that there was a lack of convincing data showing adverse impacts of spring fingerling releases. CDFG also cited lack of rearing space, lack of ability to meet mitigation and the need for fingerling releases for harvest management as reasons to maintain the status quo. CDFG's Natural Stocks Assessment Program will be given the charge to examine competition between fingerling releases and wild fish to determine if harmful levels of competition are taking place (CDFG 1992). The possibility of increased emphasis on the yearling program at IGH will also be studied.

The CDFG operates IGH and TRH primarily to meet mitigation requirements, but in recent years has also released additional fish over mitigation requirements as an "enhancement" measure (USFWS 1991). The review team members expressed concern that any production over mitigation requirements might have undesirable side effects (CDFG 1992). CDFG agreed to return to its policy of releasing only those fish required for mitigation. Egg take at IGH has been decreased from 18 million to 10 million and no fingerlings are now planted before they reach a weight of 90 to the pound. Juvenile fish from excess eggs, taken as insurance against lack of late run fish or accidental losses, will be destroyed or used in non–anadromous programs.

POSSIBLE CONTRIBUTIONS OF DISEASE PROBLEMS TO LOW ESCAPEMENTS

Stempel (1988) contended that natural spawners in the Trinity River above Junction City in 1987 were 60 percent first generation TRH fish. Polos, in Appendix C, noted that the high escapement years of 1986–1988 were disproportionately composed of Trinity River spawners. This information suggests that fisheries and escapement levels were supported to a large degree by TRH fish.

Foott (1992) stated that "disease might be influencing smolt survival in several Trinity River stocks." Significant pathogens detected at TRH included infectious hematopoietic necrosis (IHNV) and bacterial kidney disease (BKD) caused by *Renibacterium salmoninarum*. While only 3 to 10 percent of spring chinook juveniles sampled at TRH had BKD, Foott noted that a more sizeable portion of the lot would develop the disease in salt water and many more would be carriers. Foott found a high mortality rate (20 percent) from IHNV in the spring of 1991, prior to release as fingerlings. No TRH spring chinook juveniles infected with IHNV were trapped at downstream locations so Foott concluded that either the migration rate of the infected fish was much slower or they were not surviving. The problems associated with mortality related to IHNV by Foott are consistent with the disease history at the hatchery as described by Wingfield (in USFWS 1991). **Therefore, hatchery disease problems may have contributed to the decline of "natural spawners" in the Trinity River and the scarcity of fish available for harvest in the ocean.**

RECOMMENDATIONS

1. Examine benefits of shifting production toward more yearlings and less fingerlings (at least at IGH) to increase returns and decrease competition.

2. Continue to pursue abatement of fish health problems at TRH.

REFERENCES

CDFG. 1992. Results of a review of the salmon and steelhead hatchery production in the Klamath River System. Report to the Chairpersons of the Klamath River Task Force, Trinity River Task Force and KFMC. CDFG, Inland Fisheries Div., Sacramento, California. 13 p.

Foott, S. 1992. Disease survey of Trinity River salmonid smolt populations, 1991 report. USFWS, California–Nevada Fish.

Nicholas, J.W. and D.G. Hankin. 1988. Variations in distribution of juvenile chinook salmon in Oregon coastal river basins: implications to future stock transfer practices. In: Proceedings of 1988 Northeast Pacific Chinook and Coho Workshop. Ed.: B. Shepard. American Fisheries Society.

Reimers, P.E. 1973. The length of residence of juvenile chinook salmon in Sixes River, Oregon. Oregon Fish Commission Report 4 (2): 1–43. Portland, Oregon.

Reiser, D.W. and T.C. Bjornn. 1979. Habitat requirements of anadromous salmonids. In: Influence of Forest and Rangeland Management on Anadromous Fish Habitat in the Western United States and Canada. US Forest Service, Gen. Tech. Rep. PNW–96.

Smith, E.A., B.A. Miller, J.D. Rogers and M.A. Buckman. 1985. Outplanting anadromous salmonids – a literature survey. Oregon Department of Fish and Wildlife for Bonneville Power Administration. Project No. 85–68.

Solazzi, M.F., S.L. Johnson and T.E. Nickelson. 1983. The effectiveness of stocking hatchery coho pre–smolts to increase rearing densities of juvenile coho in Oregon coastal streams. Oregon Dept. of Fish and Wildlife. Portland, Oregon. 14 p.

Stempel, M. 1988. Possible implications of integrating hatchery and natural production of salmon and steelhead in the Trinity River Basin. USFWS, Weaverville, California.

Steward, C.R. and T.C. Bjornn. 1990. Supplementation of salmon and steelhead stocks with hatchery fish: a synthesis of published literature. Idaho Cooperative Fisheries and Wildlife Research Unit, Univ. of Idaho, Moscow, Idaho 83843. Tech. Report 90–1.

USFWS. 1991. Long range plan for the Klamath River Basin conservation area fishery restoration program. Klamath Field Office, Yreka, California. 320 p.

APPENDIX K
MIXED STOCK FISHERY MANAGEMENT CONCERNS AND MASS MARKING

Salmon fisheries for Klamath Basin fall chinook stocks include hatchery fish as well as natural spawners that may return to basins with poor habitat conditions. Lichatowich and McIntyre (1987) stated that stock productivity for stocks returning to impaired habitat may be lower than those returning to good habitat and much lower than hatchery stocks. Differential productivity of naturally spawning populations and lack of ability to develop stock–recruit relationships for each means that overall escapement goals for the Klamath fall chinook salmon stock may be met while sub–basin stocks decline.

To avoid loss of some naturally spawning populations in the Klamath/Trinity Basin, new harvest management methods may need to be implemented. One such potential solution may be to mark all hatchery chinook salmon and to selectively harvest them in all fisheries where feasible and to release unmarked wild fish (Wright 1993). To implement such a program it may be necessary to mark all hatchery salmon in the Pacific Northwest.

Under current management conventions, adipose fin clipped salmon must be coded–wire tagged. The prohibitive cost of marking all hatchery fish has impeded prior efforts to implement a universal marking program. The adipose fin clip is the most desirable for a marking program because of its easy visibility and lower impacts on survival of marked fish. In order to cost effectively accomplish this universal marking, several steps would be necessary. The adipose fin clip would have to be "desequestered" from the current convention that all adipose fin–clipped fish have coded–wire tags. Cheek tags, which can be sensed with an electronic device dockside or during creel census, could be implanted in a fraction of hatchery release groups. Thus, the normal coded–wire tag information could thus be gathered while not having to pay for universal coded–wire tagging.

The high costs of marking are also related to the high number of hatchery fish produced. Findings in Appendix J suggest that "more may not be better" when it comes to hatchery production. Total production of hatchery fish for all facilities in the Klamath Basin might more closely reflect the optimum number if determined by a scientific method of varying hatchery output consistently over many years. Arriving at optimal planting levels through this means is known as adaptive management.

High levels of incidental hooking mortality are also raised as reasons universal marking and selective harvest will not work. Wertheimer (1988) found that past estimates of incidental hooking mortality were much higher than in work he conducted on troll fisheries in Alaska. On the East Coast, sport anglers have been successfully taught to minimize incidental hooking mortality when practicing catch and release fishing (Malchoff et al. 1992). Educational efforts would be necessary to win cooperation to keep incidental hooking mortality to manageable levels in sport and commercial fisheries.

Universal marking would also yield information on the balance of hatchery and wild stocks in freshwater and in the ocean, which would be useful for management. Other river basins in the Pacific Northwest, such as the Columbia River, currently have similar problems to those manifest in the Klamath Basin with regard to mixed stock fisheries and potential stock loss and may support this effort. Universal marking and selective harvest is also being explored as a solution to protect Oregon coastal natural coho salmon stocks.

RECOMMENDATION

The review team recommends that the Pacific Fishery Management Council support studies of cost effectiveness and efficacy of universal marking of all hatchery salmon in the Pacific Northwest and selective harvest in all fisheries where possible. A discussion paper on the management and policy issues involved in mass marking and a study plan prepared by the technical committees of the Pacific Salmon Commission are attached.

REFERENCES

Lichatowich, J.A. and J.D. McIntyre. 1987. Use of hatcheries in the management of Pacific anadromous salmonids. American Fisheries Society Symposium 1: 131–136.

Malchoff, M.H., M.P. Voiland, and D.B. McNeill. 1992. Guidelines to increase survival of released sport fish. Cornell Cooperative Extension, Sea Grant Program. 104SGFS 14.00 33/90 4/92 4M GPP E11091G.

Stempel, M. 1988. Possible implications of integrating hatchery and natural production of salmon and steelhead in the Trinity River Basin. USFWS, Weaverville, California.

Wertheimer, A. 1988. Hooking mortality of chinook salmon released by commercial trollers. North American Journal of Fisheries Management 8: 346–355.

Wright, S. 1993. Fishery management of wild Pacific salmon stocks to prevent extinctions. Fisheries, Vol. 18, No. 5, 2 p.

State of California

Memorandum

To : Klamath Overfishing Review Group

Date November 18, 1993

From : **Department of Fish and Game**

Subject : Mass Marking Salmon

As was requested at our November 10 meeting in Arcata, attached is a memorandum I prepared discussing some of the technical, management and policy issues to consider if salmon are to be mass-marked for selective fisheries. Also attached is a study plan prepared by the U.S./Canada technical committee.

Alan

Alan Baracco
Senior Marine Biologist
Ocean Salmon Project
Marine Resources Division

Attachment

AB:alg

State of California

Memorandum

To : Mr. A. Petrovich Jr.
Deputy Director

Date : August 4, 1993

From : **Department of Fish and Game**

Subject : Mass marking of hatchery chinook salmon for the purpose of selective ocean salmon fishery management.

PCFFA's request for a discussion of mass marking of hatchery chinook so that selective fisheries can be prosecuted in the ocean raises numerous technical, management and policy questions. There has been an ongoing dialogue on many of these issues for some time. In October, 1992, a working group met in Tiburon and spent an entire day discussing mass marking. The meeting was attended by Agency personnel, commercial and sport fishery representatives, and conservation group representatives. While no consensus on the value of mass marking hatchery fish was reached, significant factors to consider were identified.

I. Technical Issues:

a. **Marking methods available are limited.** A recent report by PSMFC describes a wide variety of ways to mark fish, and new techniques are being investigated. However, at this time (if easy identification by fishers is needed) only a fin clip is available. The adipose clip would be best, both from the standpoint of ease of application and ease of seeing marked fish.

b. **Costs of marking millions of fish would be considerable.** IFD recently identified costs of marking fall chinook at Iron Gate and Trinity hatcheries. These two facilities produce about 5 million fall chinook per year, Central Valley hatcheries produce about 8 times that many. Spring chinook add another incremental cost.

c. **Logistics of marking millions of fish would be considerable.** There are restricted time frames to actually accomplish the marking of fish. In the Klamath, for instance, fish don't reach a size acceptable for marking until March and are released in May or June. Around the clock operations with many marking crews could be expected to get the job done.

d. <u>**There is a biological cost of marking fish.**</u> Mortality during the marking process should be anticipated. Mortality may approach 5%, reducing hatchery production. Some studies have shown a long-term differential mortality associated with marking. Even an adipose clip may induce an additional 5 to 10% loss.

e. <u>**Fishery induced mortality of non-target (unmarked) fish may be excessive.**</u> Some fishing methods would not be compatible with selective fishery management (gill nets and perhaps mooching, as examples). Even ocean troll fishing causes mortality, and whether or not it is 25-30%, as some studies show, or lower, as most fishermen think, fisheries may need to be restructured to reduce or avoid non-target fish. Technical aspects of non-target mortality are complex. A short list of items that must be taken into account in a selective ocean fishery include:

1. Time, area and duration of the fishery
2. Desired harvest rate of marked fish
3. Desired impact rate on unmarked fish
4. Life history of chinook, i.e., multiple year exposure to fishery.
5. Ratio of marked to unmarked fish at start of fishing.
6. Ratio of marked to unmarked fish as fishery progresses over time.

An extensive modeling effort would be required to try to quantify these items, some aspects of which are not well defined.

II. **Management issues:**

1. <u>**Coordination on a coastwide basis.**</u> Selective harvest in ocean fisheries would require that a marking program was compatible among all producers of hatchery fish, although not all hatchery fish would need to be marked.

2. <u>**Enforcement within a selective fishery may prove difficult.**</u> Inspection of fish offered for sale would need to be accomplished. Whose responsibility would that be, the fishermen's, the dealer's, or the retail buyer's? There could also be problems associated with the validity of the mark chosen. No technology currently exists to mass mark salmon with an externally visible mark that cannot be applied by unauthorized personnel.

3. **Application of selective fisheries would vary with fish abundance.** In high abundance years (i.e., 1988) it may not be necessary to carry out selective fisheries, since natural spawning escapements could be expected to be adequate. Marking would still have to be done, however, since these high abundance years cannot be anticipated three to five years in advance. In low abundance years (i.e., 1992) fisheries may not benefit from selective harvest opportunities, since restrictions in **all** fisheries may be needed to meet **hatchery** egg take needs. For instance, in 1992 only 7,600 adult chinook returned to Iron Gate and Trinity hatcheries combined, well below egg take needs. There were **no** surplus hatchery fish available for selective fisheries that year.

4. **Angler response to selective harvest regulations are unknown.** Traditionally, of course, anglers (sport and commercial) have been able to keep all fish over a minimum size. Depending on the ratio of marked to unmarked fish, in a selective fishery some fish have to be released. Would anglers stop fishing if the percent of fish they could keep were low? Would they be satisfied with releasing a large unmarked but legal sized fish? Would it be acceptable to release an unmarked fish that is bleeding? Would it be acceptable to release an exhausted fish with sea lions looking on? These situations could lead to rejection of selective fisheries as a viable management program, although it would lead to some interesting fodder for outdoor writers.

III. Policy issues:

1. **Naturally produced fish could become second rate citizens.** Managing fisheries based on hatchery production could actually reduce our ability to restore and enhance naturally produced fish and their habitats. There would be tremendous political pressure to increase hatchery production, and given limits on funding, what would that do to habitat restoration? If a dam were to be build on the South Fork Eel River, would it be our policy to retain naturally produced fish, or would we opt for hatchery production?

2. **Is an ocean mixed stock fishery the best way to manage the salmon resource?** If we need to embark on these extremely complicated and costly programs to maintain ocean fishing, there can be legitimate questions raised about our basic management policies.

3. **Would advocacy of selective fisheries be viewed as advocacy of eliminating some fishing methods?** Gill net fisheries, currently employed only by Indians on the Klamath River, would not benefit from selective fisheries. While the Department could profess not advocating the abolition of gill nets, others might.

While mass marking appears to be a desirable management tool by groups such as PCFFA, in my opinion it is not a plan that would benefit California ocean fisheries.

Alan Baracco
Senior Marine Biologist
Ocean Salmon Program

cc: Mr. L.B. Boydstun, MRD-Headquarters

M E M O R A N D U M

TO: Coho Technical Committee Members
Chinook Technical Committee Members
Pat Patillo, WDF
Pete Lawson, ODFW
Mike Grayum, NWIFC
Mike Matylewich, CRITFC
Rich Comstock, USFWS

FR: Gary S. Morishima, Co-Chair, Coho Technical Committee
Ron Kadowaki, Co-Chair, Coho Technical Committee
Brian Riddell, Co-Chair, Chinook Technical Committee
Jim Scott, Co-Chair, Chinook Technical Committee

RE: Draft Framework for Study Plan to Evaluate Selective Fisheries

DATE: September 27, 1993

Attached for your review and comment is a draft framework for a study plan to evaluate selective fisheries. The framework was developed in response to a July 29th directive from the Research & Statistics Committee of the Pacific Salmon Commission.

The study plan is to be presented for consideration by the Pacific Salmon Commission during the Executive Session scheduled for October 19-21.

Feel free to circulate the draft within your organization as you deem appropriate. Please provide comments and suggestions no later than close of business on October 8, 1993. For convenience, comments should be related to the line numbers provided for reference.

Gary Morishima will collate comments and incorporate them into the next draft. Gary can be reached at 3010-77th S.E., Suite 104, Mercer Island, WA 98040, (206)236-1406 (Phone), (206)236-6842 (FAX).

FRAMEWORK FOR EVALUATING THE FEASIBILITY AND POTENTIAL UTILITY OF FISHERIES TO SELECTIVELY HARVEST MARKED HATCHERY FISH

Introduction

Public concern for conservation of naturally-produced salmon stocks is increasing. In response, management agencies are seeking innovative approaches for fisheries regulation, including the use of selective harvest. Conceptually, selective fisheries are straight-forward and appealing; the idea is to enact regulations that provide differential protection for wild stocks by targeting harvest on hatchery-produced fish. In combination with appropriate regulations in other fisheries, selective fisheries may theoretically bring total harvest impacts within desired levels for wild stocks of concern.

However, there are some major questions that need to be addressed before this management approach can be properly implemented.

- ➢ *Can selective fishery regulations lead to reductions in harvest rates on unmarked stocks and can these reductions be translated into reductions in exploitation rates or increases in spawning escapements? Under what circumstances?*
- ➢ *If any reductions in harvest rate, exploitation rate, or spawning escapement occur, can they be measured within acceptable levels of accuracy and precision?*
- ➢ *Will there be deleterious impacts on the coastwide coded-wire-tag (CWT) program and management tools such as harvest management planning models? Can deleterious impacts be overcome?*
- ➢ *How would fisheries be affected (e.g., catch level, season length, non-catch mortality)?*
- ➢ *What are the practicalities and estimated costs of implementation? How might fisherman behavior be altered?*
- ➢ *Would changes in hatchery production strategies result? How would production of wild stocks be affected?*

The framework described in this document below attempts to identify the structure and process necessary to complete the in-depth analysis required to address these and other issues.

Suggested Framework - Time Schedule and Tasks

The suggested time frame for completion of the selective fishery assessment is fall of 1994. This would be a very ambitious time schedule that would require significant manpower from the Coho and Chinook Technical Committees as well as contributions from U.S. and Canadian domestic management agencies. The Pacific Salmon Commission and domestic management agencies will have to determine if the priority of this issue is sufficiently high so as to justify re-direction and dedication of the resources necessary to complete the work. Significant resources will be required and other activities will be affected. For example, current work on estimating coho stock composition by the Coho Technical Committee as well as technical work required to develop abundance-based management approaches could be seriously impacted.

The proposed framework would consist of three major elements: (1) a steering committee; (2) a set of work groups; and (3) a workshop to present results and facilitate dialogue.

1. **Steering Committee** - A steering committee would be established to guide and coordinate the efforts of work groups and to organize the workshop. One of this committee's first tasks would be to refine and complete the list of major questions listed above, including providing quantitative criteria where possible and appropriate. These questions would form the objectives for the study. The steering committee would be comprised of selected members of the coho and chinook technical committees (most likely the committee co-chairs) with possible participation by Panel representatives to provide user perspectives and input.

2. **Work groups** - Three work groups would be created. Each work group would be comprised of representatives of the Coho/Chinook Technical Committees plus agency staff contributions. Work groups would be charged with responsibilities for completing specific tasks, producing briefing materials, and preparing presentations at the workshop. Efforts of the work groups would continue through the summer of 1994. The work groups suggested are:

    a. ***Modeling and Analysis*** - this work group would be responsible for completing an assessment of potential effects of selective fisheries, including impacts on the CWT program and expected stock conservation benefits. A sub-committee of this work group would be responsible for designing, developing, and documenting a computer simulation model to facilitate completion of the assessment. The work group would develop an evaluation framework to determine whether the modeled effects of selective fisheries can be detected with available data. The assessment would be guided by a set of specific questions similar to the following:

    > *What are the expected effects of selective fisheries on the harvest rate, exploitation rate, and spawning escapement of wild coho stocks? Will we be able to detect these changes after they have occurred? What are the expected changes in exploitation rates and shifts in the distribution of mortalities of marked and unmarked stocks?*
    >
    > *How will selective fishery regulations affect duration of seasons, catch rate and total catch, and catch and release rates of marked and unmarked fish? How will the stock composition of fisheries harvest be affected? How will data produced by the coastwide CWT program be affected?*
    >
    > *How sensitive are estimated results to factors such as marking mortalities, mark rates, hooking and release mortality, compliance, stock composition estimates, etc.?*
    >
    > *What are the critical data requirements for post-fishery evaluation of selective fisheries?*

<u>Staffing requirements:</u> 6-7 technical committee members, supplemented by agency staff contributions - an average of 3 months for each participant (a few key individuals would likely be required for up to 6 months).

b. ***Management capabilities*** - This work group would be responsible for assessing impacts of selective fisheries on management tools such as the CWT program, cohort analysis, harvest management planning models, and stock composition methodologies. This would include an evaluation of alternative methods for overcoming these impacts (e.g., alternative marking methods and sampling procedures such as electronic tag detection).

Additionally, the work group would be responsible for performing a comparative evaluation of the effectiveness of selective fisheries versus alternative regulatory strategies such as time-area closures, quotas, or alteration of bag limits in meeting resource conservation concerns. Some of this work has already been initiated by agencies so additional requirements should be relatively modest.

<u>Staffing requirements:</u> 1-2 technical committee members, supplemented by agency staff contributions - an average of 1 month for each participant.

d. ***Implementation and Evaluation*** - This work group would be responsible for describing the programs and quantifying the costs of implementation and post-fishery evaluation (marking, regulation, monitoring). Expected responses of fishermen (compliance, redirection or re-location of fishing effort) should be considered as well as potential impacts on wild stocks, e.g., from possible future increases in enhancement. As with the Management Capabilities Work Group, work has already been initiated by agencies to address this topic.

<u>Staffing requirements:</u> 1-2 technical committee members, supplemented by agency staff - an average of 2 months for each participant.

3. **Workshop** - The final component of the framework would be a 2-3 day workshop in the fall of 1994. The purpose of the workshop would be to facilitate the exchange of information between representatives from the PSC, management agencies, and the general public, using the findings of the investigations on selective fisheries as a focus.

PRELIMINARY DRAFT MODEL SPECIFICATIONS FOR SELECTIVE FISHERIES EVALUATIONS

Background: Selective fisheries are under consideration by several management agencies as a means of protecting wild stocks while still permitting harvest of hatchery-produced fish. Major questions remain, however, regarding the effectiveness of this strategy as a resource conservation measure and impacts on management tools like harvest planning models and the coded-wire-tag (CWT). While many issues could potentially be involved in an evaluation of the potential utility of selective fisheries, the focus will most likely fall in two areas: (1) determining to what degree, if any, selective fisheries can be useful in protecting unmarked stocks; and (2) identifying the measures required to ensure that the commitment of the U.S. and Canada to maintain a viable CWT program can be fulfilled. The ability to maintain a viable CWT program is especially important to the efforts of the PSC since the CWT is the only coastwide stock-specific tool currently available for assessment exploitation rates and patterns for coho and chinook salmon.

A simple, but representative, simulation model should be constructed to provide better insight into the impacts of selective fisheries.

Basic Approach: The general concept is to utilize a Monte-Carlo approach to generate simulated CWT recovery data and then to analyze that data to evaluate effects of selective fisheries. It is proposed that a model patterned after the one developed by state, tribal, and federal domestic managers in Washington State to evaluate stock composition estimation methods be employed. Rich Comstock of the U.S. Fish & Wildlife Service has agreed to help develop model code should this approach be adopted. To expedite model development, full advantage would be taken of code and algorithms from existing models (e.g., Georgia Strait Assessment Model).

MODEL STRUCTURE

Species: Initially, the model will involve only coho salmon. Concentration on coho will simplify the analysis due to predominant exploitation as a single age class; further, the selective fisheries currently under consideration are directed at this species. In practice, however, other species could well be affected under a variety of circumstances (e.g., effort shifts; encounter rates of "keepable" fish; multi-species bag limits for sport fisheries or ratios for troll fisheries). Depending upon results of the initial assessment for impacts of selective fisheries on coho, consideration of other species, particularly chinook, may be required in the future.

Stocks: The following stock groups are proposed: Fraser, Georgia Strait, West Coast Vancouver Island, North Puget Sound, South Puget Sound, Hood Canal, North Washington Coast, Columbia River, Oregon Coast. Details regarding the stocks represented, the proportion of each stock comprised of hatchery fish, the stock management objective, and the initial cohort size are presented in the section entitled "MODEL SETUP".

Note that not all possible stocks have been suggested. Instead, attempts have been made to include a representative subset of stock groups to provide information on how implementation of specific selective fisheries would affect stocks with different distribution patterns. Within stock groups, stocks with different potentials for selective removal have been incorporated for the purpose of producing data for evaluation of impacts on resource conservation and allocation objectives.

Time Periods: Three: (1) January-June; (2) July-September 15; (3) September 16-December. Fixed monthly natural mortality rates. The first time period occurs before major marine ocean fisheries are conducted; only sport fisheries in a few areas would be modeled during this period. The second time period includes all major marine harvests of coho by troll and sport fisheries and impacts of net fisheries on actively migrating fish (it may be useful to break the second period down into monthly time steps). The last time period would primarily concern harvests by terminal sport and net fisheries.

Fisheries: The area and fisheries combinations proposed are depicted in Table 1. Fisheries in each of these areas would operate simultaneously on the same pool of fish.

Fisheries Regulation: The nature of regulations that could be effectively employed to control impacts of selective fisheries is highly uncertain. Indeed, it is not all obvious just how goals and objectives for management of selective fisheries would be defined, much less translated into regulatory form. Therefore, the model would have to be capable of simulating a wide variety of regulatory measures, as indicated for gear types in Table 2.

Brief descriptions of regulatory measures follow:

Catch quota: model removal of a fixed number of fish in the catch.

Bag limit: model alteration of sport fishery bag limits (total number of fish retained, marked fish retained)

Effort Quota: model fixed number of encounters

Abundance threshold: model removal of landed and incidental mortality until a specified threshold for total population size is reached. This measure is intended to simulate a fishery operating by season.

Harvest Rate: removal of a fixed proportion of the population entering the fishing area.

Spawning Escapement Goal: removal of all fish from an area which are not required to meet spawning escapement goal targets.

Stock-Specific Exploitation Rate: removal of a fixed proportion of the initial population size of a specified stock.

Stock-Specific Harvest Rate: removal of a fixed proportion of the population of a specified stock entering a fishing area.

Selective Fisheries: Selective restrictions could be implemented for all types of fisheries. Selection rules could be optionally imposed on fisheries individually.

For troll and net fisheries, the rules would be restricted to retention/non-retention of unmarked fish.

For sport fisheries, rules would be more complex, allowing for retention of a number of unmarked fish in the bag limit (0=non retention, of course) or adjustment in the bag limit based on catch retention rates (under quota management, bag limits may vary depending upon the retention rate and management objectives for season length. Additionally, effort may be responsive to success rates, expressed in either total encounters or encounters of fish that can be retained); algorithms used in the Georgia Strait model may be helpful in developing these model features.

MODEL OUTPUT

Statistics to be generated:

Fisheries: Catch, incidental mortality.

Stocks:

For each component (marked, unmarked, CWT-marked, CWT-unmarked), number of fish retained, released, or lost to incidental mortality by fishery strata, and spawning escapement level, stratified by the number of times that fish were hooked and released (there may be some concern that fish that are hooked and released have lower reproductive success, see Bendock and Alexandersdottir (1992)). For fish with CWTs, estimated number of recoveries in catch sampling.

MODEL PARAMETERS AND SET-UP

Initial Cohort Characteristics: The stock groups proposed, the stocks represented, the proportion of each stock comprised of hatchery fish, the stock management objective, and the initial cohort size are depicted in Table 3. All stocks within a stock group share the same distribution and migratory patterns. Initial cohort sizes were selected to conform with estimates used to generate stock distribution patterns using a least-squares fit from desired target levels. Percent hatchery for U.S. stocks reflect recent abundance estimates; for Canadian stocks, this percentage was chosen arbitrarily.

Distribution of Stocks By Fishery & Time Period:

Target catch by time period and fishery: Table 4 presents the target catch levels for time-fishery strata, along with desired stock distribution targets, and cohort abundance estimates, utilized to generate estimates of stock distributions by time period, in the absence of selective fisheries.

Stock distribution to fishery areas: The proposed distribution of stock groups to fishing areas by time period is presented in Tables 5 through 7.

Time Period 1: For the initial time period, the number of fish in individual stocks would be distributed according to the proportions indicated in Table 5.

Time Period 2: In the second time step, five stocks (Fraser, Georgia Strait, North Puget Sound, South Puget Sound, and Hood Canal) would be modeled with inside and outside substocks. After completion of fisheries in the first time period, fish remaining in populations located in Georgia Strait, North Puget Sound, South Puget Sound, and Hood Canal would be combined into inside substocks; the remainder of fish would be combined into outside substocks. Note if multiple time steps are employed for this period, the same parameters would be used for combining and distributing stocks for each time step. Fish in the substocks would be distributed according to the proportions depicted in Table 6.

Time Period 3: After time step 2, substocks would be eliminated. All remaining fish would be consolidated into single stocks and distributed according to the proportions indicated in Table 7.

MODEL FLOW

Sequence of Events:

(0) User specification of model parameters.

For each hatchery stock component, a user-specified portion of production could be marked for selective removal. Normally-distributed random variation would be introduced in "natural" mortality of fish marked for selective removal, based on user-specified means and variances.

For each hatchery and wild stock component, an associated CWT release of user-specified size could be modeled. As with fish marked for selective removal, fish marked with CWTs would be subject to normally-distributed random variation, based on user-specified means and variances.

Specifications for fisheries would include:

(a) specifications for the conduct of fisheries (i.e., type of regulation, selection, etc.) for each time period;

(b) means and variances for the following rates: (i) mortality for release (may vary, depending upon time of capture and whether the fish has be subjected to prior release); (ii) mark recognition rates; and (iii) catch sampling.

(1) Natural mortality and growth (data and algorithms employed in other models may be usefully adapted, for example, growth functions in the Georgia Strait and National Bureau of Standards models) ;

(2) Distribute stocks and substocks to fishing areas;

(3) Simulate fisheries under specified regulatory restrictions. Each component (marked, unmarked, CWT-marked, CWT-unmarked) of each stock is to be treated as a separate population. Encounters in each aggregate population within a fishing area are random.

Selective fisheries would be modeled according to the following procedure:

(a) Randomly select a fish from the aggregate population;

(b) Determine if the fish is to be retained (allow user to specify mark identification rates separately for fish marked for selective removal and fish not marked for selective removal).

  (1) If so, remove from population; else,

  (2) Determine in the fish has been released previously and apply appropriate release mortality rate. If fish dies, remove from population, else return to population;

(4) Simulate catch sampling . CWT recovery sampling would be simulated to generate estimated recovery data.

(5) Collation of fish remaining into stocks or substocks as appropriate.

(6) Repeat steps (1)-(4) for each time step.

TABLE K–1. Areas and fisheries proposed for selective fisheries simulation model.

Area	Troll	Sport	Net
Northwest Vancouver Island	X	X	–
Southwest Vancouver Island	X	X	–
Georgia Strait	X	X	X
Juan de Fuca Strait	–	X	X
North Puget Sound Preterminal	–	X	X
North Puget Sound Terminal	–	–	X
South Puget Sound	–	X	X
Hood Canal	–	X	X
Washington Coastal Terminal	–	X	X
Columbia River	–	X	X
Washington Ocean	X	X	–
Oregon/California	X	X	–

TABLE K–2. Types of regulatory controls by fishery type proposed for the selective fisheries simulation model.

Regulation	Troll	Sport	Net
Catch Quota	Yes	Yes	Yes
Bag Limit	No	Yes	No
Effort Quota	Yes	Yes	Yes
Abundance Threshold (pseudo CPUE)	Yes	Yes	No
Harvest Rate	Yes	Yes	Yes
Escapement Goal	No	No	Yes
Stock–specific Exploitation Rate	Yes	Yes	Yes
Stock–specific Harvest Rate	Yes	Yes	Yes

TABLE K-3. Initial stock groups and characteristics proposed for the selective fisheries simulation model.

Stock Group	Representing	Percent Hatchery	Management Objective	Initial Cohort Size
Fraser	Upper & Lower Fraser River	30%	Natural	556,856
Georgia Strait	Mainland	70%	Natural	802,248
	Vancouver Island	50%	Natural	300,000
West Coast Vancouver Island	WCVI	50%	Natural	492,392
North Puget Sound	Nooksack/Samish	95%	Hatchery	837,430
	Skagit	40%	Natural	142,034
	Stillaguamish/Snohomish	30%	Natural	835,133
South Puget Sound	South Puget Sound	85%	Hatchery	1,232,566
Hood Canal	Hood Canal	60%	Natural	467,805
North Washington Coast	Quillayute	10%	Natural	68,270
	Hoh	0%	Natural	28,959
	Queets	60%	Natural	74,773
	Quinault	60%	Hatchery	75,024
	Grays Harbor	55%	Natural	342,155
Columbia River	Willapa Bay	95%	Hatchery	296,089
	Columbia River Early	100%	Hatchery	562,700
	Columbia River Late	100%	Hatchery	291,393
Oregon Coastal	Oregon Coastal	25%	Natural	300,000

TABLE K–4. Target catch levels in the absence of selective fisheries (used to generate stock distribution patterns) proposed for the simulation model.

Area	Troll 1	Troll 2	Troll 3	Sport 1	Sport 2	Sport 3	Net 1	Net 2	Net 3
Northwest Vancouver Island	0	378	0	0	10	0	0	0	0
Southwest Vancouver Island	0	953	0	0	100	0	0	0	0
Georgia Strait	0	150	0	454	350	21	0	25	0
Juan de Fuca Strait	0	0	0	0	0	50	0	175	0
North Puget Sound	0	0	0	40	100	10	0	50	0
North Puget Sound Terminal	0	0	0	0	0	0	0	45	120
South Puget Sound	0	0	0	0	50	10	0	50	390
Hood Canal	0	0	0	0	5	10	0	15	15
Washington Coastal Terminal	0	0	0	0	1	5	0	9	45
Columbia River	0	0	0	0	50	25	0	50	75
Washington Ocean	0	100	0	0	300	0	0	0	0
Oregon/California	0	200	0	0	400	0	0	0	0

TABLE K–5. Time Period 1: The proportion of stock groups distributed to fishing areas for the first time period.

Stock/Fishing Area	NWVI	SWVI	Georgia Strait	Juan de Fuca Strait	N. Puget Sound	S. Puget Sound	N. Puget Sound Term.	Hood Canal	WA Coastal Term.	Columbia River Term.	WA Ocean	OR/CA Ocean
Fraser	0.1170	0.2090	0.5431		0.0033						0.1173	0.0101
Georgia Strait	0.2312		0.4217		0.3091						0.0380	
W. Coast Vancouver Isl.	0.1139	0.8790			0.0039						0.0033	
N. Puget Sound	0.1832	0.0621			0.4775						0.2671	0.0100
S. Puget Sound	0.1561	0.4550				0.200					0.1561	0.0328
Hood Canal	0.3071	0.1675	0.0453		0.3770						0.0492	0.0594
N. Washington Coast	0.1571	0.5882									0.1106	0.1442
Columbia River	0.1090	0.2617	0.0735		0.0123						0.1097	0.4338
Oregon Coastal											0.1000	0.9000

TABLE K-6. Time Period 2: The proportion of stock groups and substocks distributed to fishing areas during the second time period.

Stock/Fishing Area	NWVI	SWVI	Georgia Strait	Juan de Fuca Strait	N. Puget Sound	S. Puget Sound	N. Puget Sound Term.	Hood Canal	WA Coastal Term.	Columbia River Term.	WA Ocean	OR/CA Ocean
Fraser Inside			0.7083	0.2185	0.0732							
Fraser Outside	0.2314	0.7671										0.0015
Georgia Strait Inside			0.7679	0.1777	0.0544							
Georgia Strait Outside	0.4339	0.5661										
W. Coast Vancouver Isl.	0.5906	0.4094										
N. Puget Sound Inside			0.5132	0.1817	0.1412	0.0900	0.0740					
N. Puget Sound Outside		0.6756									0.1174	0.2070
S. Puget Sound Inside			0.3629	0.0568	0.3805	0.1998		0.1546				
S. Puget Sound Outside	0.2323	0.7677										
Hood Canal Inside				0.1724	0.1839	0.4893						
Hood Canal Outside		0.7133									0.2867	
N. Washington Coast		0.4342							0.0233		0.1425	0.4000
Columbia River										0.1246	0.3049	0.5706
Oregon Coastal										0.0100	0.1796	0.8104

TABLE K-7. Time Period 3: The proportion of stock groups distributed to fishing areas during the third time period.

Stock/Fishing Area	NWVI	SWVI	Georgia Strait	Juan de Fuca Strait	N. Puget Sound	S. Puget Sound	N. Puget Sound Term.	Hood Canal	WA Coastal Term.	Columbia River Term.	WA Ocean	OR/CA Ocean
Fraser					0.5649		0.4351					
Georgia Strait			0.5806		0.4194							
W. Coast Vancouver Isl.	0.5000	0.5000										
N. Puget Sound			0.0053		0.0102		0.9845					
S. Puget Sound						1.000						
Hood Canal					0.0177			0.9823				
N. Washington Coast									1.000			
Columbia River										0.9900		0.0100
Oregon Coastal												1.0000

APPENDIX L
INCIDENCE OF MARINE MAMMAL DEPREDATION MARKS OBSERVED ON KLAMATH RIVER FALL CHINOOK

Since 1978, the U.S. Fish and Wildlife Service Coastal California Fishery Resource Office (CCFRO) in Arcata, California has monitored the tribal gill net fishery on the Yurok Indian Reservation (YIR). CCFRO also conducted an adult fall chinook beach seining project in the estuary. Data on the occurrence of depredation marks attributable to marine mammals, primarily harbor seals (*Phoca vitulina)* and to a lesser degree California sea lions (*Zalophus californianus*), were collected during the field operations of these projects (Table L–1). When available, similar data for the Middle and Upper Klamath monitoring areas are also presented. "Seal bites" observed in the Middle and Upper Klamath monitoring areas probably occurred while the fish were migrating through the estuary or in the ocean prior to entering the river. Although the occurrence of pinnipeds above the estuary is not uncommon, the majority of the seal/sea lion activity occurs in the estuary and, therefore, it seems reasonable to assume that the majority of the wounding of salmonids occurs there.

The occurrence of "seal bites" in the estuary gill net fishery has ranged from 1.3 percent in 1988 to 14.2 percent in 1983. These are minimum values for the impact of marine mammals on the net fishery because they account for only the proportion of fish that were not completely removed from the gill net and were retained by the fisher. Fish that were removed from the net by marine mammals and damaged fish that were discarded before harvest monitors sampled the catch were not included in this data.

The incidence of "seal bites" observed during the beach seine project has ranged from 0.6 percent in 1985 to 3.3 percent in 1987 (Table L–1). This is probably the best indicator for indexing marine mammal impacts because there is probably little interaction between marine mammals and chinook during beach seine sampling.

The occurrence of marine mammal predation marks observed in the net harvest and beach seine data were not correlated ($r=-0.19$, $n=7$, $p=0.6849$). The frequency of "seal bites" in the gill net fishery is generally greater than that observed in the beach seine data (Figure L–1). This is to be expected because of the increased vulnerability of fish caught in a gill net to marine mammal depredation. In 1987, the incidence of "seal bites" was actually less than that observed in the beach seine and in 1988 it was equal to the beach seine "seal bite" rate. The reversal in the trend of higher "seal bite" rates in the net fishery can be attributed to the execution of a commercial gill net fishery during which fishers were more attentive to their nets, thus reducing the potential for depredation by marine mammals.

There was no significant correlation between marine mammal predation marks observed in the net harvest or beach seine data and the inriver chinook run size (net harvest: $r=-0.50$, $n=11$, $p=0.1155$; beach seine: $r=0.05$, $n=7$, $p=0.9231$). It was anticipated that as run size increased, the incidence of "seal bites" would decrease because the marine mammals would become satiated (Figures L–2 and L–3). The data does not support this hypothesis.

TABLE L-1. Incidence (percent) of seal/sea lion bites observed on fall chinook salmon harvested on the Yurok Indian Reservation and sampled during the USFWS beach seine operation, 1981-1992.

	Harvest Monitoring Area			
Year	Estuary	Middle Klamath	Upper Klamath	Beach Seine
1981	5.3	1.0	N/A	N/A
1982	N/A	N/A	N/A	N/A
1983	14.2	30.2	N/A	N/A
1984	7.3	N/A	N/A	1.6
1985	3.2	N/A	N/A	0.6
1986	5.6	N/A	N/A	1.1
1987	1.8	1.0	1.6	3.3
1988	1.3	0.6	2.3	1.3
1989	3.4	1.5	3.5	2.8
1990	7.4	3.2	5.2	2.0
1991	4.7	6.1	4.8	N/A
1992	3.8	9.2	12.2	N/A

NOTES: 1. Estuary = mouth to U.S. 101 bridge.
Middle Klamath = U.S. 101 bridge to Surpur Creek.
Upper Klamath = Surpur Creek to Weitchpeck.
2. In 1981 and 1983, Middle Klamath = U.S. 101 bridge to Terwer Creek.

The loss of salmon to marine mammals is often highly visible in the estuary of the Klamath River, especially to tribal gillnetters and sport fishers. Although the magnitude of marine mammal depredation may seem large to some observers, salmon actually contribute little to the diet of marine mammals. Bowlby (1981) studied the feeding habits of seals and sea lions in the Klamath River estuary. He found that sea lions fed primarily on Pacific lamprey (*Entosphenus tridentata*) and the majority of the sea lions vacated the estuary prior to the entry of fall chinook into the river. During the fall, the diet of harbor seals primarily consisted of smelt (63.7 percent of total number), flounder (14.7 percent), and lamprey (7.8 percent). Salmonids accounted for 1.5 percent (Table 2). Bowlby noted that the preponderance of marine species in the diet of seals indicated that a majority of their feeding occurred offshore.

TABLE L-2. Percent of total number and seasonal occurrence of major fish families in Phoca scats.

Family	Spring	Summer	Fall
Petromyzontidae	51.8	74.9	7.8
Osmeridae	31.2	9.9	63.7
Pleuronectidae	1.8	1.2	9.3
Bothidae	0.0	0.0	5.4
Salmonidea	0.3	0.4	1.5

Source: Table 11 in Bowlby, 1981.

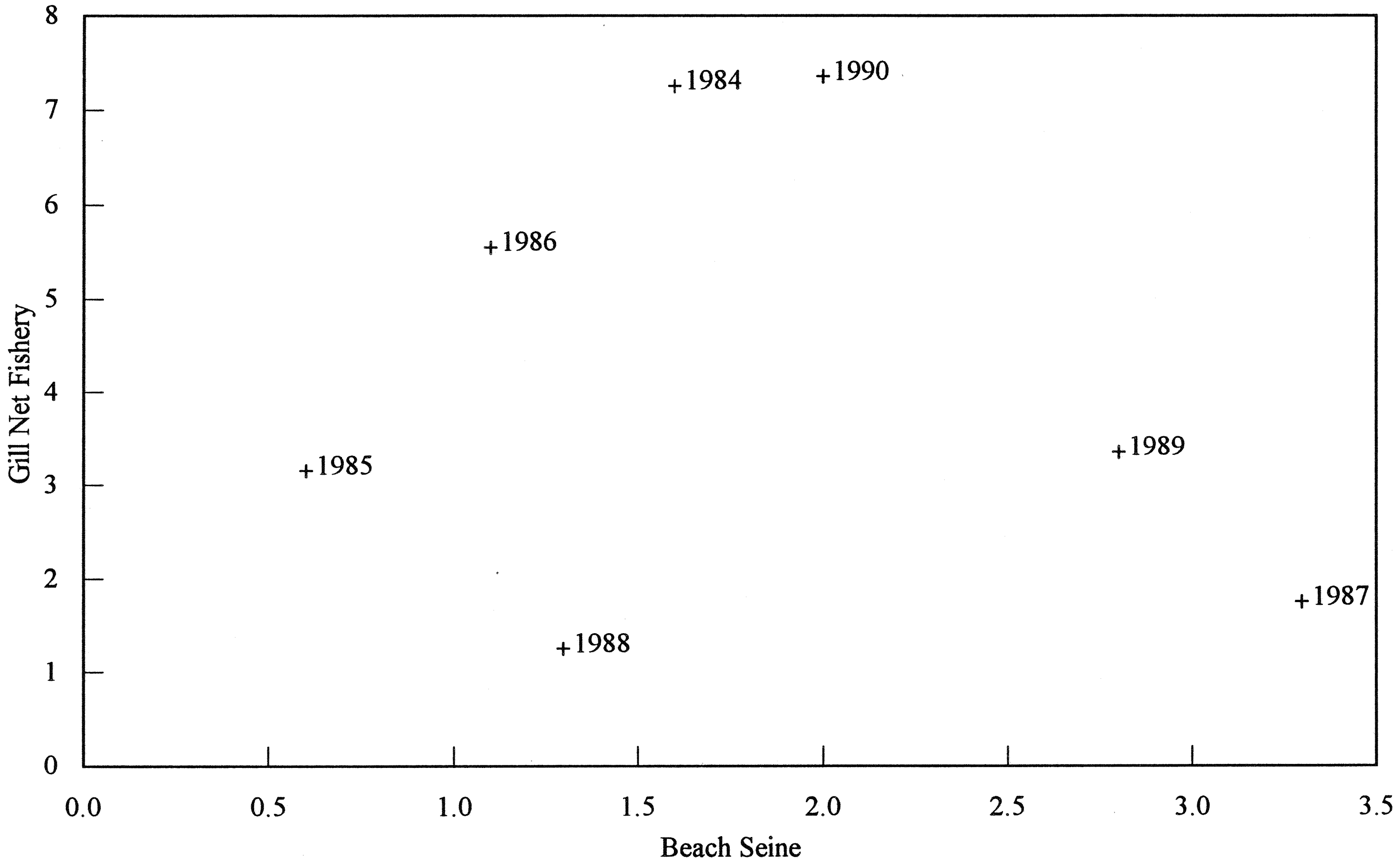

FIGURE L-1. Frequency (percent) of seal/sea lion predation marks on fall chinook observed in the gill net fishery (Estuary Area) vs. beach seine (sample year next to data point).

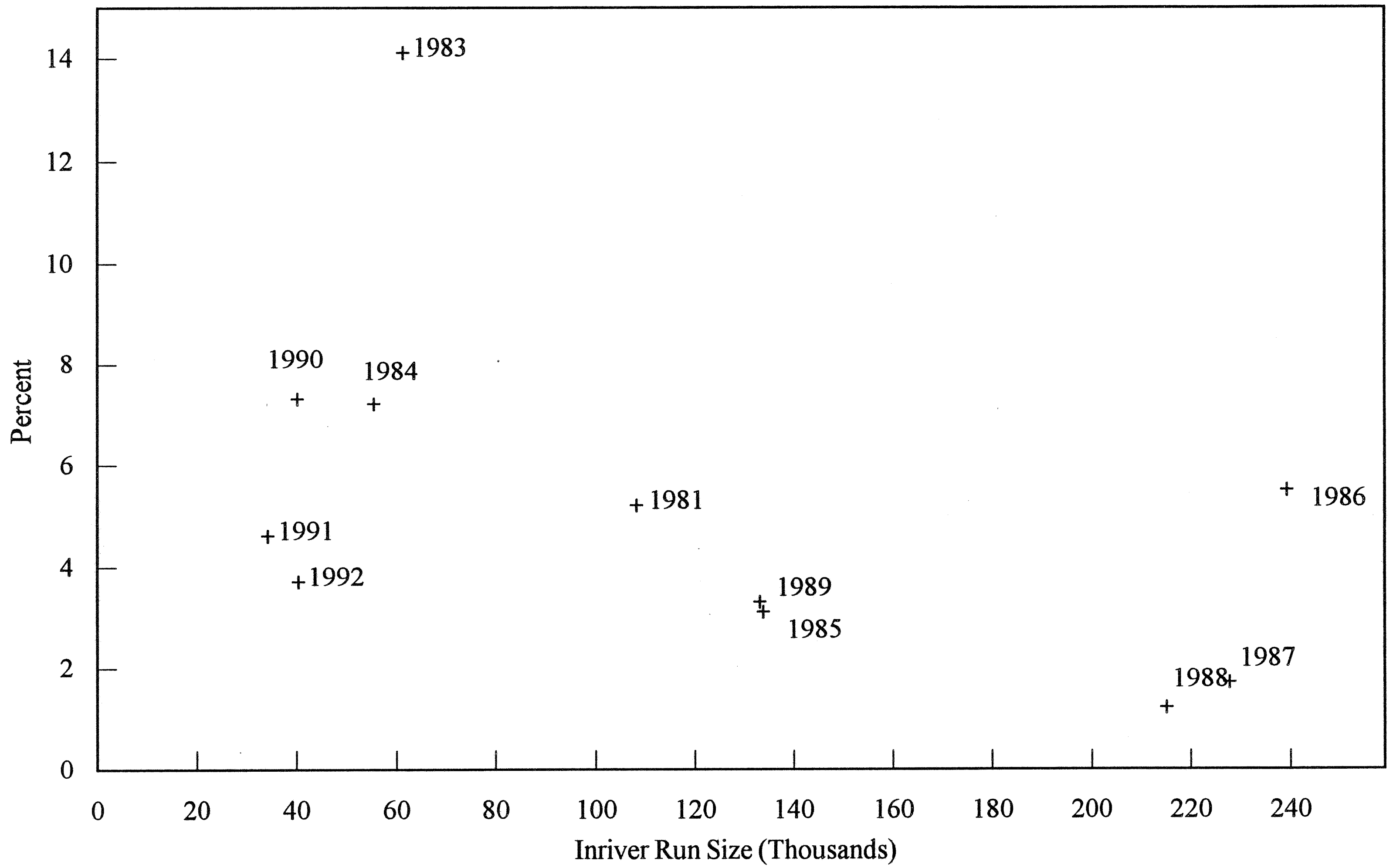

FIGURE L-2. Incidence (percent) of seal/sea lion predation marks observed on fall chinook harvested in the estuary gill net fishery and inriver run size, 1981-1992 (sample year adjacent to data point).

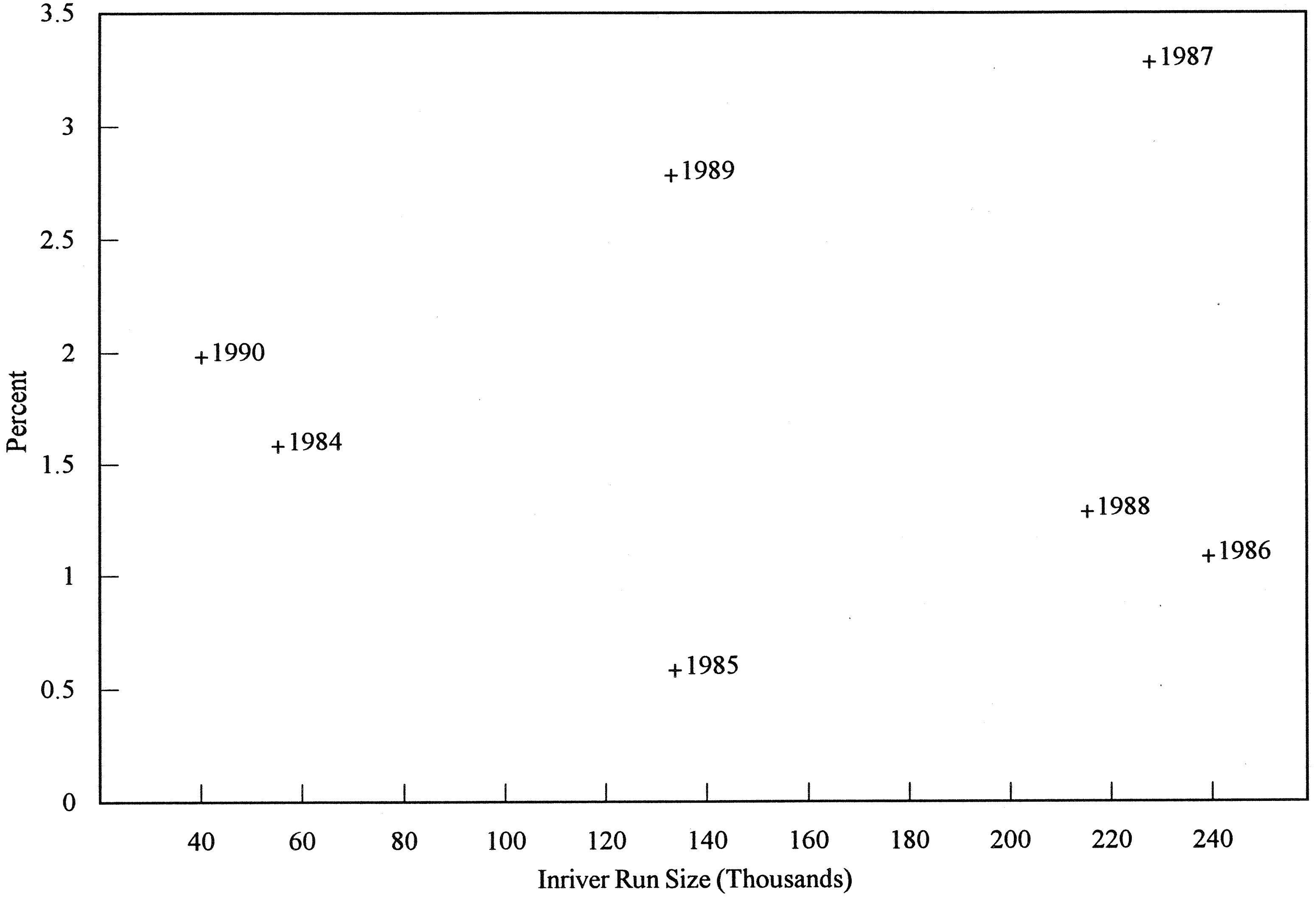

FIGURE L-3. Incidence (percent) of seal/sea lion predation marks observed on fall chinook sampled by USFWS beach seine operation and inriver run size, 1981-1992 (sample year adjacent to data point).

SUMMARY

Although marine mammals do have an observable impact on the Klamath River fall chinook resource, it is not reasonable to believe that they have caused the sharp decline that has been observed over the past four years. Marine mammal populations have not experienced accelerated, uncontrolled increases that would lead to the assertion they are the cause of this precipitous decline. Predation marks attributable to marine mammals have ranged from 1.3 percent (1988) to 14.2 percent (1983) in the estuary gill net fishery data and 0.6 percent to 3.3 percent in the beach seine data. The impacts of marine mammals (based on frequency of "seal bites" in the estuary for 1991 and 1992 return years) do not appear to be a major contributor to the shortfall in spawning escapement. Although the frequency of seal bites in 1990 was the highest observed, it was not at such a high level to indicate that marine mammal predation was a significant contributor to the underescapement in this year. Bowlby (1981) found that during the fall, when fall chinook are entering the river, seals fed primarily on smelt and flounder.

REFERENCES

Bowlby, C.E. 1981. Feeding behavior of pinnipeds in the Klamath River, Northern California. MS Thesis. Humboldt State University, 74 pp.

APPENDIX M
SALMON BYCATCH IN OTHER MARINE FISHERIES

Besides the commercial troll and recreational ocean salmon fisheries, salmon are sometimes taken as an incidental bycatch in other commercial marine fisheries. Two fisheries of concern have been the groundfish fishery occurring off the Pacific Coast in waters managed by the Pacific Fishery Management Council and the recently ended high seas drift net fishery beyond the 200 mile limit.

HIGH SEAS DRIFT NET FISHERY

The high seas drift net fishery, which peaked in the late 1980s and early 1990s, has been a source of some concern with regard to possible impacts on North American salmon stocks. Prior to 1993, high seas drift nets of many miles in length were used primarily to capture squid by fishers from Japan, Korea, Taiwan, China and other countries. In addition, some illegal effort occurred in which other species, including salmon, were targeted.

The fishery was conducted primarily in waters several thousand miles beyond the southern Oregon/northern California coastline. Salmon, primarily species other than chinook, along with numerous other fishes, marine mammals and birds, were found to be captured by the huge monofilament nets. Because of their extensive detrimental impacts on numerous nontarget marine species, a global moratorium was enacted to end all drift net fishing. Since the moratorium took effect on January 1, 1993, surveillance of the former fishery area has confirmed a high degree of compliance with the moratorium (personal communication from Mr. Jim Coe, National Marine Fisheries Service [NMFS]). Based on the area in which the fishery took place, monitoring of the squid drift net fishery by trained observers including U.S. personnel, and sampling of some illegal catches, it appears unlikely that California salmon stocks, and Klamath River fall chinook in particular, were impacted by this fishery.

U.S. GROUNDFISH FISHERY

Stocks of flatfish, rockfish and other bottom dwelling species of groundfish are harvested primarily with bottom trawls. Midwater trawls are the primary gear used to harvest Pacific whiting. In recent years, about 80 percent of all Council–area groundfish landings have been taken by trawl gear. Effort and landings from other commercial fishing gear, which includes traps, long–lines, shrimp trawls and various nets (other than trawls), is unlikely to have significant impacts on salmon. It is illegal to retain any salmon caught in the commercial groundfish fishery.

The following sections summarize information on groundfish landings and salmon bycatch for bottom and midwater trawl gear fished in the Eureka and Monterey International North Pacific Fishery Commission statistical areas. The Eureka and Monterey areas stretch roughly from Cape Blanco, Oregon to Point Lobos, California, and encompass the area in which impacts on Klamath River fall chinook could be expected to be significant.

Trawl Fisheries for Groundfish Other Than Whiting

Trawl fisheries for Pacific Coast groundfish species other than whiting primarily utilize bottom trawls, with or without roller gear (rollers or wheels to lift the net off the bottom). Some limited use of midwater trawls also occurs. Use of these gears is a long–standing and common practice. While bycatch of salmon does occur, anecdotal evidence indicates the numbers of salmon are generally low and irregular, perhaps because bottom trawls are usually pulled at a rather slow speed and the gear is fished primarily in areas which favor aggregation of groundfish rather than salmon.

There is only very limited data available to estimate bycatch of salmon by bottom trawls in the groundfish fishery. However, a bycatch monitoring program is currently in the process of development. NMFS has summarized the available bycatch data in its 1992 biological opinion for the Pacific Coast groundfish fishery (NMFS 1992). The summarized data comes primarily from two studies involving trawl discards and impacts of different trawl mesh sizes.

Erickson and Pikitch (unpublished data reported in NMFS 1992) sampled salmon bycatch from bottom trawls off northern Oregon and Washington in 1985–1987 and off the entire Pacific Coast in 1988–1990. They found that chinook were the dominant salmon species observed in the salmon bycatch (over 90 percent) and that nearly all salmon were taken in relatively shallow water (very few were taken at depths greater than 100 fathoms). This is similar to the results found by NMFS in bottom trawl samples in which 96 percent of the salmon bycatch was chinook (NMFS 1992).

Based on expansions of the bottom trawl bycatch data, NMFS (1992) estimated that the average annual coastwide bycatch of chinook salmon in bottom trawls from 1985–1990 could be as high as 11,000 fish. Table M–1 indicates that during this same time period, the groundfish harvest in the Eureka and Monterey statistical areas averaged about 38 percent of the coastwide groundfish landings. If bycatch were evenly distributed, then the average annual chinook bycatch in areas affecting Klamath River fall chinook could be as high as 4,200 fish.

Trawl groundfish landings, exclusive of whiting, in the Eureka and Monterey statistical areas have ranged from a high of 30,800 tons in 1985 to a low of 17,500 tons in 1993, with an average of 23,700 tons (Table M–1). Given the relatively stable to declining landings since 1986, the impact of bycatch of Klamath River fall chinook could be expected to be relatively stable to declining. It appears very unlikely that the trawl bycatch could contribute significantly to the precipitous decline of the Klamath River fall chinook in recent years.

TABLE M-1. Estimated commercial groundfish trawl landings, exclusive of whiting, for the Eureka and Monterey International North Pacific Fishery Commission statistical areas and the Pacific Coast off Washington, Oregon and California.[a/]

	Trawl Catch by Area in Metric Tons			
Year	Eureka	Monterey	Eureka and Monterey Subtotal	Pacific Coast Total
1984	13,300	12,200	25,500	70,400
1985	14,600	16,200	30,800	70,800
1986	11,500	13,500	25,000	59,000
1987	13,200	14,400	27,600	69,600
1988	12,100	12,700	24,800	68,900
1989	10,300	10,100	20,400	69,100
1990	12,500	14,100	26,600	71,300
1991	8,400	11,600	20,000	64,100
1992	9,600	8,900	18,500	62,900
1993	9,600	7,900	17,500	62,000

a/ Preliminary PacFIN data.

Midwater Trawl Whiting Fishery

In recent years, landings of Pacific whiting have averaged over 70 percent of the total tonnage of all species of groundfish in Council-managed waters (NMFS 1992). The fish are harvested with large, rapidly towed midwater trawls. At the present time, the majority of the whiting harvest is taken by U.S. catcher/processor vessels which exceed 200 feet in length and fish with trawls capable of taking 50 tons or more of whiting in a single tow.

The whiting fishery has been composed of various industry segments during its history, depending on the catching and processing arrangements of the involved vessels. Initially, the fishery was utilized only by foreign catcher and processor vessels. Then, as the fishery became Americanized, joint ventures were created between U.S. catcher boats and foreign processors. In addition, some very limited initial efforts began with shore-based processors and U.S. vessels. By 1989, all foreign catcher vessels were phased out and the fishery was conducted with only joint venture operations and some shore-based processors. By 1991, the joint ventures had been eliminated from the fishery by arrangements between U.S. catcher boats and domestic motherships, U.S. catcher/processors and increased shore-based processing. Figure M-1 shows the whiting landings by industry category from 1982 to the present.

The estimated number of salmon taken as a bycatch in the foreign, joint venture and domestic at-sea processing segments of the whiting fishery in the Eureka and Monterey statistical areas from 1982-1993 is shown in Table M-2. The harvest of the offshore segment of the industry has been continuously monitored and sampled by trained observers since 1977 to determine estimates of whiting harvest and bycatch, including salmon. Estimates of shore-based salmon

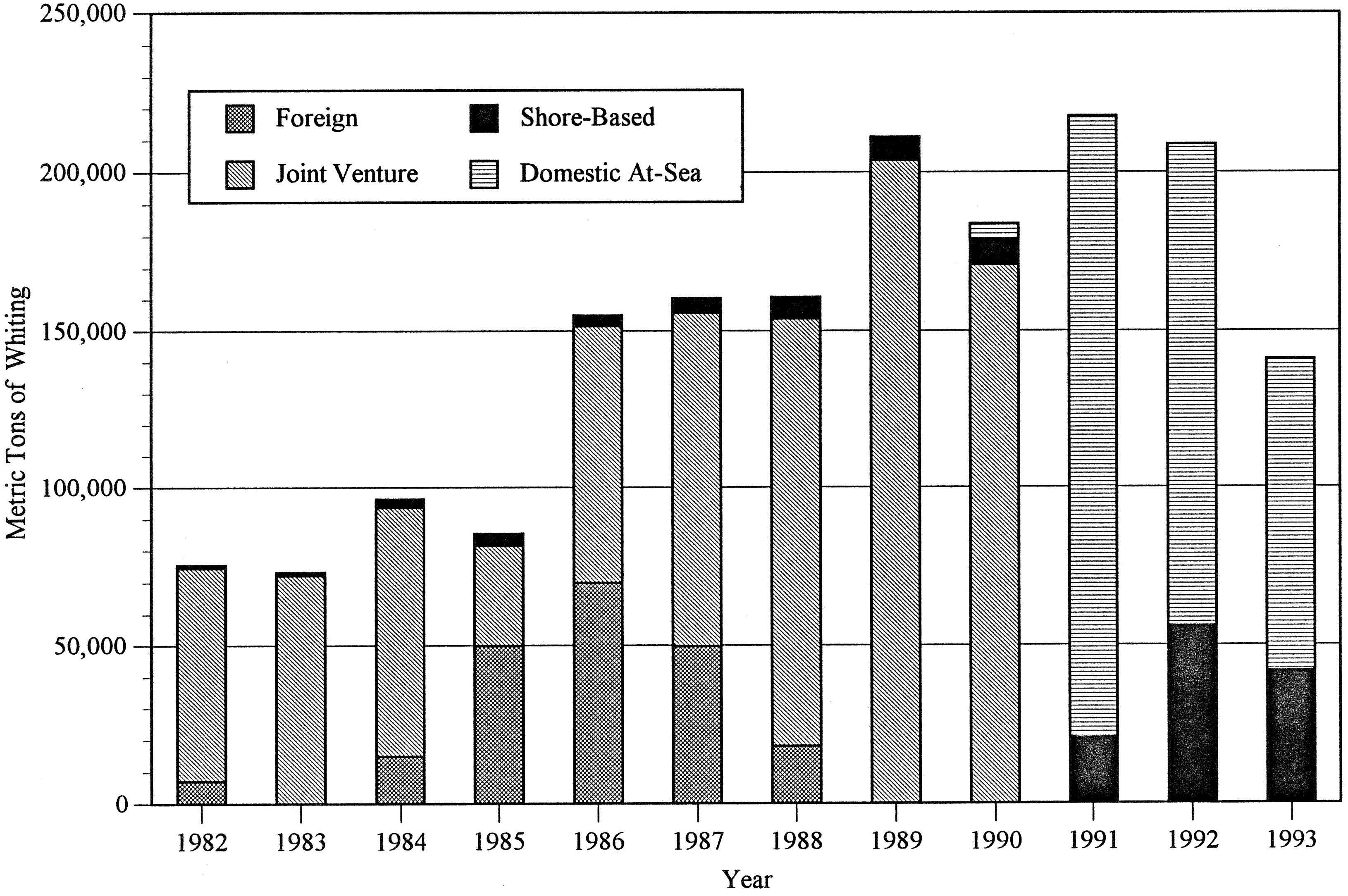

FIGURE M-1. Total whiting harvest off Washington, Oregon and California by industry segment.

bycatch off Oregon is available beginning in 1991. Estimates for the shore-based sector included both Oregon and Washington in 1992 and the entire Council management area in 1993. The shore-based bycatch estimates (compiled by Mark Saelens, Oregon Department of Fish and Wildlife) are as follows: 26 salmon in 1991 for the 13,136 metric tons of whiting taken off Oregon; 681 salmon in 1992 for the 51,046 metric tons of whiting taken off Oregon and Washington; and 473 salmon in 1993 for the 41,778 metric tons of whiting taken coastwide by the shore-based fishery.

TABLE M-2. Estimated catch of Pacific whiting and bycatch of all species of salmon in the Eureka and Monterey groundfish statistical areas, and the harvest of chinook salmon in the Klamath management zone (KMZ).[a]

	Whiting Landings in Metric Tons[b]			Salmon Bycatch[c]		KMZ
Year	Shore-based	Offshore[e]	Total	Numbers of Fish	Salmon per mt of Whiting	Chinook Harvest[d]
1982	1,000	7,400	8,400	6,100	0.82	268,100
1983	1,000	5,500	6,500	700	0.13	104,000
1984	2,300	3,800	6,100	500	0.13	70,400
1985	3,000	6,500	9,500	<50	<0.01	91,400
1986	3,000	31,600	34,600	11,400	0.36	133,500
1987	4,500	100	4,600	0	0.00	182,500
1988	6,500	26,300	32,800	2,700	0.10	148,900
1989	7,300	101,800	109,100	3,700	0.04	111,200
1990	5,500[f]	63,300	68,800	6,000	0.09	46,600
1991	6,900[f]	130,700	137,600	4,800	0.04	24,700
1992	4,900	17,700	22,600	100	0.01	5,200
1993	3,100	No Fishing	3,100	<100[g]	<0.03	8,600

a/ The Eureka and Monterey statistical areas extend from approximately Cape Blanco, Oregon to Point Lobos, California. The KMZ extends from Humbug Mountain, Oregon to Horse Mountain, California.

b/ Estimates of whiting catch are rounded to the nearest 100 metric tons. Except for 1991, when about 50 percent of the whiting harvest occurred in the Monterey area, over 90 percent of the annual whiting harvest has occurred in the Eureka statistical area.

c/ Estimates of bycatch are rounded to the nearest 100 fish. Estimates for 1982-1992 are for the offshore fishery only. The estimate for 1993 is for the shore-based fishery in California.

d/ Total recreational and commercial harvest of chinook (in numbers of fish) in the area between Humbug Mountain, Oregon and Horse Mountain, California.

e/ The offshore fishery consisted of foreign and joint venture operations from 1982-1988. In 1989 the entire offshore harvest was taken by joint ventures (U.S. catcher boats and foreign processors). In 1990 domestic catcher/processors and motherships entered the fishery. Beginning in 1991, the entire offshore harvest has been caught and processed by domestic vessels.

f/ In addition, a small amount of whiting landed in Coos Bay, Oregon may have been caught south of Cape Blanco. Total whiting landings to Coos Bay were 63 metric tons in 1990 and 416 metric tons in 1991.

g/ Estimate for the California shore-based fishery.

In the area of concern for Klamath River fall chinook, the peak estimate of salmon bycatch for the offshore fishery of 11,400 salmon (predominantly chinook) occurred in 1986 when Klamath River fall chinook abundance was high and over 133,000 chinook were harvested by commercial and recreational salmon fisheries in the KMZ (Table M-2). Since 1986, the annual salmon bycatch in the Eureka and Monterey statistical areas has not exceeded 6,000 salmon and has averaged less than 2,500 salmon.

Observer sampling has shown that chinook salmon are the dominant species in the salmon bycatch of the offshore whiting fishery. From 1986-1990, chinook constituted an estimated 82 to 98 percent of the salmon bycatch of the joint venture vessels (NMFS 1992). The size of salmon taken in the midwater trawls tends to be small. Sampling of the joint venture fisheries in 1986-1990 showed a range of average annual lengths of chinook from about 19 to 22 inches (Berger, *et al.* 1988a and 1988b; and Guttormsen, *et al.* 1990 and 1992).

Based on the comparatively low numbers of salmon in the bycatch and the actual decrease in the bycatch since 1986, it appears highly unlikely that the Pacific whiting fishery has been a major factor in the recent decline of Klamath River fall chinook. While monitoring of the California shore-based whiting fishery on a consistent basis did not begin until 1993, the shore-based fishery has been conducted at a very low level and accounted for a very small portion of the total whiting landings in most years. The sampling of bycatch which has been done in the shore-based fishery since 1991 confirms relatively low impacts on salmon, including less than 100 salmon in 1993 for 3,100 tons of whiting landed in California (all landings were in the Eureka statistical area).

CONCLUSION

Based on a review of the available data, it appears unlikely that the high seas drift net fishery (under moratorium since January 1, 1993) and the U.S. commercial groundfish fishery have played a significant role in the drastic decline of Klamath River fall chinook. The Pacific whiting fishery, which employs large, fast moving midwater trawls and takes the greatest biomass of groundfish of any gear type, appears to have the greatest potential for impacts on salmon. This fishery has been relatively well monitored to determine salmon bycatch rates and to help limit impacts during the actual fishing process. The trawl fishery for groundfish species other than whiting has had only limited sampling to determine the salmon bycatch. However, this fishery is less likely to have significant salmon impacts and has a long and relatively stable history on the Pacific Coast.

REFERENCES

Berger, J., R. Nelson Jr., J. Wall, H. Weikart and R. Maier. 1988a. Summary of U.S. observer sampling of foreign and joint venture fisheries in the northeast Pacific Ocean and eastern Bering Sea, 1986. NOAA Technical Memorandum NMFS F/NWC–128. U.S. Department of Commerce.

Berger, J. and H. Weikart. 1988b. Summary of U.S. observer sampling of foreign and joint venture fisheries in the northeast Pacific Ocean and eastern Bering Sea, 1987. NOAA Technical Memorandum NMFS F/NWC–148. U.S. Department of Commerce.

Berger, J. and H. Weikart. 1989. Summary of U.S. observer sampling of foreign and joint venture fisheries in the northeast Pacific Ocean and eastern Bering Sea, 1988. NOAA Technical Memorandum NMFS F/NWC–172. U.S. Department of Commerce.

Erickson, D.L. and E.L. Pikitch. In preparation. Incidental catch of chinook salmon (*Oncorhynchus tshawytscha*) in commercial bottom trawls off the U.S. west coast. School of Fisheries, Univ. of Washington, Seattle, WA 98195.

Guttormsen, M., R. Narita and J. Berger. 1990. Summary of U.S. observer sampling of foreign and joint venture fisheries in the northeast Pacific Ocean and eastern Bering Sea, 1989. NOAA Technical Memorandum NMFS F/NWC–189. U.S. Department of Commerce.

Guttormsen, M., R. Narita and J. Berger. 1992. Summary of U.S. observer sampling of joint venture fisheries in the northeast Pacific Ocean and eastern Bering Sea, 1989. NOAA Technical Memorandum NMFS–AFSC–4. U.S. Department of Commerce.

NMFS. 1992. Endangered Species Act, section 7 consultation: biological opinion for fishing conducted under the Pacific Coast groundfish fishery management plan for the California, Oregon and Washington groundfish fishery. NMFS, Northwest Region, Seattle, Washington.