RECOMMENDED SPAWNING ESCAPEMENT POLICY FOR KLAMATH RIVER FALL-RUN CHINOOK

by

Klamath River Technical Team1/

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1/ The Klamath River Technical Team is comprised of representatives of the various entities responsible for the regulation of fisheries impacting Klamath River chinook, the major fishery user groups and the U.S. Forest Service (Appendix I).

SUMMARY

1) This report presents the recommendation of the Klamath River Technical Team on a spawning escapement policy for Klamath River fall-run chinook.

2) The report was prepared assuming a long term allocation agreement will be reached among the managers of the major user groups impacting the stock beginning in 1986.

3) Four management policy options were developed for consideration and analysis: (1) continue the current escapement goal of 115,000 adult spawners, (2) adopt respective goals for natural and hatchery spawners of 43,000 and 17,500 adult fish, (3) provide for two high escapements in the next six years to test the production response of the stock, and (4) regulate by harvest rate consistent with the probable productivity of the resource.

4) Use of a single number escapement goal for Klamath River chinook is not advised at this time because of uncertainty about the capacity of the natural areas for spawning fish.

5) The stock-recruitment data base for Klamath chinook is limited to the 1978-82 broods. Higher escapement levels are needed to evaluate basin capacity for natural spawners.

6) Higher escapement levels could be achieved by the "probing" approach (option 3), but it would be highly disruptive to the fisheries and probably not produce enough data to clearly define the stock recruitment relation for the resource.

7) The harvest rate option is recommended for management purposes beginning in 1986 assuming an allocation agreement will be reached. Without a long term allocation agreement, continuation of the current escapement rebuilding schedule is recommended because successful management by harvest rate would not be possible. Several acceptable offshore and terminal area harvest rate combinations are presented. Harvest rate in this option represents the rate at which the most vulnerable age class in a fishery is contacted by the fishing gear. This approach to management would provide higher escapement levels than have occurred since 1979 while providing relatively stable harvest opportunity in the respective fisheries.

8) An escapement floor of 35,000 natural spawners is recommended as part of the harvest rate option. This level of spawners is needed to protect the production potential of the resource in the event of several consecutive years of adverse environmental conditions.

9) Several management and research needs are identified and comments provided about the future management of this important natural resource.

INTRODUCTION

This report fulfills the Team assignment to develop a recommendation on spawning escapement policy for Klamath River fall-run chinook salmon. The report was prepared assuming an allocation agreement will be reached among the managers of the major fishery user groups beginning in 1986. The need to reassess the current goal of 115,000 adult spawners was identified by the Klamath River Management Group at their first meeting in San Francisco on May 23, 1985. The present goal has never been met since its adoption by the Pacific Fishery Management Council (PFMC) in 1978 (Figure 1) and there is concern among many that the 115,000 spawner goal is too high for current habitat conditions. The Management Group believed that a thorough reassessment of the goal might help managers and fishermen to work more cooperatively toward managing this important natural resource of northwestern California.

The Team began work with a June 12-14 tour of the Klamath and Trinity rivers for those less familiar with the spawning grounds and juvenile rearing habitats. We met monthly from

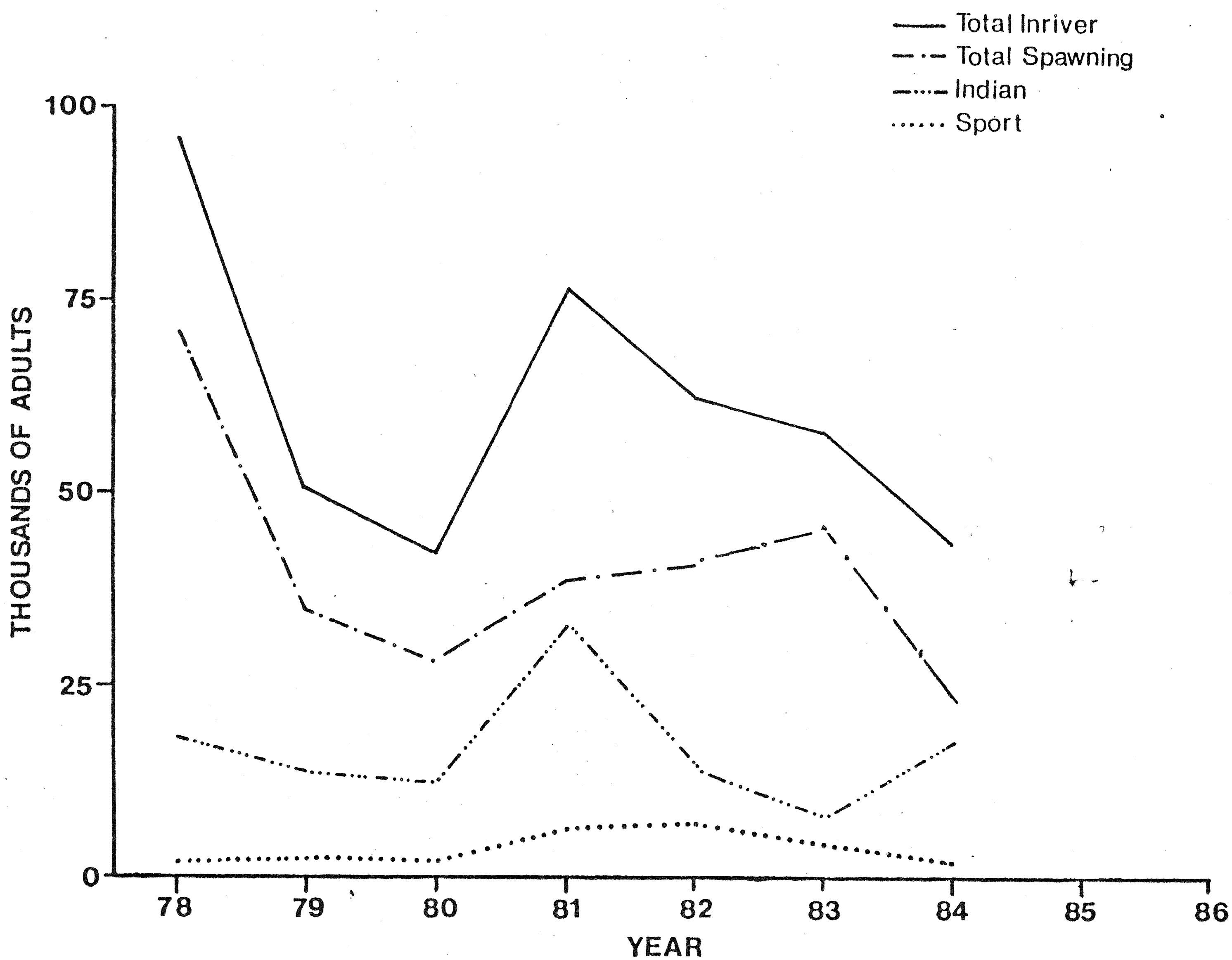


FIGURE 1. Klamath River adult fall-run chinook salmon escapements and inland landings, 1978-1984.

August, 1985 through January, 1986 and communicated less formally on various work assignments between meetings. Our goal was to produce an objective assessment of and recommendation for spawning escapement policy to guide management of fisheries impacting Klamath River fall-run chinook.

METHODS

The team has reviewed methods used in other areas to set escapement goals (Adair 1981), discussed these and other approaches among ourselves and with guests to develop a set of management options for study. These options were reduced to four that we believed worthy of further consideration and analysis.

Management Options

<u>OPTION 1</u> Continue current escapement goal of 115,000 adult fall-run chinook salmon.

This option provides for continuation of the current escapement goal for the basin of 115,000 adult fall-run chinook. That goal was based on estimates of run size in the early 1960's, (CDFG 1965). The goal includes 97,500 natural and 17,500 hatchery spawners.

OPTION 2 Adopt fixed escapement goals of 43,000 natural spawners and 17,500 hatchery adults.

For natural spawners, this option is based on the range of spawning capacity estimates made in June 1985 by CDFG biologists familiar with the watershed (Hubbell and Boydstun 1985, Appendix II). Two yield curves bracketing the range of biologists' estimates of maximum spawning ground capacity were constructed. The dome-shaped Ricker function (c.f. Ricker 1975) was used to estimate the stock recruitment relationship (Figure 2). Alpha (the coefficient of productivity) for age 3 recruits was set equal to 10 and beta (the coefficient of spawner capacity) equal to 2.46×10^{-5} for the low assessment of 41,000 natural spawners and 9.44×10^{-6} for the high assessment of 106,000 natural spawners. Annual natural mortality was set at 25 percent, and 40 percent of the stock was assumed to mature at age 3. All age 4 fish were assumed to be maturing. Instantaneous rates were used to estimate fishery-related and natural deaths.

With the low assessment of spawning capacity, maximum equilibrium yield would require about 29,000 spawning adults. With the high assessment, maximum equilibrium yield would require about 74,000 spawning adults. This option assumes that either curve is possible for Klamath chinook. An alternative to arbitrarily selecting one or the other curve -- or to disregarding the June 1985 CDFG input -- is to select a spawning

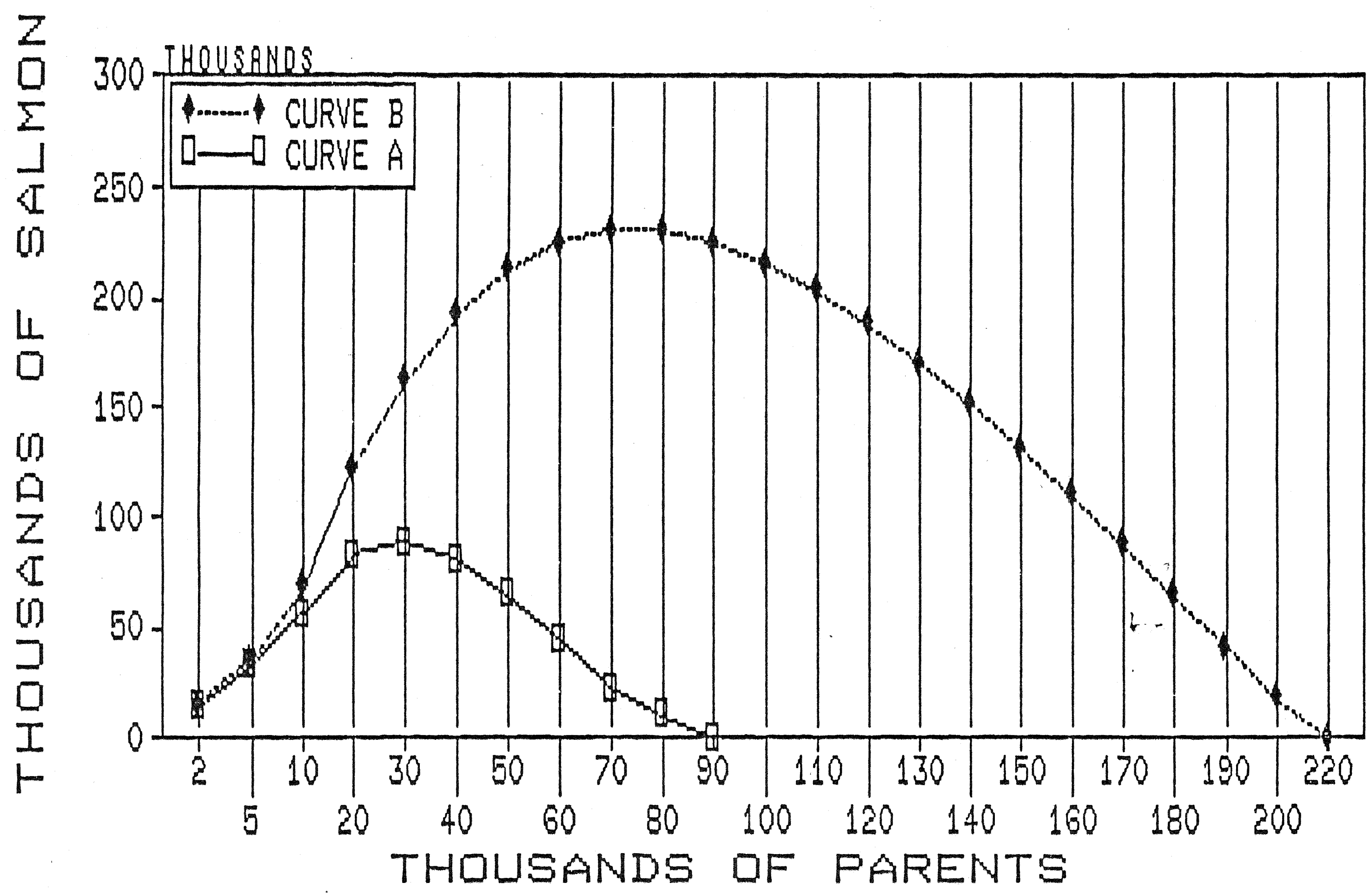


FIGURE 2. Fishery yield curves using a low estimate of basin capacity (Curve A, 1/Beta = 41,000) and a higher estimate of basin capacity (Curve B, 1/Beta = 106,000).

escapement level at which the percentage reduction in potential yield is the same with either curve. This "low risk" escapement level is 43,000 adult fish. At this level of spawning escapement fishery yield is 87 percent of maximum with either curve.

This option also includes 17,500 fall-run adults returning to the two basin hatcheries: 9,000 to the Trinity River Hatchery and 8,500 to the Iron Gate Hatchery. These are the numbers required by mitigation agreements.

OPTION 3 Adopt probing approach to further define the stock recruitment relationship.

Under this proposal, the fisheries would be managed annually to permit a recent average escapement level except for two of the next six years when ocean abundance exceeded some fixed number of fish. In these years, the escapement goal would be raised to a higher level (e.g. 70,000).

The intent of this option is to provide the high escapement levels needed to test their value by adding two additional points to the stock recruitment data base which currently consists of five points most of which represent low numbers of spawners (Figure 3). The existing data are insufficient to define the spawner-recruit relationship for Klamath River Basin fall-run chinook.

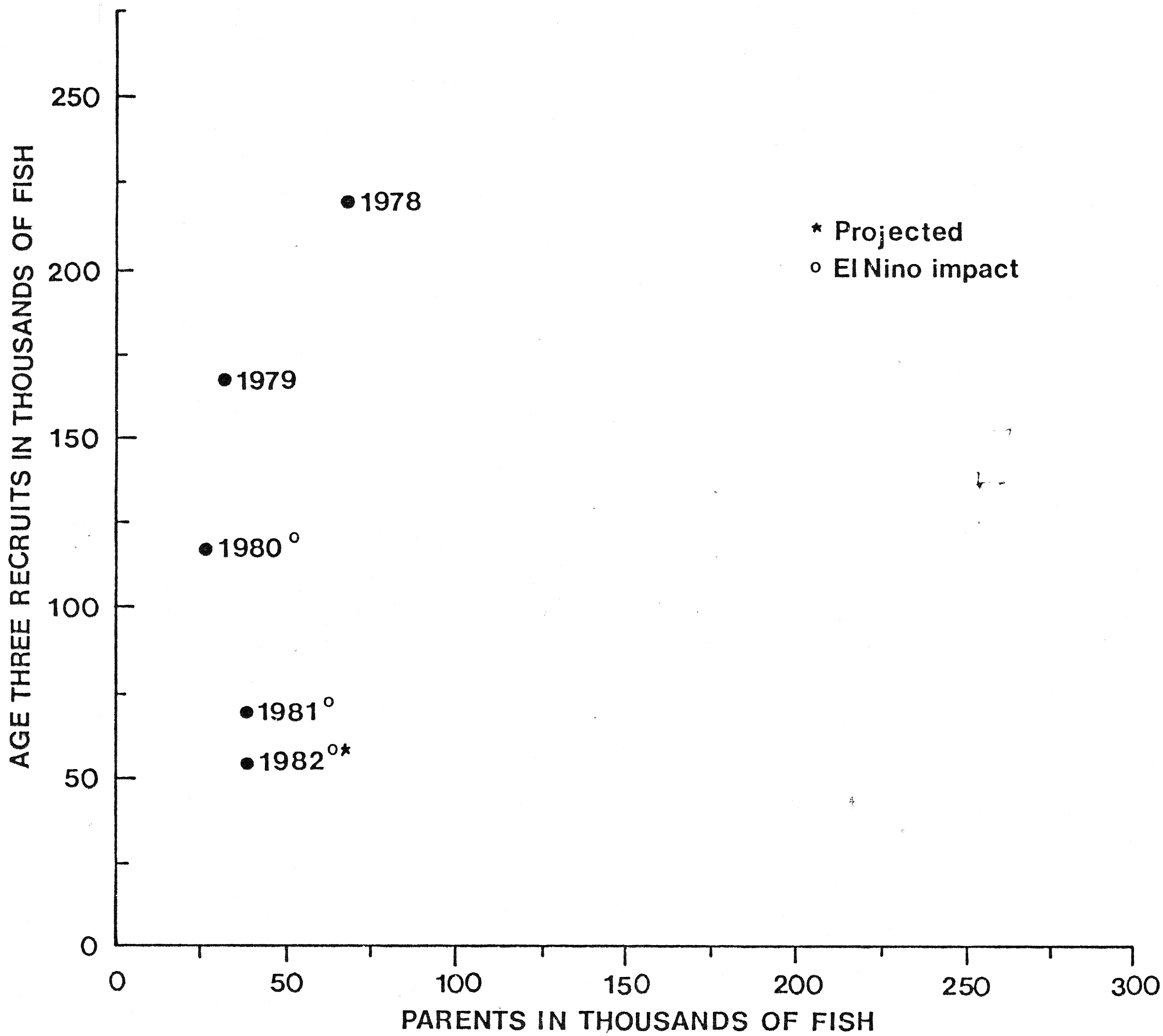


Figure 3. Klamath River fall chinook stock-recruitment data, 1978-1982 broods.

OPTION 4 Regulate by harvest rate.

Under this proposal, the goal of management would be to regulate harvest rates in offshore and terminal fisheries to produce the maximum sustainable yield (MSY). Harvest rate level to achieve MSY for chinook stocks depends on the productivity of the stock and average age at maturity (Hankin and Healy, MS). Regulations would allow a fixed percentage of each year class of chinook to be caught and to spawn.

A computer model was constructed to estimate the long-term impacts of a wide range of harvest rate combinations on combined fishery yields. This model is described in Appendix III. Harvest rate in this model represents the rate at which the most vulnerable age class of fish in a fishery is contacted by the gear. Contact rates for the other age classes are adjusted based on estimates of gear selectivity. Fishery yields are estimated after 40 years of constant fishing pressure under equilibrium conditions.

Harvest rate combinations (ocean/river) producing maximum long-term yields were determined at 5 percent increments for ocean rates ranging from 0.15 to 0.55 and in-river rates ranging from 0.30 to 0.70 (Table 1). These ranges produce eight combinations which would maximize yields from the combined fisheries. They also represent a continuum of combinations which

TABLE 1. Results of Computer Evaluation of a Selected Range of Offshore and Terminal Area Harvest Rate Combinations on Maximum Long-term Yield of Klamath River Fall-run Chinook, Measured in Terms of Numbers of Landed Fish[1/]

Offshore harvest rate	Terminal harvest rate[2/] 0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
0.15:	63	68	74	79	84	89	93	96 [3/] ←	97
0.20:	71	76	81	86	90	94	96 ←	98	97
0.25:	79	83	88	91	95	97 ←	98	98	95
0.30:	86	90	93	96	98 ←	99	98	96	90
0.35:	92	95	97	99	99	98	96	91	82
0.40:	97	99 ←	100 ←	100	98	96	91	83	71
0.45:	100 ←	100	99	98	95	89	82	71	55
0.50:	100	99	96	92	87	79	68	54	36
0.55:	97	93	89	82	74	63	49	33	18

1/ Landings estimates are expressed as a percent of the maximum landing (0.50/0.30) for the harvest rate combinations shown in this table.

2/ Harvest rate is expressed as the rate at which the most vulnerable age class of fish is impacted.

3/ The arrows show the maximum yield for a given harvest rate combination.

shift the majority of the yield between the two fishery areas (ocean and river) (Figure 4).

Under this option, any of the combinations shown in Figure 4 would be available for developing annual ocean and river management plans and would allow about 35 percent of potential adults to spawn. The only exception to management based on the combinations shown in Figure 4 would be if the projected escapement of spawners would fall below 35,000 naturally spawning adults. If this occurs, harvest rates would be lowered to the extent necessary to protect this "escapement floor" (an allocation decision).

An escapement floor of 35,000 naturally spawning adults is intended to protect the production potential of the stock for future fisheries. It represents approximately 50 percent of the adults required to achieve MSY by the Ricker method using the high CDFG assessment of basin capacity (106,000) and an alpha for age 2 recruits of 14, which the Technical Team believes is appropriate for the Klamath River Basin.

A minimum spawning escapement of 35,000 natural spawners would be higher than any natural escapement since 1978, levels that have been widely regarded as too low for the basin.

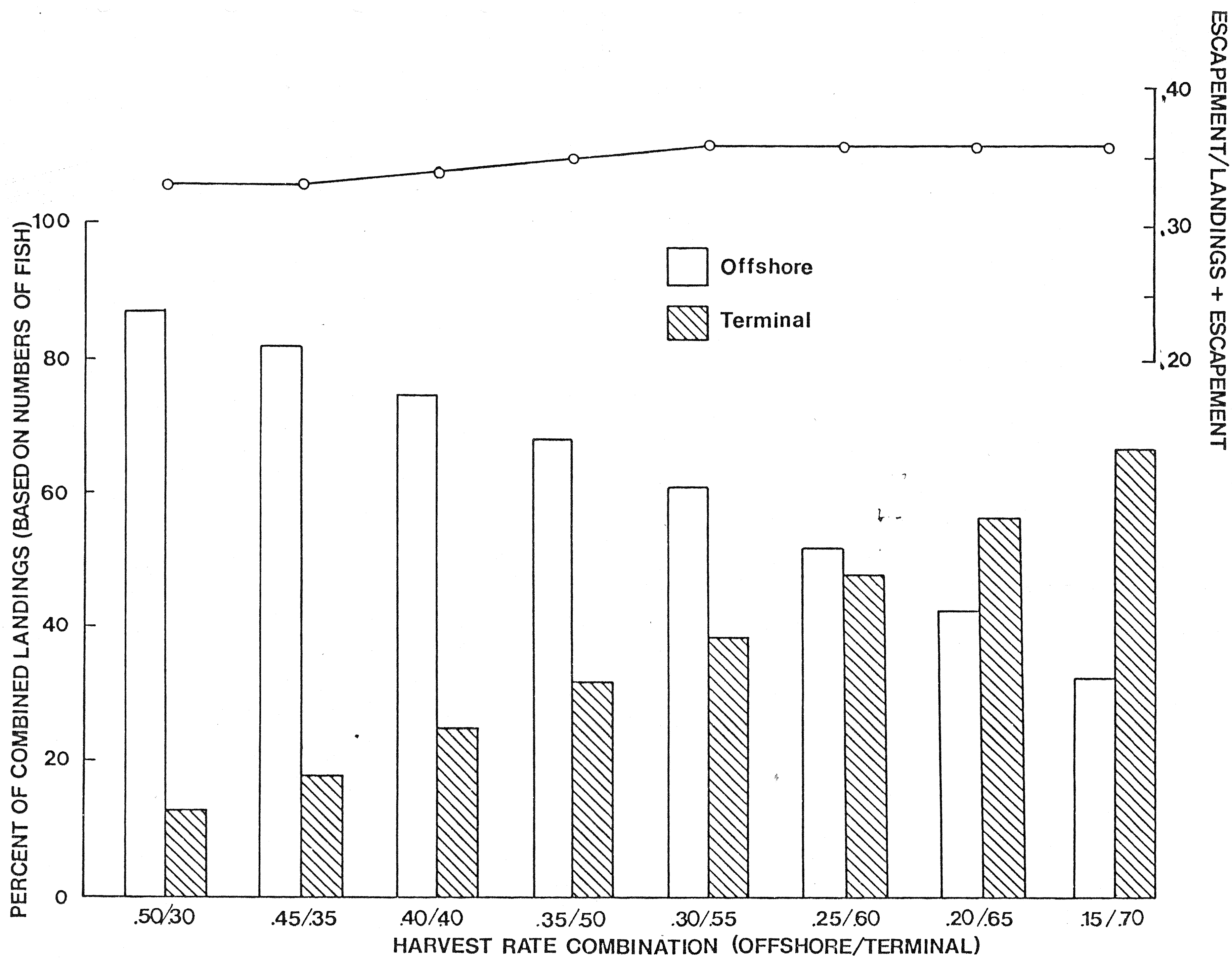


Figure 4. Distribution of Klamath River fall-run chinook landings over the long term under a selected range of harvest rate combinations including relative impact on the adult spawning escapement.

Analytical Methods

We measured each of the four options described in the preceding section against the following criteria:

(1) Is the option biologically and analytically sound? How well can the assumptions required for its valid use be met? Are the required data available?

(2) Will data useful for management of harvest and habitat be generated?

(3) Has it a good chance of achieving maximum sustained yield?

(4) Will it provide adequate protection when stocks are very low?

(5) Will it provide enough returns to the hatcheries to meet current goals?

(6) Will it minimize adverse impacts upon users relative to stability of fisheries, harvest opportunity and catch level?

(7) Can it be clearly described and will it be understood by users and managers?

(8) Will its effectiveness be seriously reduced by errors inherent in estimating stock size?

(9) Will it provide for evaluation in a cost effective manner?

To aid in evaluation of our management options, a time series computer model was constructed that incorporates the essential elements of Klamath River fall chinook life history and the selectivities of ocean and river fisheries under recent years' regulations. Computations were performed in a manner simulating the sequential nature of offshore and in-river fisheries. Recruits in the model are estimated using the Ricker formula for age 3 fish and all fish are assumed to mature at or before age 4. Alpha for age 3 recruits is assumed to be 50 percent of that for age 2 recruits. This adjustment is consistent with the 50 percent natural mortality rate between age 2 and age 3 recruits used in the harvest rate model. Omitting age 5 fish has little impact on the results because the probability of an age 3 recruit surviving to age 5 is only 4 percent.

Most time series analyses used a survival rate multiplier to simulate the effect of natural variation on year class production. Multipliers were drawn from a table of normally distributed numbers with mean equal to 1.0 and standard deviation equal to 0.3. This distribution was based on the degree of variation observed in ocean salmon landings in the Klamath River management area between 1952 and 1984. Multipliers were held constant between model runs so that each option was analyzed under the same set of conditions.

Options were generally analyzed with alpha equal to 7.0 (approximately 14 for age 2 recruits). Beta was tested at two levels representing the low and high CDFG biologists' assessments described in Option 2; i.e., 2.46×10^{-5} for 41,000 and 9.44×10^{-6} for 106,000 (Figure 5). Predictions of catch and escapement were generated over a 40-year time series.

An example output from the time series model showing the various input variables is shown in Table 2.

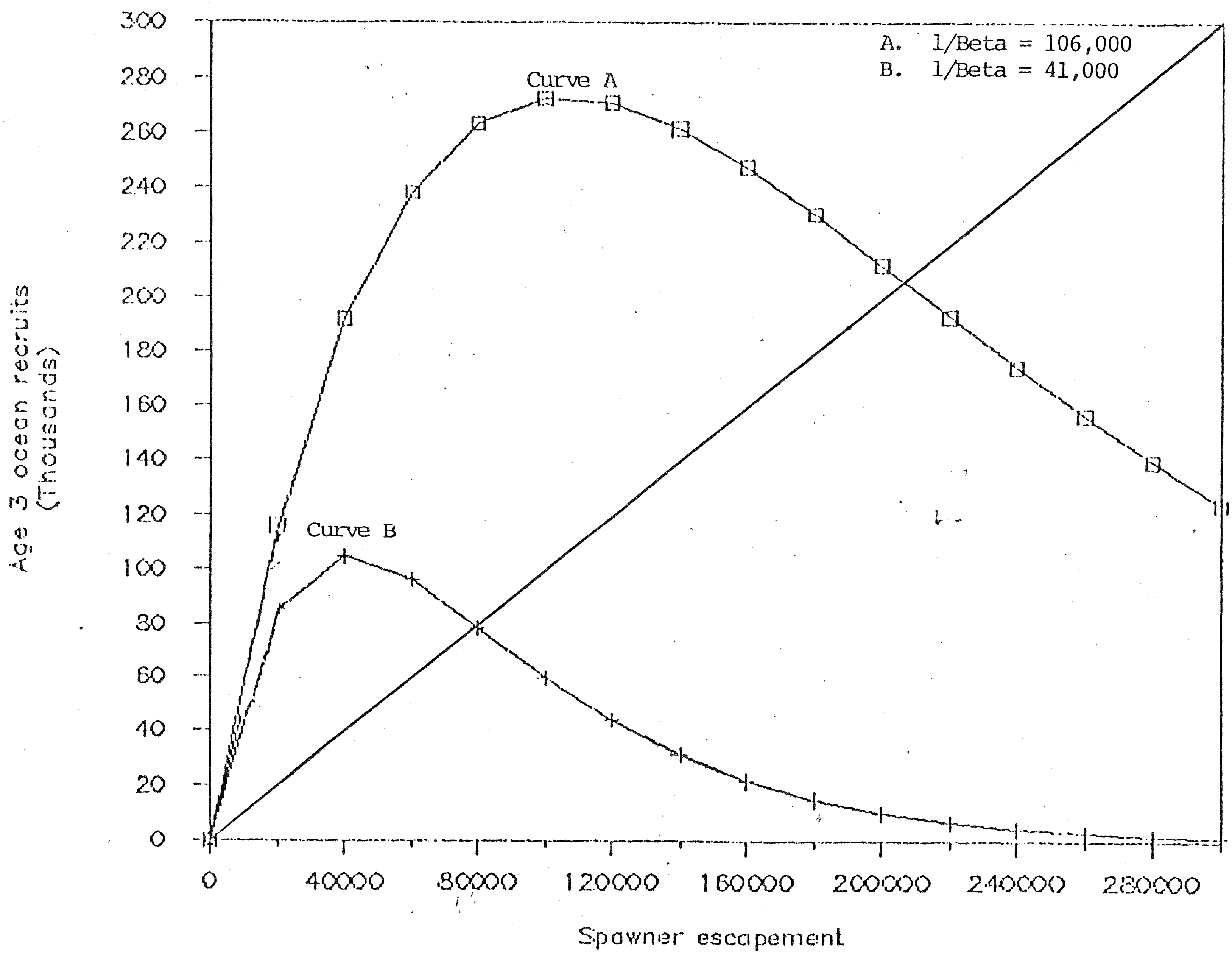


FIGURE 5. Ricker curves bracketing the probable range of stock recruitment curves for naturally spawning Klamath River fall-run chinook. (Alpha based on age 3 recruits)

TABLE 2. Example output from the Time Series Model showing the various input parameters.

Harvest year (t)	1981	1982	1983	1984
Offshore harvest rate	0.6	0.6	0.6	0.6
Terminal harvest rate	0.5	0.5	0.5	0.5
Age 3				
Offshore contact rate	0.88	0.88	0.88	0.88
Percent legal	0.8	0.8	0.8	0.8
Shaker mortality rate	0.3	0.3	0.3	0.3
Maturity rate	0.43	0.43	0.43	0.43
Terminal contact rate	0.66	0.66	0.66	0.66
Terminal drop-off rate	0.11	0.11	0.11	0.11
Natural mortality rate	0.2	0.2	0.2	0.2
Age 4				
Offshore contact rate	1	1	1	1
Maturity rate	1	1	1	1
Terminal contact rate	1	1	1	1
Terminal drop-off rate	0.11	0.11	0.11	0.11
Spawning escapement (t-3)	58492	30637	21483	33857
Survival multiplier	1.2	1.3	0.9	1.7
Age 3 ocean recruits	242452.6	178952.2	94713.95	250867.1
Offshore landings	102412.0	75589.42	40007.17	105966.2
Offshore shaker deaths	7680.900	5669.206	3000.538	7947.470
In-river run size	56914.69	42008.24	22233.68	58889.95
In-river landings	16715.84	12337.82	6530.033	17295.97
In-river drop-offs	2066.003	1524.899	807.0827	2137.705
Spawning escapement	38132.84	28145.52	14896.56	39456.26
Age 4 ocean recruits		60356.05	44548.28	23578.04
Offshore landings		36213.63	26728.96	14146.82
In-river run aize		24142.42	17819.31	9431.218
In-river landings		10743.37	7929.594	4196.892
In-river drop-offs		1327.833	980.0621	518.7170
Spawning escapement		12071.21	8909.656	4715.609
Exploitation rate		0.770322	0.773278	0.762232
Total offshore landings		111803.0	66736.14	120113.1
Total in-river landings		23081.19	14459.62	21492.87
Total landings		134884.2	81195.77	141605.9
Total spawning escapement		40216.73	23806.22	44171.87

	40 year period			
	Average	Minimum	Maximum	S.D.
Offshore landings	80938.77	25539.12	127336.9	27051.98
In-river landings	26074.51	10088.95	42453.20	8682.365
Total landings	107013.2	35856.09	163793.1	34753.43
Spawning escapement	61997.79	21623.83	101673.0	22942.96

1/ Parameter values do not necessarily agree with final simulation run estimate.

ANALYSIS OF OPTIONS

AND

RECOMMENDATIONS

OPTION 1 Continue current escapement goal of 115,000 adult fall-run chinook salmon.

The Team recommends that Option 1 be rejected if a long-term allocation agreement is reached.

This goal is currently in place and is understandable to users, managers and the general public. Managing for a fixed spawner goal can produce MSY providing the goal matches the actual capacity of the basin. While the 115,000 spawner goal is tied to historic run sizes, the amounts of spawning and rearing habitat in the basin have probably been changed to weaken the basin's ability to produce seaward migrant fish. In 1985 CDFG biologists' estimates of the maximum number of natural spawners that could be accommodated in the basin ranged from 41,000 to 106,000 (Hubbell and Boydstun, 1985). The long term yield from fall-run chinook decreases sharply if the fisheries are managed for a single number spawning escapement goal that does not approximate the system's current carrying capacity. If the capacity is greater than the escapement goal, the spawning stock will be held below that which would produce MSY. If the capacity is less than the goal, the fisheries would be shut off frequently to ensure the goal is met but recruitment in subsequent years would not increase (Figure 6).

We believe that the option of a fixed 115,000 spawning escapement goal may be inappropriate for current habitat conditions, particularly considering the wide range of expert opinion on spawner capacity. Thus continuation of this goal would be costly to users and therefore criterion 6 is not met. For these reasons other approaches should be explored.

OPTION 2 Adopt fixed escapement goals of 43,000 natural and 17,500 hatchery adults.

The Team recommends that this option not be selected.

This goal shares the same problems as other fixed spawner goals. Benefits of managing for the fixed goal depend heavily on the goal approximating the system's capacity for spawners. As pointed out under Option 1, we do not know the Klamath system's spawning or rearing capacity and errors in setting the goal too high or too low would have similar impacts as under Option 1. Unlike Option 1 this goal would not provide higher spawner escapements to test the basin capacity and improve future management by increasing our knowledge of the spawner-recruit relationship.

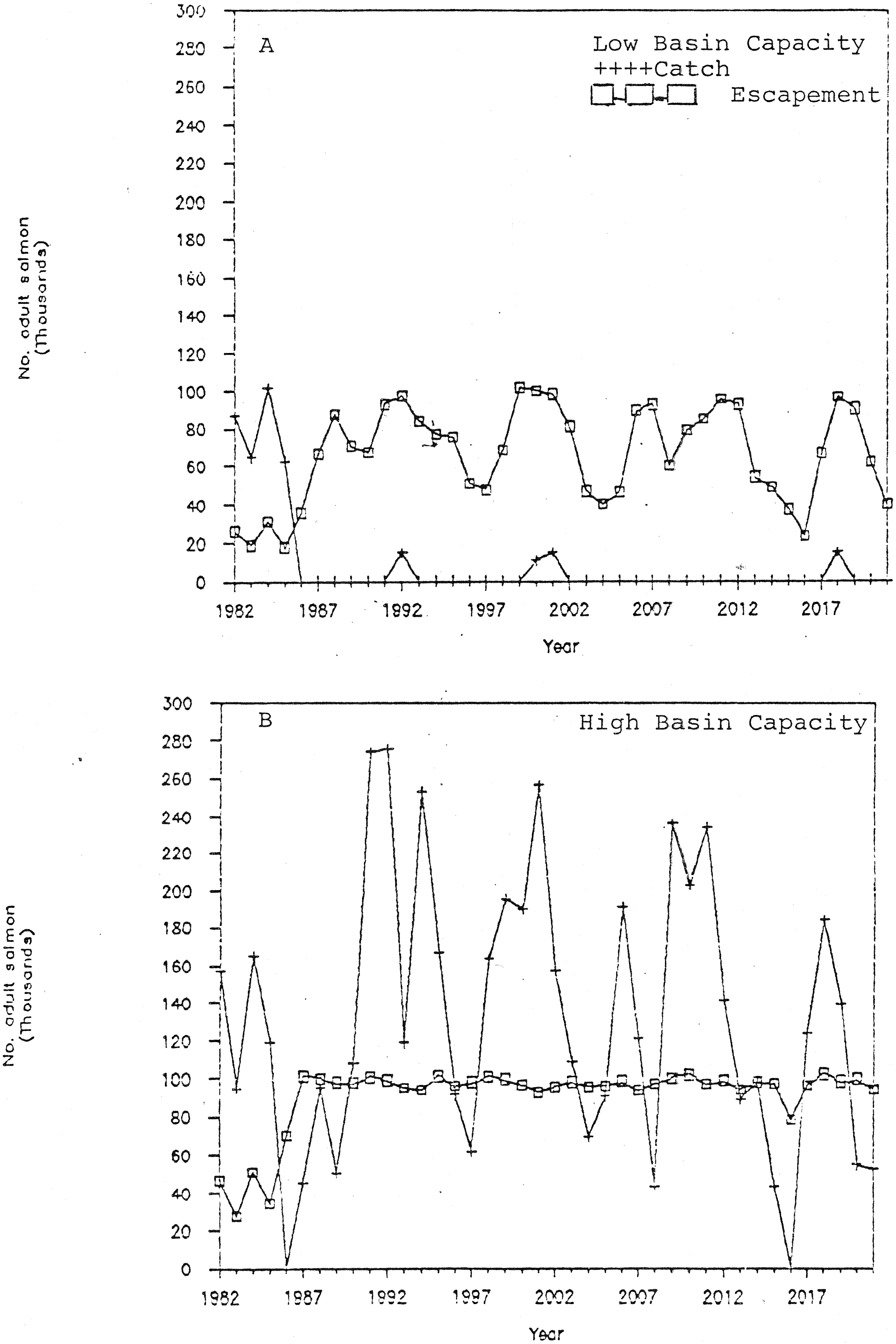


FIGURE 6. Simulated annual catch and escapement of Klamath River fall-run chinook salmon under a fixed escapement goal of 97,500 spawners and basin capacity equal to 41,000 (A) and 106,000 (B). Alpha is set at 7 for age 3 recruits in both illustrations.

This goal would protect the stock at low levels of abundance but would be disruptive to the fisheries during low production years. The separate goals for hatchery and natural spawners would not likely be achieved simultaneously due to the variation in hatchery contribution to the run from year to year (Appendix III, Table III-2).

Initially landings in the fisheries under this option would be greater than under Option 1, but the long term effect on fishery yield cannot be estimated with any certainty.

Because of its failure to meet criterion 2 (generate needed stock-recruitment data), the Team recommends that Option 2 not be selected.

<u>OPTION 3</u> Adopt a probing approach to further define the stock recruitment relationship.

The Team recommends that this option not be selected.

This option was not developed in detail by the Team. In theory it manages the fisheries to provide larger spawning escapements for the purpose of investigating the spawner-recruitment relationship. Because these larger escapements would be planned in years of greater abundance, the fisheries would not necessarily suffer a decrease in total landings. This method would generate data not currently available but, considering the natural annual variation in survival to smolt, the results of two large spawning escapements would not likely be conclusive. Since this option apparently offers a resolution after two brood cycles, there is a distinct possibility that the two data points would be viewed as conclusive and possibly be misused.

In the near-term, it is not specified how the fisheries would be managed in years of average or low abundance. This option would need to be combined with some other escapement policy for those years. Finally, users of the resource would probably oppose this probing method.

<u>OPTION 4</u> Regulate by harvest rate.

The Team recommends adoption of this option.

Analysis of available data indicates that Klamath chinook are being overfished and that reduction in harvest rate would increase the long term yield from the resource (Figure 7). Other evidence of overfishing include declining returns of spawners throughout the basin and increasing percentage of hatchery spawners compared to natural spawners (Appendix III, Table III-2). Adoption of this proposal would require a reduction in recent harvest rate levels. Allocation decisions would determine the degree of change in any particular fishery.

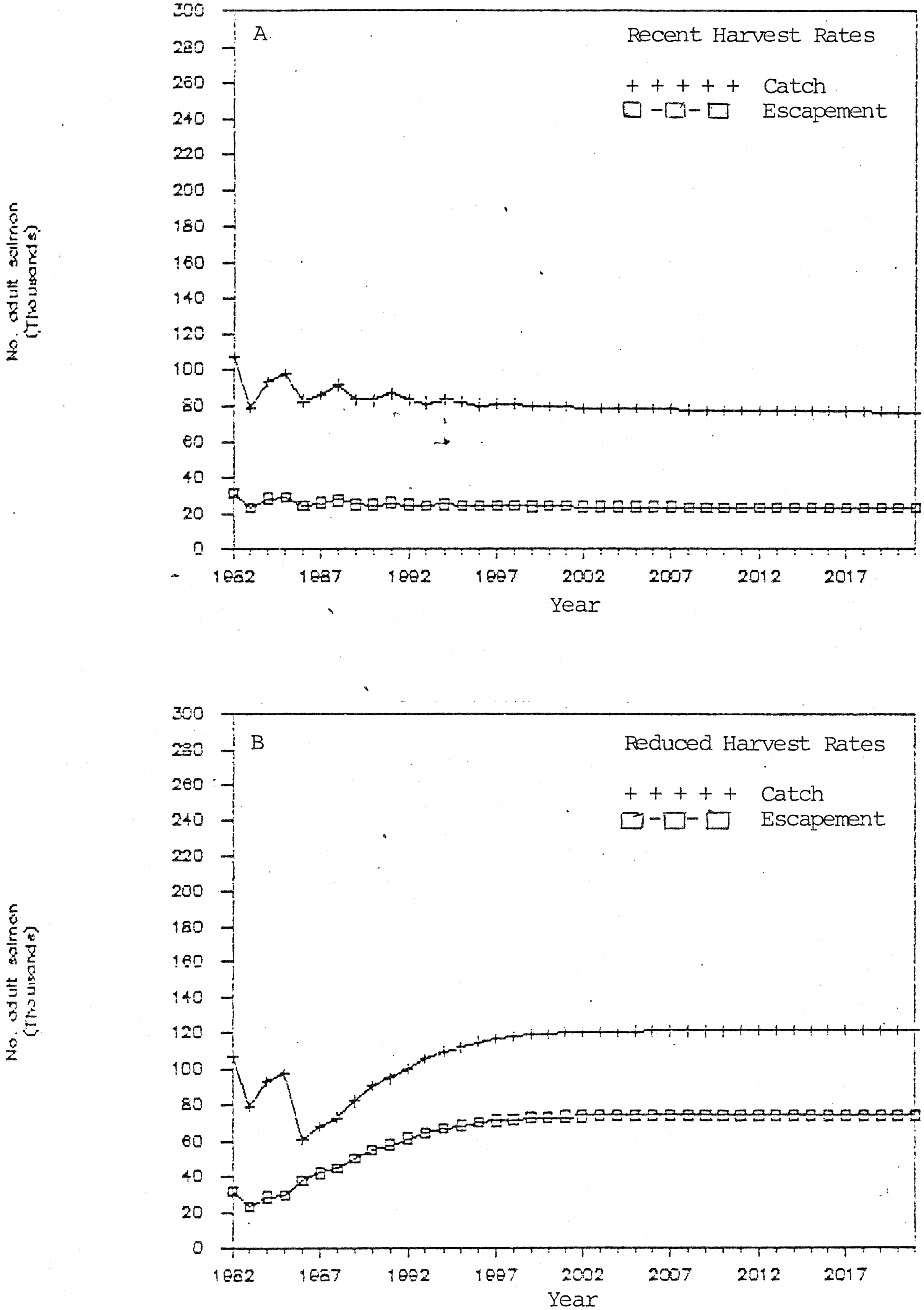


FIGURE 7. Annual catch and escapement of Klamath River fall-run chinook under equilibrium conditions with recent harvest rates (A) and reduced rates (B) (.40/.40 in FIGURE 4).

Regulation by harvest rate would provide for variations in spawning escapement needed to develop an understanding of the stock recruitment relationship.

The approach would also provide for more stabilized fishing opportunity than a single number goal would allow. The harvest rate approach would provide greater long term yields than management based on a single number goal unless the goal was set very close to the actual spawning level needed for MSY (Table 3). It also provides a variety of spawning escapements while allowing some level of fishing in all but exceptionally poor years.

We tested the effectiveness of the 35,000 escapement floor by subjecting the stock to three consecutive years (1995, 1996, 1997) of poor recruitment (20 percent of that predicted), with and without a floor in place. Elimination of fishing in 1996 and 1997 because of imposition of the floor, resulted in 30 percent higher average escapement during the period 1996-2005 which is about two brood cycles (Figure 8). Average yield to fishermen during this period was larger by 17 percent.

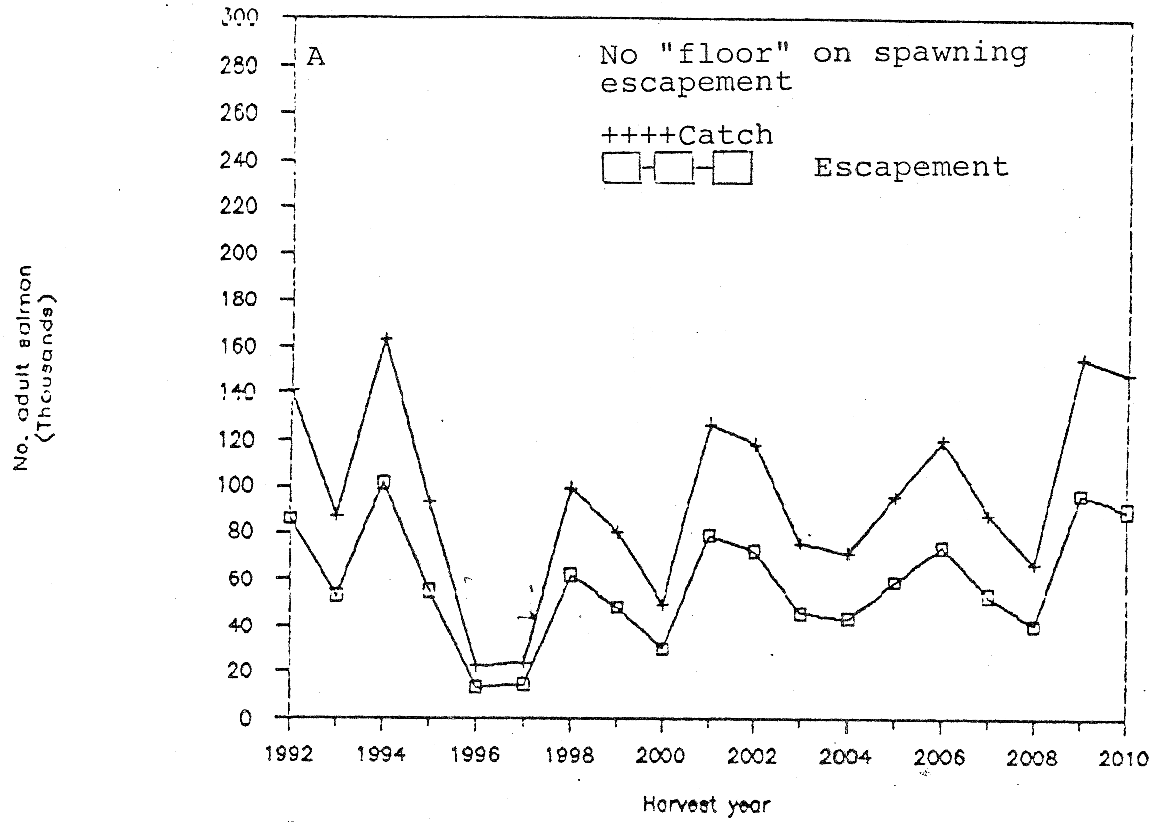
Our analysis is that this approach meets the criteria we have adopted for evaluating options much better than any other. The Technical Team's recommendation is that Option 4, regulation

Table 3. Comparisons of average annual fishery yield, escapement and their standard deviations over a 40 year time series for Options 1, 2, and 4 in thousands of fish (alpha = 7 for age 3 recruits in all comparisons).

	Basin Carrying Capacity for Maximum Production: 41,000 Adults	106,000 Adults
Fishery Yield		
Option 1 (115,000)	9(24)a/	132(73)
Option 2 (43,000)	50(28)	131(55)
Option 4 (Harvest Rate)b/	55(16)	132(34)
Escapement		
Option 1 (115,000)	66(25)	91(18)
Option 2 (43,000)	40(6)	43(4)
Option 4 (Harvest Rate)b/	31(10)	77(28)

a/ (Standard deviation).

b/ Based on a .40/.40 (ocean/river) harvest rate combination.



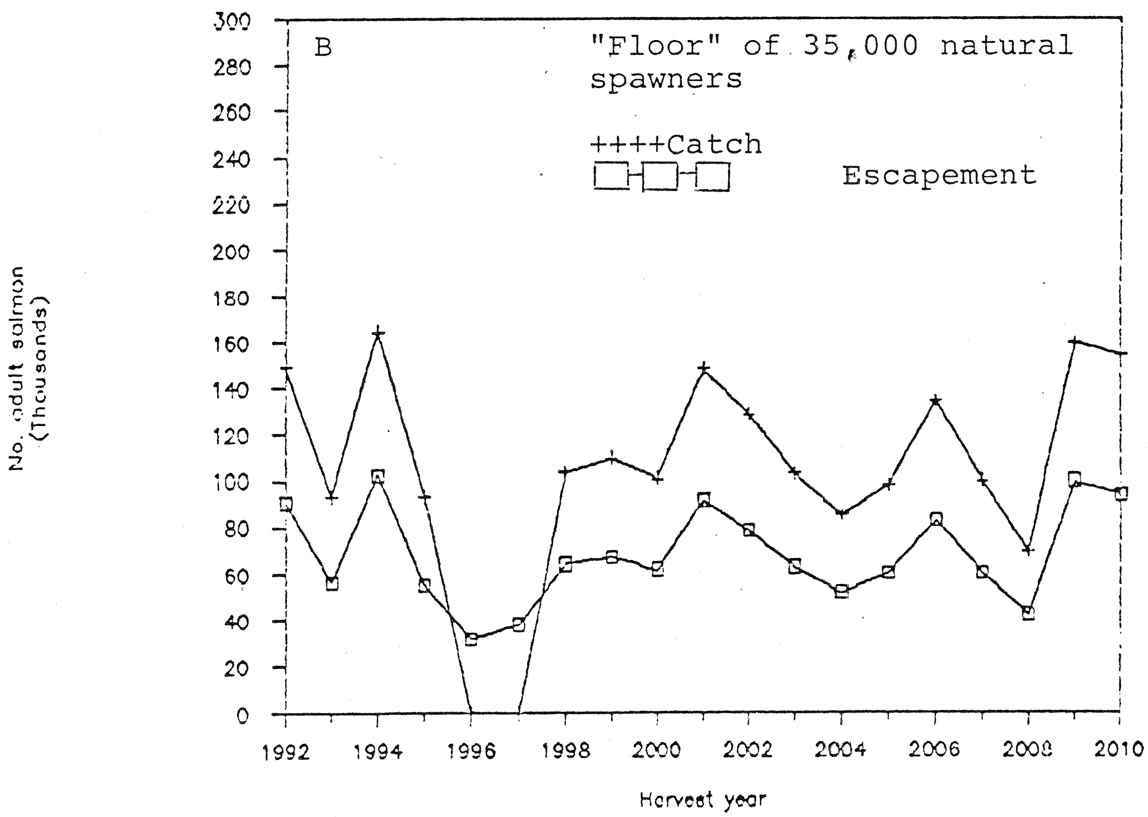


FIGURE 8. Simulated catch and adult spawning escapements with a fixed harvest rate of 0.4 ocean and 0.4 in-river, and assuming an environmental catastrophe which reduced adult recruitment in 1995, 1996, and 1997 to 20 percent of average. The imposition of a 35,000 spawning escapement "floor" which permitted no fishing in 1996 and 1997 resulted in more rapid recovery of the stocks and higher subsequent catches.

by harvest rate, be implemented in 1986 under the assumption that beginning in 1986 allocation agreements will be reached for the foreseeable future.

DISCUSSION

The Team recommends that the Klamath River Management Group adopt our harvest rate option to guide the management of Klamath River fall-run chinook beginning in 1986. This recommendation was developed under the assumption a long term allocation agreement will be reached among the various entities responsible for the management of fisheries that impact Klamath River chinook. In the absence of an allocation agreement, no change is recommended in the current rebuilding schedule aimed at reaching 115,000 adult chinook by the year 2002.

We recommend this approach because the current data base for Klamath chinook places managers in the precarious position of adopting a single number goal which may be inappropriate for the stock. The consequences of an improper selection include reduced fishery yields and collection of less valuable information than the harvest rate option would provide. A major strength of the harvest rate approach is that it does not depend on an assumption about basin carrying capacity. The approach will produce higher long term yields than any single-number escapement goal except one very close to the actual carrying capacity for the basin

(Cooney 1984). The harvest rate approach, however, is highly dependent for its success on a close approximation of the average productivity of the stock (alpha in the Ricker model). Selection of the appropriate value of alpha will allow for varied escapement considerably above those observed since 1979, and after one brood cycle the escapement floor is unlikely to be imposed except in the event of a major catastrophe.

The harvest rate management method is based upon long term sustained yield at equilibrium condition established over a period of 40 years. In reality annual environmental variability may well cause wide differences in annual production. We expect a moderate increase in average escapement in the short term, because of reduced harvest rates, however, it will take at least two brood cycles (eight years) to reasonably evaluate harvest rate management and the appropriateness of the alpha selected.

A relatively narrow range of escapements to natural spawning areas has been observed in the Klamath River since 1979. Only once since 1978 has it exceeded 34,000 adult chinook. Higher escapement levels are needed for Klamath River chinook in order to better define the stock-recruitment relation for the resource, and thereby achieve the greatest sustained yield for the combined fisheries.

From a user standpoint, harvest rate management should be preferred to single number escapement goal management because it provides for more stability in harvest opportunity. However, in high production years it might result in larger escapements than many people will believe are necessary. High escapements are essential to define the basin's capacity. Even if escapements should exceed the most optimistic assessment of basic carrying capacity, managers and users must not deviate from the harvest rate approach until an accurate spawner-recruit relationship has been developed.

Adoption of an escapement floor of 35,000 naturally spawning adults should be an integral part of harvest rate management of Klamath River chinook. The floor would protect the reproductive potential of the stock and not allow it to fall below natural escapement levels observed since 1979.

It should be noted that annual stock projections for Klamath chinook must address hatchery and natural components in order to protect the escapement floor. The proposed floor does not include fish that will enter the hatcheries.

Recent years' harvest rates of 0.6 offshore and 0.5 in-river are excessive in terms of maximizing long term yield of Klamath chinook. Under harvest rate management, continuation of an offshore harvest rate of 0.6 would not provide for any in-river fisheries. Continuation of an in-river rate of 0.5 would require a reduction in offshore fishing rate by about 40 percent (to 0.35). There are several other harvest rate combinations available to the fisheries that would maximize long term yields for the combined fisheries. These are shown in Figure 4.

The procedure for setting annual fishing regulations under the harvest rate approach would be as follows.

Implementing Harvest Rate Management

(1) Stock projections are made for the current year. These are age-specific with separate estimates for hatchery and natural components.

(2) Allowable ocean and river catches of Klamath fall chinook are decided based on an allowable harvest rate combination that is consistent with allocation agreements between ocean and river managers. Total ocean catch from all chinook stocks would be based on projections of Klamath River contributions by time and area.

(3) Season lengths, gear restrictions, area closures, quotas or other regulations are adopted which are consistent with allowable catch levels and will produce

an age-structured spawning escapement that is in close agreement with the output from the harvest rate model.

Adoption of the harvest rate management approach by the PFMC would probably require amendment of the PFMC Framework Plan Amendment. Table 3-2 and page 3-20 of that Amendment describe the current escapement management plan for Klamath River chinook. These sections are reproduced here as Tables 4 and 5. Under the harvest rate approach, the PFMC Framework Plan might be amended to reflect that the goal of Klamath River chinook management now is to regulate fishery harvest rates consistent with stock productivity with the aim of maximizing combined fishery yields on a long term basis. To protect the recruitment potential of the stock, a minimum spawning escapement of 35,000 naturally spawning adults will be provided in all years.

MANAGEMENT AND RESEARCH NEEDS

Successful management by harvest rate is dependent upon continuation of coded-wire-tagging of all hatchery production releases at current levels as well as continuation of tag recovery programs for all fisheries harvesting significant numbers of Klamath fall chinook. Continuation of coded-wire-tagging of naturally produced chinook salmon is needed to determine differences in biological characteristics of hatchery and natural stocks. It is important that annual estimates of in-

Table 4. Current ocean salmon management goals for Klamath River chinook as shown in the PFMC Framework Plan Amendment.

System	Spawning Escapement Goal a/	Management Objectives: Other	Management Objectives: Rebuilding Schedule
California Central Valley Fall Chinook Adults			
Total Sacramento b/	Range of 122,000 to 180,000 for natural and hatchery	Provide for inside recreational fishery	As determined by the state c/ for components of the system
Klamath Fall Chinook	97,500 natural 17,500 hatchery	Provide for inside Indian subsistence and recreational fishery	Achieve in-river run sizes (natural and hatchery combined) as follows: 1983-86 68,900 1987-90 82,700 1991-94 99,200 1995-98 115,000+ d/
Oregon Coastal Chinook	150-200,000 natural	Meet hatchery requirements	None
South Coast	not yet established		
North Coast	not yet established		
Columbia River Chinook		Manage consistent with U.S./Canada treaty if ratified; meet treaty Indian obligations and provide fish to inside non-Indian fisheries and meet hatchery requirements	The Council recognizes that certain factors at work such as (1) the implementation of the Pacific Northwest Electric Power Planning and Conservation Act, (2) the conclusion and ratification of a U.S./Canada salmon treaty, (3) renegotiation among the parties of a plan for allocation of in-river harvests of Columbia River salmon, could lead to improved status of depressed Columbia River stocks. This will require reassessment and perhaps changes in ocean and spawning escapement goals for the Columbia River as improvements are realized. Estimates of the magnitude of these changes are not possible at this time. It is recognized that current management practices which prevent directed ocean fisheries on up-river chinook stocks will be required until substantial improvements occur.
Upper-River Fall	40,000 bright adults above McNary Dam	"	
Upper-River Summer	80,000 adults above Bonneville	"	
Upper-River Spring	100-120,000 adults above Bonneville	"	
Lower-River Fall	Meet hatchery requirements	Provide for inside net and recreational fisheries	
Lower-River Spring (Willamette)	30,000-35,000	"	
Washington Coastal Fall Chinook	e/ f/	Meet treaty allocation requirements and inside non-Indian needs	None
Washington Coastal Spring/ Summer Chinook	e/ f/	"	None
Puget Sound Chinook	e/ f/	Meet treaty allocation requirements and provide fish to inside non-Indian fisheries	None
Columbia River and Oregon Coastal Coho	575,000 OPI ocean escapement 200,000 adult natural coastal spawning escapement	Provide for Columbia River treaty obligations, and inside non-Indian harvest opportunities, and hatchery requirements	Achieve escapement of natural spawning stocks as follows: Year: Cycle 1 / Cycle 2 / Cycle 3 1983: Cycle 2 140,000 1984: Cycle 3 135,000 1985: Cycle 1 175,000 1986: Cycle 2 170,000 1987: Cycle 3 200,000 1988: Cycle 1 200,000 1989: Cycle 2 200,000

Table 5. Narrative of Klamath River chinook management goal as shown in the PFMC Framework Plan Amendment.

Klamath River Fall Chinook

The Council adopted a rebuilding schedule for Klamath River fall chinook which extends the time beyond 1988 that the long-term escapement goal will be met. Under this rebuilding schedule, Klamath escapements will be increased by an average of 20 percent every four years until the long-term goal is met.

Goals for the Klamath River are expressed as in-river escapement until in-river Indian and recreational harvest allocations are established. Once these harvest allocations are agreed upon, spawning escapement goals will be set.

The rebuilding schedule is to achieve the following in-river run sizes (natural and hatchery combined) for the Klamath River:

1983-86	68,900
1987-90	82,700
1991-94	99,200
1995-98	115,000+1/

1/ The long term escapement goal of 115,000 chinook is spawning escapement to which in-river harvest must be added to calculate the ocean escapement goal.

The Klamath River escapement goal may be adjusted in the future upon evaluation of habitat quality, spawner success, and contribution of natural spawning stocks. Also, if in the future an allocation for Indian harvest is set at a level that, when combined with recreational needs and the spawning escapement goal, would require an in-river escapement goal that would result in underutilization of other stocks in the ocean, the escapement goal may be reevaluated. Such changes would be made by an amendment to the FMP.

river age composition, catch by all major fisheries and spawning escapements be available to evaluate the success of annual management measures. These monitoring programs are necessary to define the stock recruitment relationship for Klamath basin fall chinook and to project stock abundance annually. To facilitate approval of annual stock projections and management measures, the Klamath River Technical Team should continue to meet and provide recommendations to the Management Group and the Salmon Plan Development Team.

Additional research is needed in several areas to better define parameter estimates used in the mixed fishery model and to gather information needed to maximize fishery yields. The following subjects deserve further research.

(1) Effect of escapement level and environmental factors on smolt production.

(2) Stock contribution studies to better define the contribution of Klamath stocks (and others) to ocean fisheries. These should include (a) electrophoresis comparisons (b) representative marking of all hatchery releases (c) area of catch information for the ocean fisheries.

(3) Comparison of mark-recapture methodology with alternate estimation or monitoring techniques used for measuring spawning escapements.

(4) The distribution and relative success of naturally spawning hatchery fish and the contribution of instream propagation projects.

(5) Methods of targeting ocean and river fisheries on stronger salmon stocks (particularly hatchery stocks).

(6) Research to better define maturity schedules and exploitation rates for naturally produced fish.

(7) Research on non-catch mortality rates in the various fisheries harvesting Klamath fall chinook.

(8) Additional research on size and age selectivity in the fisheries and the influence on productivity of Klamath fall chinook.

(9) Research on natural mortality rates in the ocean and in the Klamath and Trinity rivers during the spawning run.

TEAM CONCERNS

(1) Level or augmented funding of existing chinook salmon monitoring and tagging programs is essential to evaluate the success of annual management plans. Any reduction in funds will result in less accurate data. Klamath River chinook are important to the local and state economies and to the subsistence and ceremonial needs of the Klamath-Trinity tribes. Thus, high priority must be given to the data collection needs for Klamath River salmon management. Managers and administrators must not be led to believe that the harvest rate approach requires a less intensive data collection effort than management based on spawning escapement level. Data needs are intensive and identical regardless of approach to effectively manage this resource.

(2) Our team wishes to express concern that both hatchery management and habitat improvement programs need to be planned with adequate analysis of how they may affect future adult stocks and their ability to support fisheries. It is important to recognize that neither catch regulation, restoration of high spawning escapements, nor increases in spawning habitat alone,

will increase survival rates of weaker stocks in the Klamath and allow a higher percentage of the population to be harvested with safety.

(3) The team is concerned that a specific mechanism be provided to ensure future review of the status of harvest rate management regarding the Klamath River fall chinook population. In the event that short term increases in spawning escapement are not realized, that the established floor comes into frequent use, or that actual harvest rates exceed those specified during pre-season negotiation, this mechanism should be triggered.

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Appendix I. Members of the Technical Advisory Team to the Klamath River Salmon Management Group.

Organization	Representative
Bureau of Indian Affairs	Del Robinson
California Dept. of Fish and Game	L.B. Boydstun & Paul Hubbell*
Hoopa Valley Business Council	Bob Hannah
Klamath River Restoration Committee	Bill Bemis
National Marine Fisheries Service	Rod McInnis
Oregon Dept. of Fish and Wildlife	Steve Cramer
Pacific Coast Federation of Fishermens Associations	Don Kelley & Mike Maahs*
United Anglers of California	Bob Hayden
U.S. Fish and Wildlife Service	Robert Adair
U.S. Forest Service	Jerry Barnes

* Alternate

ACKNOWLEDGMENTS

Dave Hankin of Humboldt State University conceived and helped to develop the Team's harvest rate model. He also provided considerable input to the Team's deliberations. John Geibel of the CDFG wrote the actual harvest rate model program. Bill Mitchell of D.W. Kelly and Associates helped conceive and was responsible for programming the Time Series model.

Appendix II

An Assessment of the Current Carrying Capacity of the Klamath River Basin for Adult Fall Chinook Salmon1/

by

Paul M. Hubbell and L. B. Boydstun
Inland Fisheries Division
California Department of Fish and Game

In 1978, the California Department of Fish and Game (CDFG) adopted a spawner escapement goal for fall chinook salmon in the Klamath River basin of 115,000 adult fish. That escapement goal was based on estimates from the California Fish and Wildlife Plan (1965) of the average annual number of chinook spawners occurring in the system in the early 1960's. The 115,000-fish goal included 97,500 natural spawners and 17,500 hatchery spawners. Subsequent to its adoption by the CDFG, the Pacific Fishery Management Council (PFMC) adopted the goal for use in regulating ocean salmon fisheries.

Since CDFG began developing basin-wide spawner escapement figures there in 1978, estimates of adult fall chinook escaping to spawn each year in the Klamath River system ranged from 71,451 in 1978 to 22,666 in 1984. During those years, the average spawning escapement amounted to only 34.9% (40,125 fish) of the spawner escapement goal (range: 19.7%-62.1%). Because during this period the spawner escapements have never approached the 1978 goal, an interim 86,000-adult spawning escapement goal was established beginning in 1980 (PFMC 1980). A subsequent stock rebuilding schedule, with attendant lowered annual in-river escapement objectives, was established and implemented in 1983 (PFMC 1985) (Figure 1).

The stock rebuilding program that is currently in place, and the 86,000-adult spawner escapement goal that preceded it, were implemented in order to minimize adverse social and economic impacts on the various user groups and those servicing them. However, since implementation of the rebuilding schedule in 1983, adult fall chinook in-river escapements in the Klamath basin have failed to approach even these lowered annual target levels. Successive failures at meeting annual goals led to progressive tightening of ocean and river fishery regulations. These regulation changes culminated in 1985 in a total closure of the ocean commercial salmon fishery between Point Delgada, California, and Cape Blanco, Oregon, and further restrictions on the ocean sport and in-river sport and Indian gill-net fisheries.

The 1978 Klamath River adult spawner escapement goal has, from the onset, been contested. The ocean commercial fishermen have been the most vocal of the various user groups in expressing concerns regarding its appropriateness for the Klamath system as it presently exists.

1/ Prepared September 30, 1985. Presented to the Klamath River Technical Team of the Klamath River Salmon Management Group, Pacific Fishery Management Council, October 9, 1985.

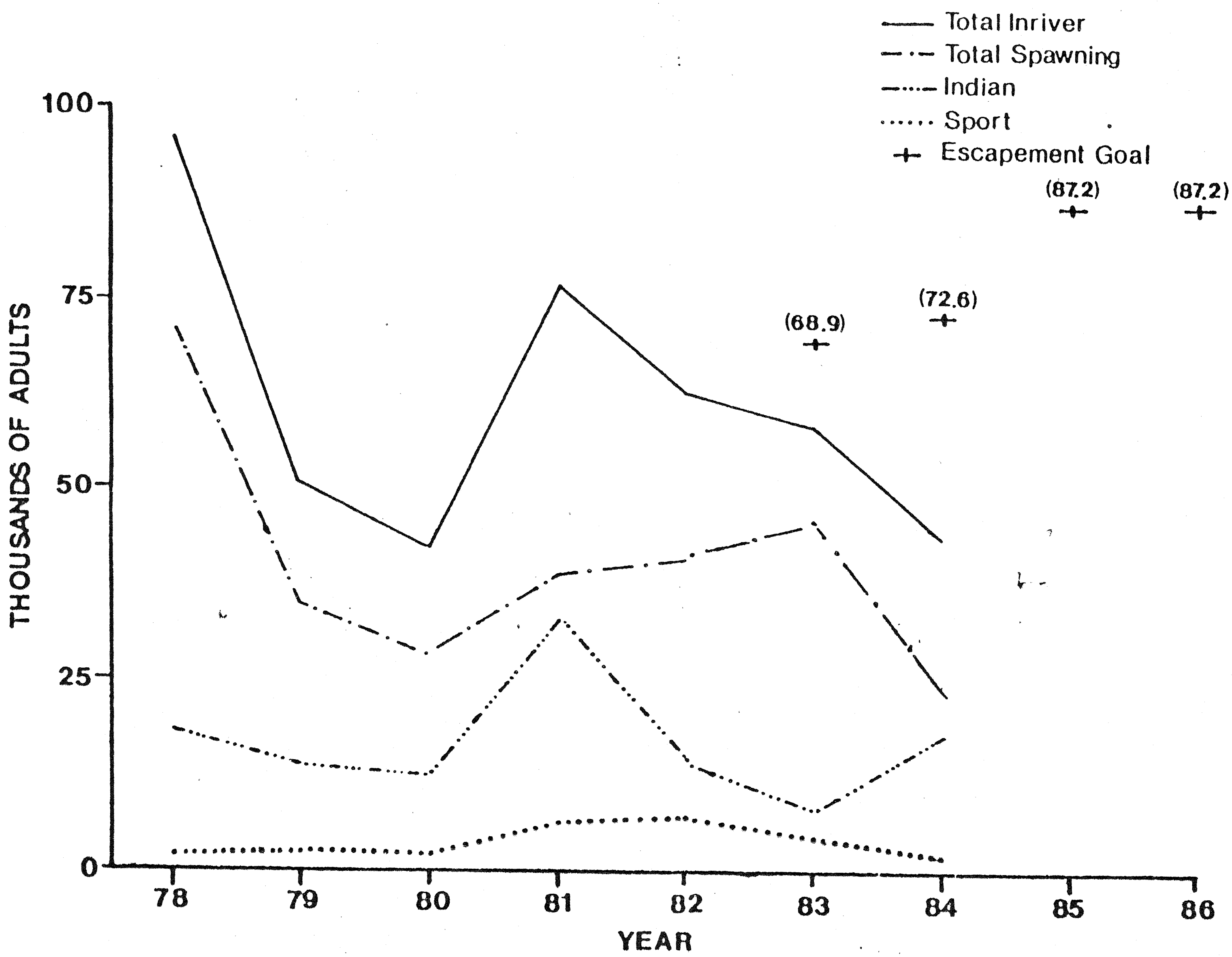

FIGURE 1. Klamath River adult fall-run chinook salmon escapements and inland landings, 1978-1984, including 1983-1986 escapement goals. (From PFMC 1985.)

In 1982, partly in response to concerns expressed by the commercial trollers, a PFMC-sponsored task force reviewed the 115,000 adult goal. Following their review, members of the task force elected not to recommend a change in the goal at that time. However, one of several recommendations the group did put forward called for reevaluation of habitat quantity and quality, spawner success and contributions made by naturally spawning fish in the system, with the intent of adjusting basin spawning escapement goals upward or downward to accommodate existing conditions (Figure 2).

In the seven years since the initial 115,000 adult spawner escapement goal was adopted, CDFG personnel have made annual determinations of the distribution and numbers of fall chinook salmon spawning naturally in the Klamath River system. They have, additionally, made assessments of both the amounts and qualities of spawning habitat occurring in the various parts of the basin, and of the relative use made by fall chinook salmon of the available habitat in those years.

In June 1985, a meeting of CDFG fishery biologists working with chinook salmon in the Klamath River basin was convened in Redding, California. Purpose of the meeting was to pull together all pertinent data regarding current capabilities of the Klamath River basin to produce fall chinook salmon, and to identify, based on existing knowledge, optimum numbers and distributions for adult fall chinook salmon spawners in the system. For purposes here, optimum spawning stock size is defined as that number of adult spawners needed to maximize the Klamath River system's output of seaward migration.

Results of the June meeting are summarized in the following paragraphs.

PROCEDURES

For purposes of discussion during the meeting, the Klamath-Trinity basin below Iron Gate and Lewiston dams was broken into its various components subbasins. In the case of the four major subbasins (Shasta, Scott, Salmon, Trinity), stream systems within each were further broken down and discussed individually. The main stems of the Klamath and Trinity rivers were also segmented and discussed by river section.

Field biologists working in, and most familiar with, the various areas presented and discussed their assessments of the numbers of adult fall chinook salmon needed to achieve optimum spawner escapements in each subbasin or stream reach under current habitat conditions. Estimates were based on currently available data on stream accessibility to fall chinook, spawning and rearing habitat abundance and quality, the area's current and past utilization by fall chinook salmon, and the biologist's personal knowledge of the particular area and of Klamath River fall chinook salmon life history requirements.

Miles of habitat accessible to fall chinook salmon for virtually all streams in the Klamath River basin have been previously determined through field surveys conducted by CDFG and U. S. Forest Service (USFS) fisheries personnel. Much of the information on stream accessibility for fall chinook salmon in the Klamath-Trinity basin has been summarized by CH2M HILL (1985).

FIGURE 2

RECOMMENDATIONS OF KLAMATH RIVER TASK FORCE

November 10, 1982 1/

The Klamath River Task Force does not at this time recommend a change in the long-term Klamath Basin fall chinook escapement goal of 115,000 adults, but recommends:

1. That a plan needs to be presented for meeting the goal specifying yearly escapements of hatchery and natural fish that will continually move toward the goal.

2. That the Council recognize that the state of California, in conjunction with other management authorities and user groups, has the primary responsibility for developing a fully supported escapement and rebuilding program.

3. That distribution of spawners in the system is also important and needs to be monitored, and where necessary, evaluated.

4. That habitat quantity and quality needs to be reevaluated in some areas of the Klamath Basin. Upon evaluation of future data such as habitat quality, spawner success, and contribution of natural spawning stocks, escapement goals could be adjusted up or down.

5. That guaranteed instream flows need to be provided, especially in the Trinity River, to make escapement productive.

The Task Force further recommends that a plan be developed that contains a step-by-step process to achieve an escapement goal that allows for year-to-year contingencies.

1/ Presented to PFMC at its November 17-18, 1982 meeting in Monterey, California.

The problems of the Klamath River are not comparable to the Columbia and analogies should not be made.

The plan should be agreed to by all entities involved (i.e., the management authorities and the represented user groups). The plan should address the problems which have impeded and will impede the attainment of a long-term goal, and should outline the stategies to arrive at that goal. The Pacific Fishery Management Council is responsible for allowing escapement from the ocean but is not responsible for allocating in-river.

*The Klamath River Task Force supports the document "Trinity River Basin Fish and Wildlife Management Program" and the results from the Bureau of Indian Affairs contract will not be available for another 18 months. The Request for Proposal and the Task River Basin reports are in the Council office for reference.

PFMC
11-10-82

CDFG and USFS fishery biologists have conducted habitat surveys and developed recent estimates of total chinook salmon habitat area available in those streams lying within the Klamath National Forest. CDFG Region 1 fishery biologists provided estimates of the percentages of the total available habitat area for each stream that was suitable for spawning, as part of the present spawner escapement assessment. These estimates were based on individuals' knowledge and familiarity with those waters. A comparative data set for the main stem Shasta River was developed for this assessment by CDFG biologists working in that drainage. This data set included estimates of mean stream width, stream mileages, and proportions of available habitat consisting of suitable spawning riffles.

Optimum spawning densities for streams in that part of the Klamath system upstream of the Klamath-Trinity confluence for which spawning habitat estimates were available were calculated based on the following: 1) ideal distribution of females (i.e., no overlap or unused spawning area); 2) each female requiring 100 square feet of spawning gravel; and 3) the male:female ratio for adult spawners being 1:1 (no consideration was given to jacks).

For the South Fork Trinity River (main stem), estimates of available spawning habitat were based on field measurements and observations made during the fall 1984 spawning season. An average redd area of 65 square feet was assigned to each spawning female. Using these and other available data and their knowledge of the river, biologists working on the South Fork Trinity concluded that optimum spawning densities would be realized when about 50% of the available spawning habitat was utilized. As in the upper Klamath, the male:female ratio for adult spawners in the South Fork was assumed to be 1:1.

Optimum spawning densities presented here for many streams and/or stream sections were based on assessments by field biologists of percent utilization by fall chinook of suitable spawning gravels. These assessments were developed for the most part during salmon carcass surveys conducted from 1978 through 1984. However, certain portions of the system have been consistently surveyed for longer periods, some since the early 1960's.

Where data were available, stock-recruitment analyses were used to estimate optimum adult spawner densities. Recruit numbers were estimated based either on juvenile or adult production estimates.

In addition to one or more of the above approaches, historic fall chinook counts were also used in assessing the numbers of spawners currently needed.

In most instances, more than one of the biologists present at the meeting gave an assessment for a particular stream or stream section. As a result, two or more differing estimates were proffered for some areas.

For purposes of this assessment, goals for Trinity River and Iron Gate hatcheries were based on current hatchery capacities for fall chinook salmon as proposed by regional hatchery personnel. It should be noted that the previous high spawning escapements of adult fall chinook were 12,600 at Iron Gate in 1976 and 6,000 at Trinity River in 1978. Regulation of the fisheries to achieve annual spawning escapements of 12,000 adults at both facilities would represent a significant increase in man-power needs and operating costs. The current mitigation goals for adult fall chinook are 8,500 at Iron Gate and 9,000 at Trinity River.

RESULTS

During the June 1985 meeting, CDFG field biologists identified approximately 50 streams in the Klamath River basin below Iron Gate Dam that are currently accessible to and capable of supporting fall chinook salmon spawning (Figures 3-10).

Using the smallest and largest values presented for each area, low and high estimates of 40,610 and 105,850 fall chinook salmon adults, respectively, were identified as necessary to optimize utilization of currently available natural habitat in the Klamath River system below Iron Gate Dam. The number of adults required to fill current capacities at Trinity River and Iron Gate hatcheries was determined to be 12,000 at each facility, 24,000 total. This brings the low and high estimates of the total numbers of adult fall chinook spawners needed to achieve optimum utilization of currently available habitat to 64,610 and 129,850 fish, respectively. A stream-by-stream comparison of these estimates with the 115,000-adult escapement goal developed in November 1978 is presented in Table 1.

DISCUSSION

In reviewing the various estimates generated, it appears that, in general, those based on calculations involving measured redd areas and spawning habitat availability yielded higher spawner numbers than those based on field observations of the percent utilization of available spawning habitat.

When compared with figures for the natural spawning components contained in the November 1978 escapement goal, those from the current assessment display no definite pattern. The range of values generated by the current assessment are considerably lower for the Trinity River basin than the 1978 escapement goal. For the Shasta and Salmon rivers, the 1978 values fall within the ranges generated during the current effort. The 1978 figure for the Scott River is somewhat smaller than the low end of the current range, while for the balance of the Klamath system, the 1978 number was slightly above the upper end of the 1985 range.

The variations in estimates for the different waters are caused by differing methodologies and individual biologist's preferences. This fact is most clearly reflected in the substantial variation in estimates for the main stem Klamath, Salmon and mid-Trinity areas. All three of these areas have received relatively less attention to date than many of the smaller, more accessible streams.

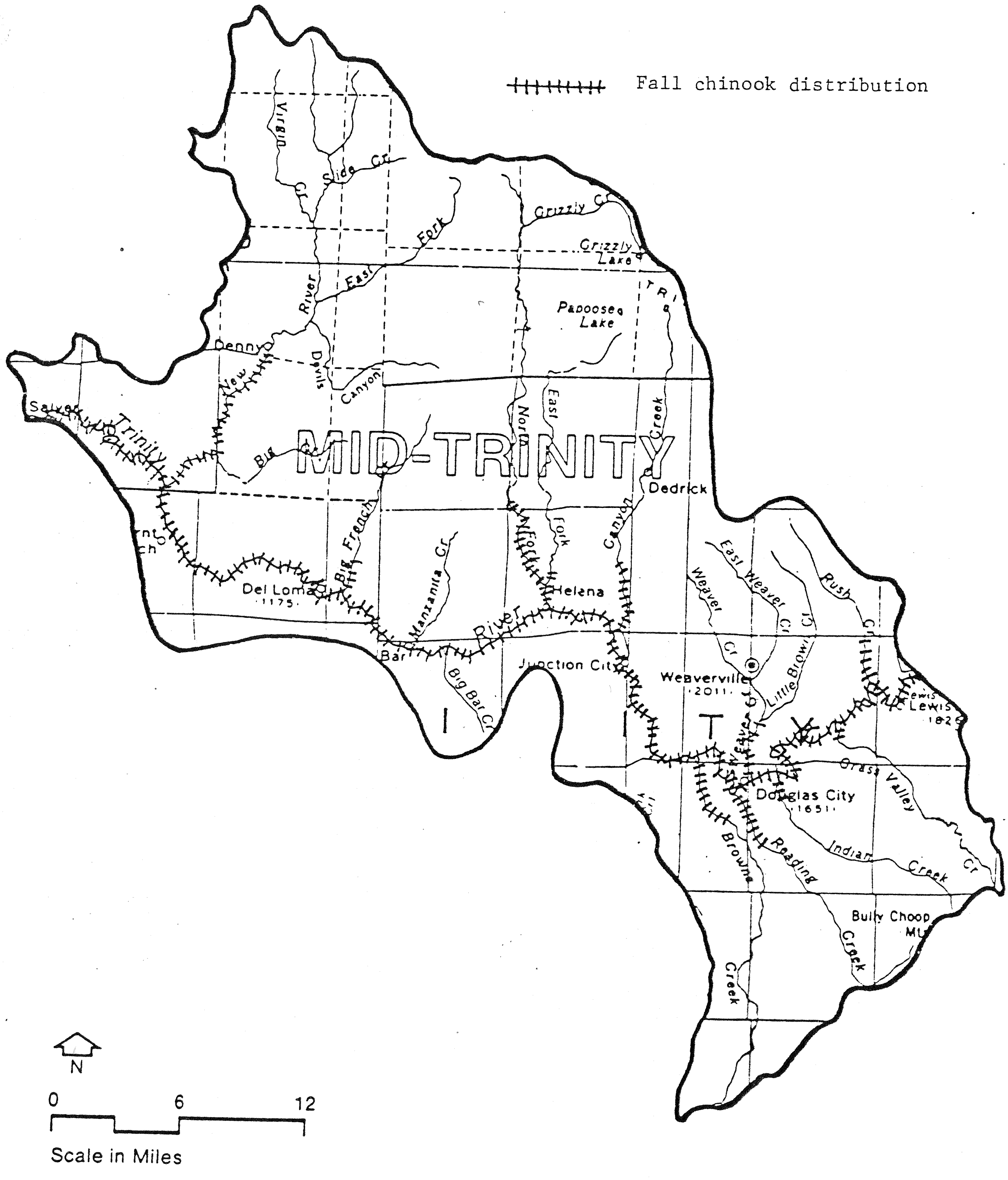

FIGURE 3. Fall chinook salmon distribution in mid-Trinity subbasin (Adapted from CH2M HILL 1985).

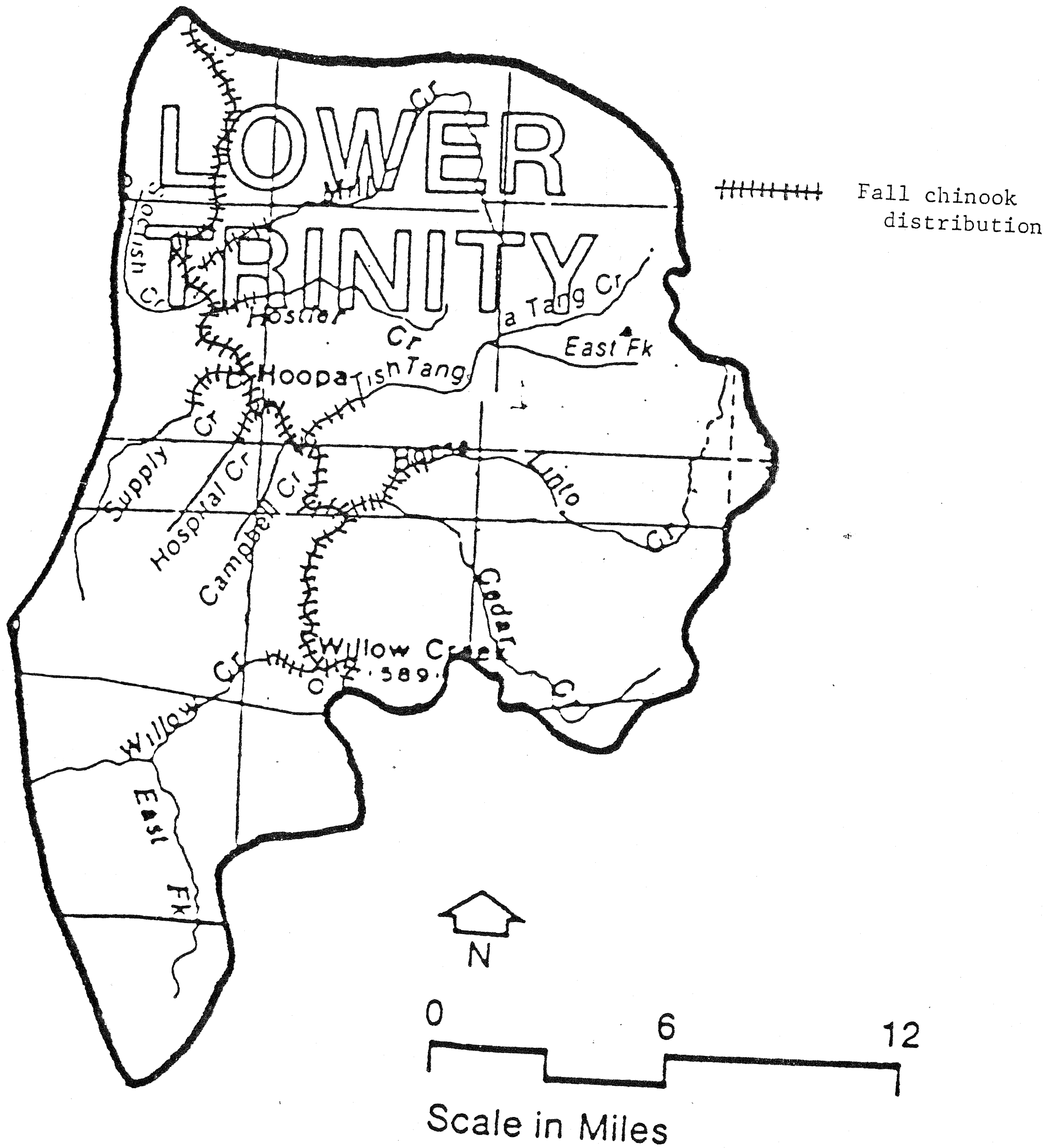

FIGURE 4. Fall chinook salmon distribution in lower Trinity subbasin (Adapted from CH2M HILL 1985).

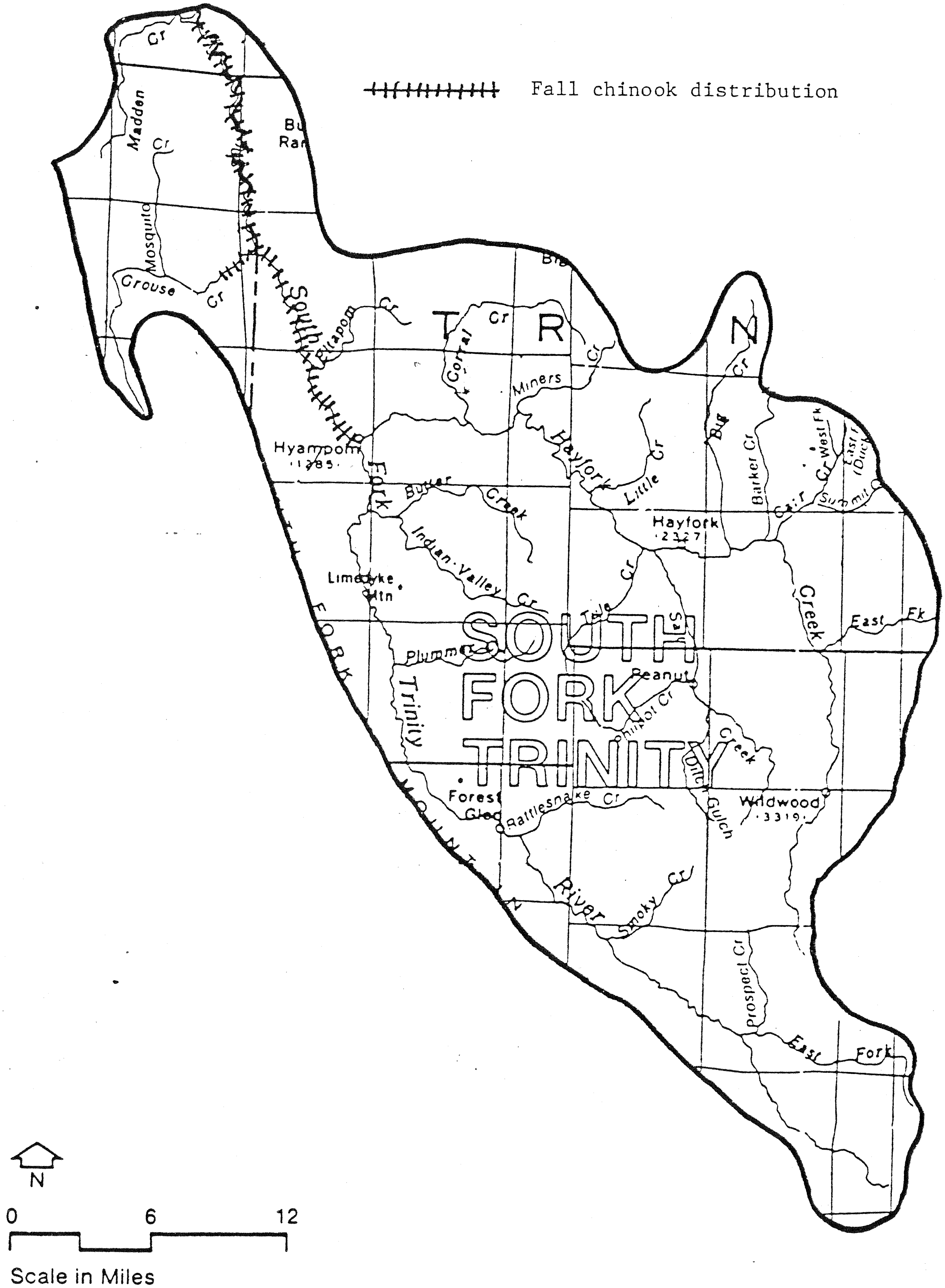

FIGURE 5. Fall chinook salmon distribution in South Fork Trinity River subbasin (Adapted from CH2M HILL 1985).

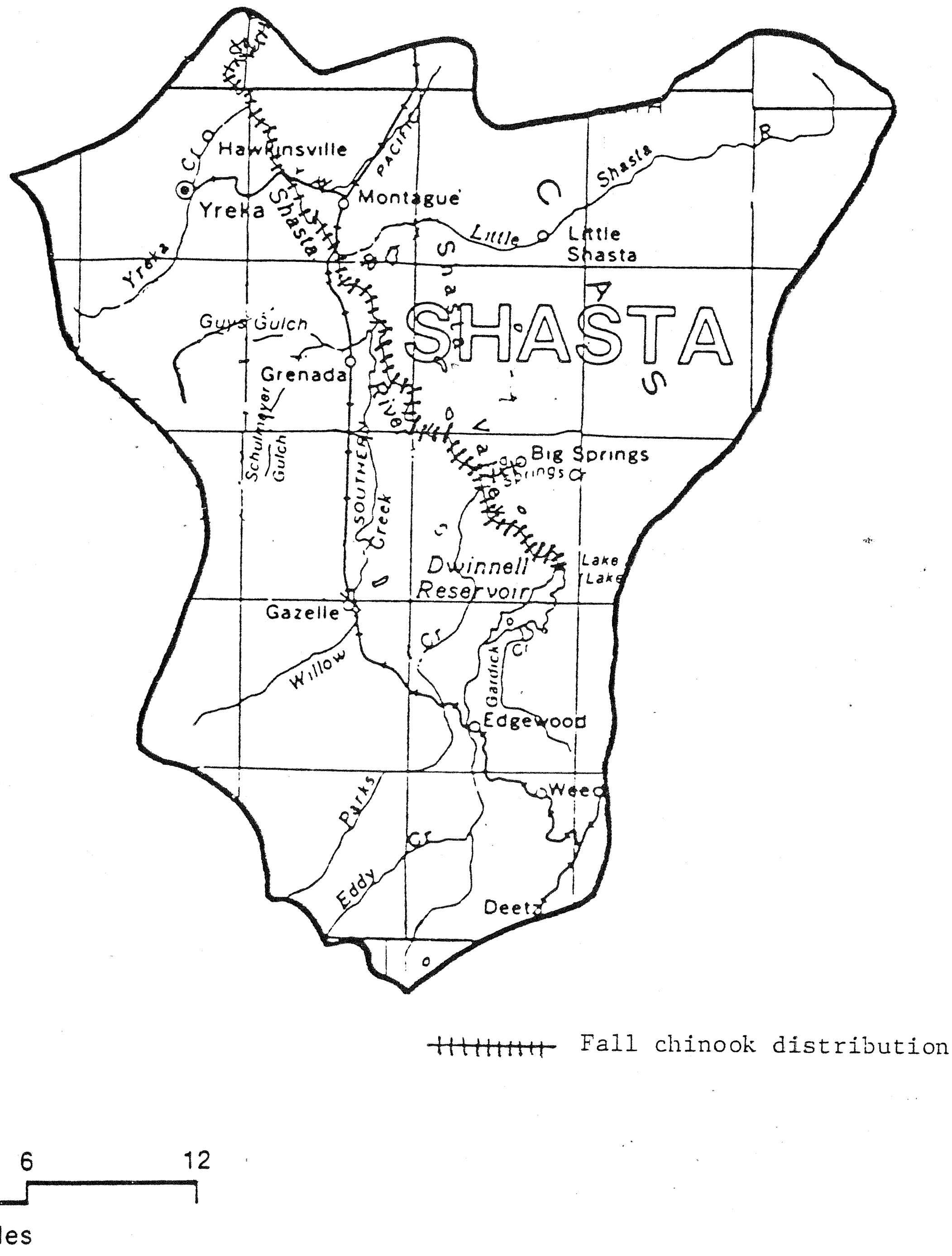

FIGURE 6. Fall chinook salmon distribution in Shasta River subbasin (Adapted from CH2M HILL 1985).

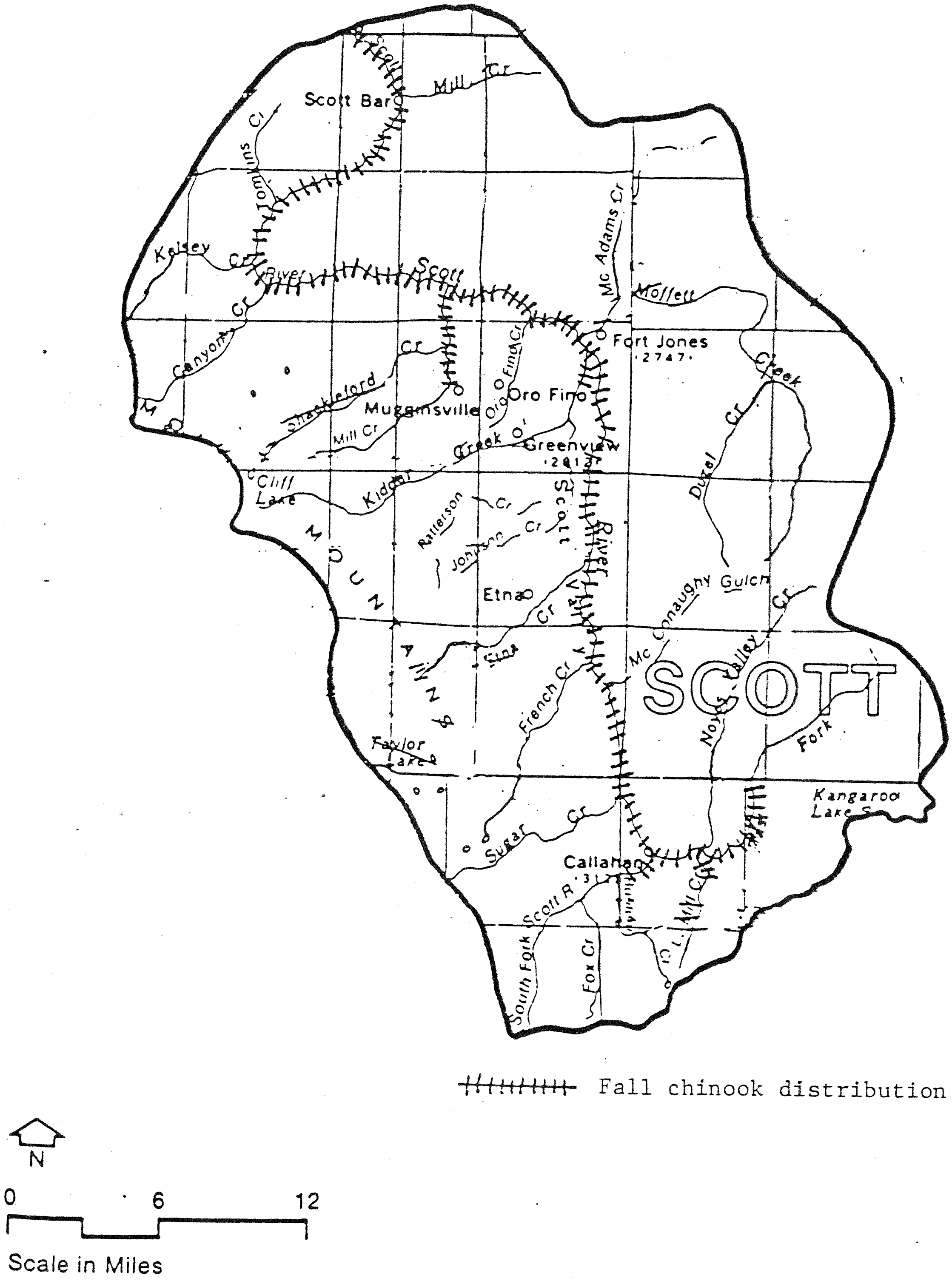

FIGURE 7. Fall chinook salmon distribution in Scott River subbasin (Adapted from CH2M HILL 1985).

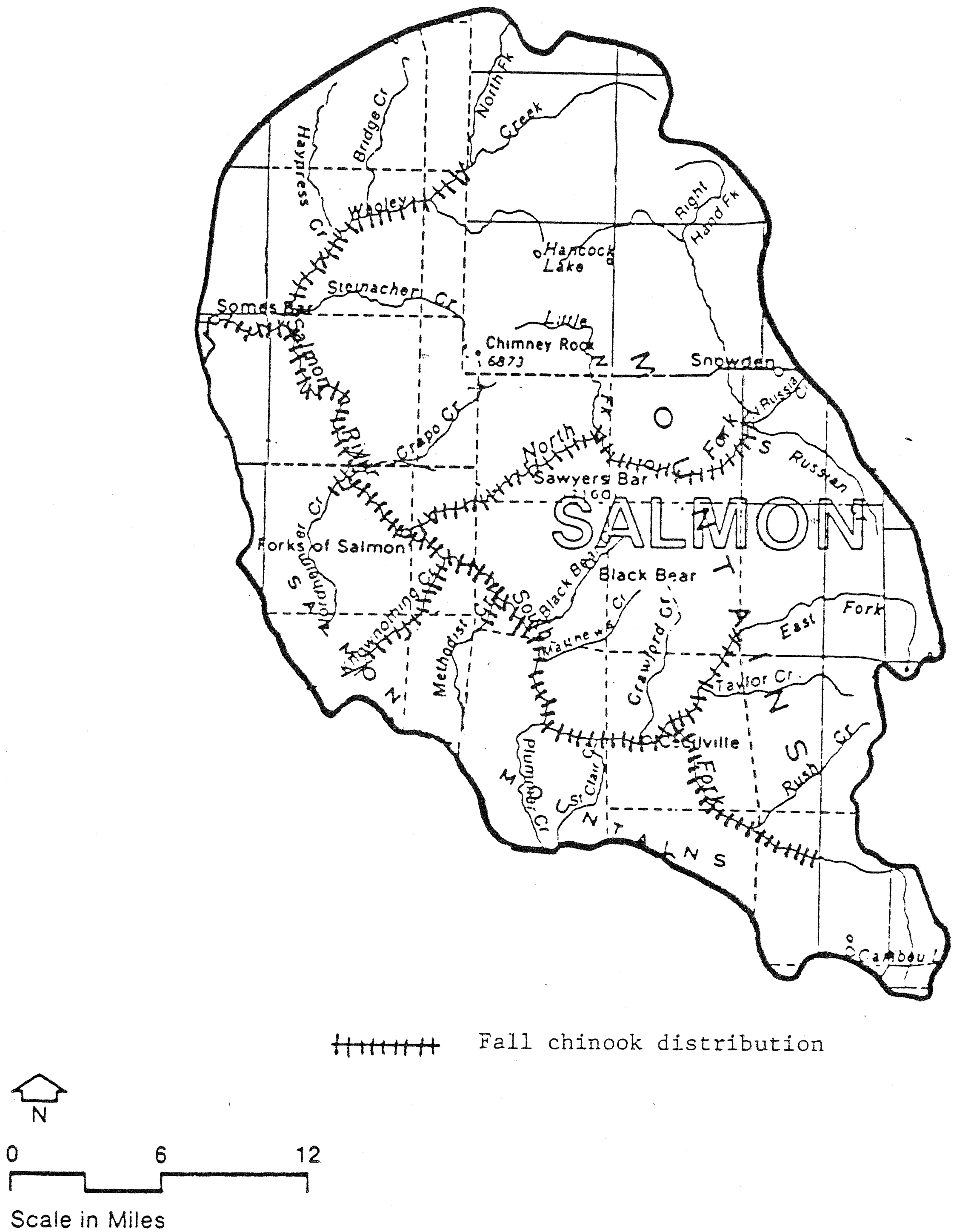

FIGURE 8. Fall chinook salmon distribution in Salmon River subbasin (Adapted from CH2M HILL 1985).

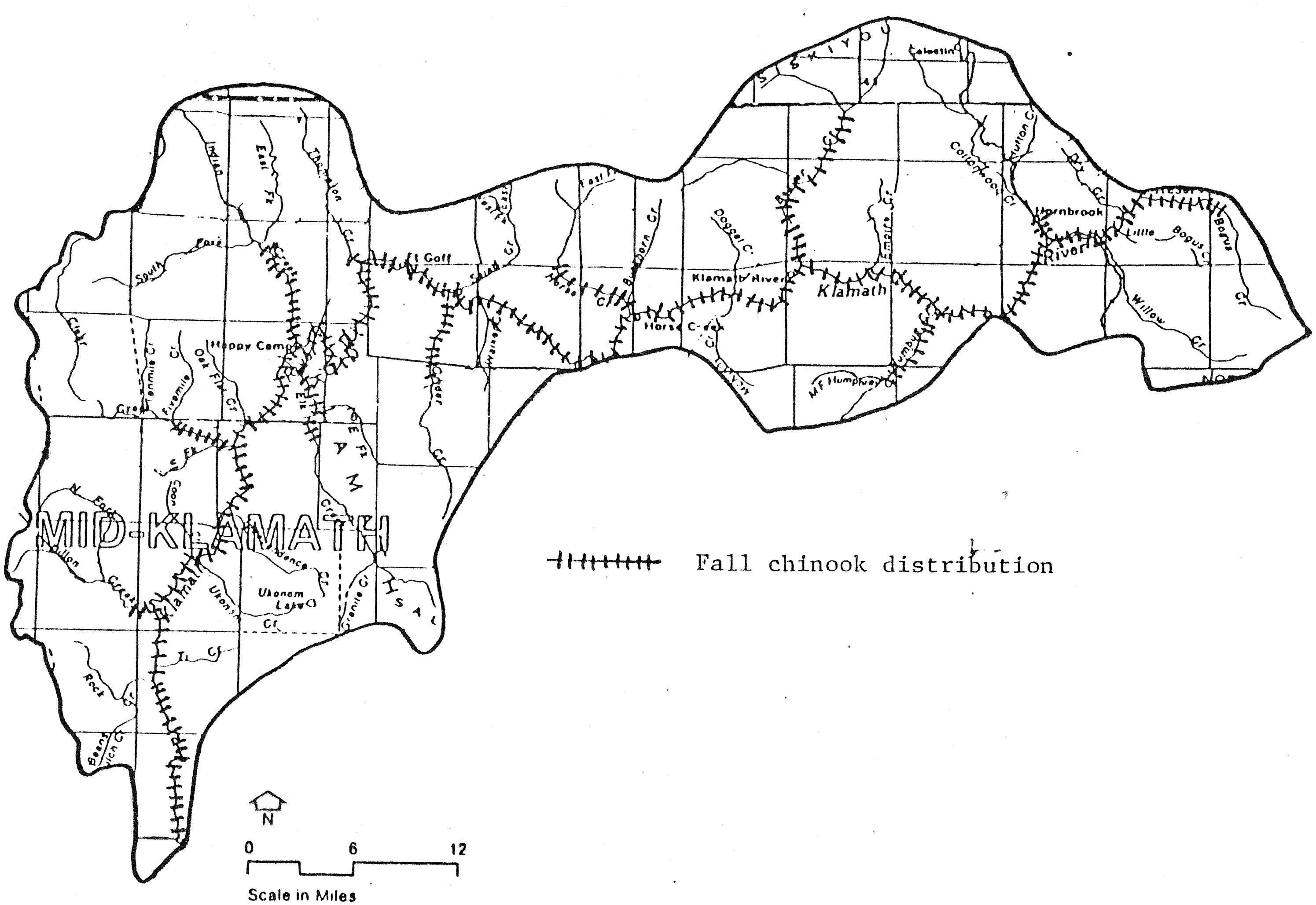

FIGURE 9. Fall chinook salmon distribution in mid-Klamath subbasin (Adapted from CH2M HILL 1985).

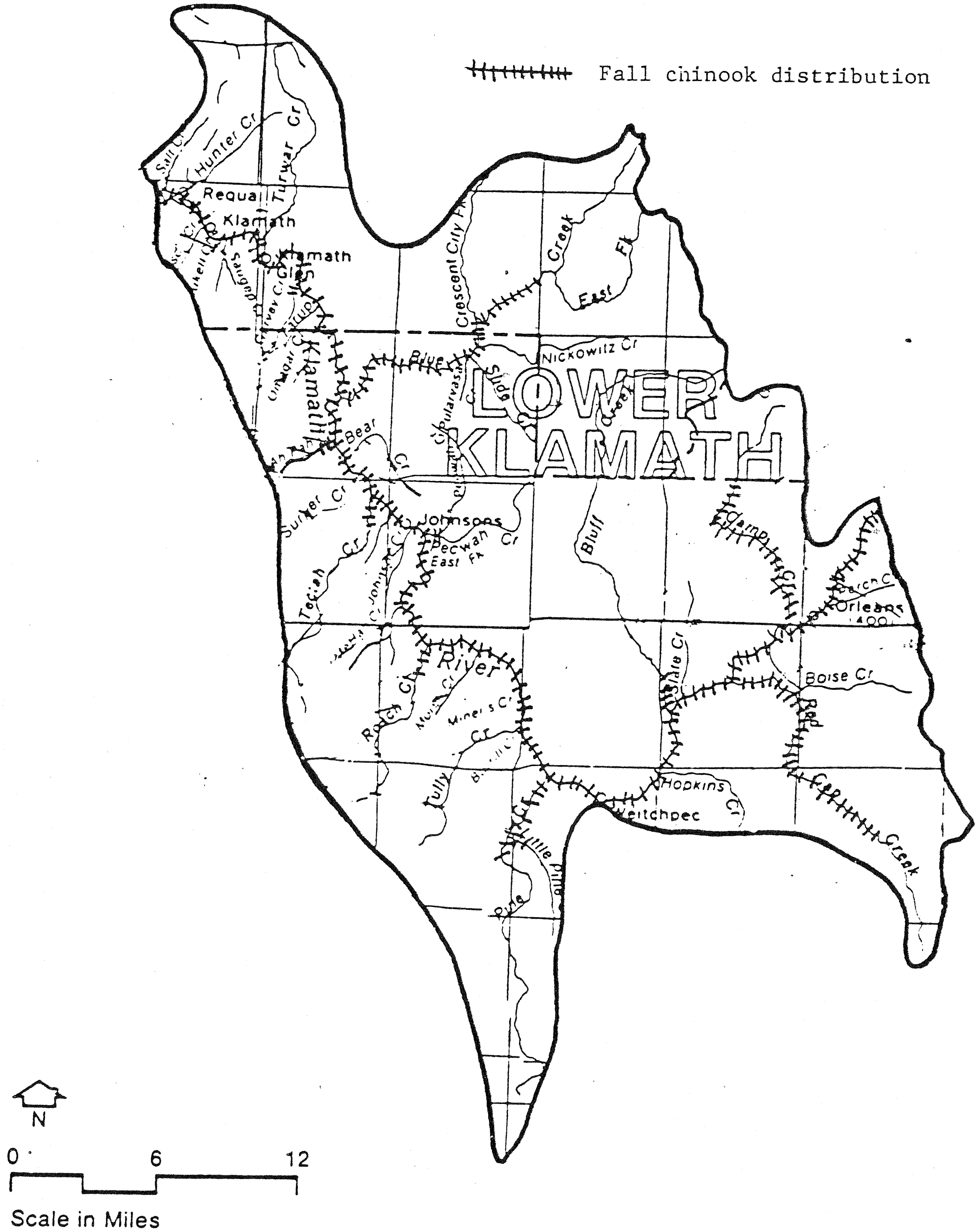

FIGURE 10. Fall chinook salmon distribution in lower Klamath subbasin (Adapted from CH2M HILL 1985).

TABLE 1. Comparison of California Department of Fish and Game November 1973 Adult Spawner Escapement Goal and June 1985 Assessment of Current Optimum Spawning Escapement Levels for Adult Fall-run Chinook Salmon in Klamath River Basin Spawning Areas.

Subunit	Element	Nov. 1978	June 1985 Low	June 1985 High
	NATURAL COMPONENTS			
TRINITY RIVER	Main stem			
	Upper (Lewiston Dam-Douglas City)	NA	3,500(a)	3,500(a)
	Middle (Douglas City-N.F. Trinity R.)	NA	1,000(b)	6,000(b)
	Lower (N.F. Trinity R.-mouth)	NA	2,500(b)	2,500(b)
	Rush Creek	NA	500(b)	1,000(b)
	Reading Creek	NA	40(b)	40(b)
	Browns Creek	NA	50(b)	100(b)
	Canyon Creek	NA	1,000(b)	1,000(b)
	North Fork	NA	1,000(b)	1,000(b)
	Big French Creek	NA	200(b)	200(b)
	New River	NA	7,200(a)	7,200(a)
	Willow Creek	NA	240(a,c)	240(a,c)
	Horse Linto Creek	NA	360(a,c)	360(a,c)
	Hoopa Res. streams in Trinity basin	NA	400(b)	400(b)
	South Fork Trinity River	NA	1,500(a)	1,500(a)
Subtotals - Trinity River		43,341	19,490	25,040
SHASTA RIVER		14,400	5,600(d)	18,220(a)
SCOTT RIVER		5,760	6,000(b)	9,260(a)
SALMON RIVER		6,480	3,000(b)	26,000(a)
BALANCE OF KLAMATH SYSTEM	Main stem (Iron Gate Dam-mouth)	NA	negl(e)	10,000(b)
	Bogus Creek	NA	1,000(f)	3,500(g)
	Willow Creek	NA	negl(b)	negl(b)
	Cottonwood Creek	NA	460(b)	460(b)
	Humbug Creek	NA	100(b)	100(b)
	Beaver Creek	NA	1,000(b)	2,500(a)
	Horse Creek	NA	200(b)	600(a)
	Seiad Creek	NA	negl(b)	negl(b)
	Grider Creek	NA	300(b)	1,120(a)
	Thompson Creek	NA	250(b)	1,390(a)
	Indian Creek	NA	750(b)	2,800(a)
	Elk Creek	NA	100(b)	400(a)
	Clear Creek	NA	250(b)	740(a)
	Dillon Creek	NA	250(b)	920(a)
	Camp Creek	NA	400(b)	800(b)
	Boise Creek	NA	negl(b)	negl(b)
	Red Cap Creek	NA	260(a,c)	800(b)
	Bluff Creek	NA	200(b)	200(b)
	Blue Creek	NA	1,000(a)	1,000(a)
Subtotals - Balance of Klamath system		27,500	6,520	27,330
TOTAL - NATURAL COMPONENTS		97,481 (rounded to 97,500)	40,610	105,850
	HATCHERY COMPONENTS			
Trinity River Hatchery		9,000	12,000(h)	12,000(h)
Iron Gate Hatchery		8,500	12,000(h)	12,000(h)
TOTAL - HATCHERY COMPONENTS		17,500	24,000	24,000
GRAND TOTALS		114,981 (rounded to 115,000)	64,610	129,850

(a) Based on redds per unit of available spawning area.
(b) Based on field observations of percent utilization of available spawning habitat.
(c) U.S. Forest Service estimate.
(d) Based on stock recruitment analysis (L.B. Boydstun, unpublished manuscript).
(e) Based on Klamath and Shasta rivers spawning gravel enhancement study (Calif. Dept. Wat. Res. 1981. 178 p.).
(f) Based on two years of egg-to-fry survival estimates.
(g) Based on historic counts.
(h) Current hatchery capacity.

These varied results point up the dilemma faced by the CDFG in deciding on a single escapement goal--for Klamath River fall chinook there is little or no agreement on a preferred number.

At best the data provided by the current assessment afford a basis for setting an escapement goal range, or perhaps, the basis for setting a minimum (floor) escapement, below which no fishing would occur.

It is recognized that the preferred approach for setting a spawner escapement goal for Klamath River fall chinook salmon would be through stock recruitment analyses. However, the lack of a comprehensive data base makes it presently impossible to use this approach for the basin population as a whole, or for most of its component stocks. A wide range of spawning escapements is needed in order to develop a comprehensive stock-recruitment model for Klamath River basin fall chinook salmon. Sampling programs needed to estimate annual spawning escapements of these fish and their recruits are currently ongoing in the basin. To permit eventual modeling of the population, it is imperative that these programs continue. In the interim, alternative fishery management strategies should be explored.

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Appendix III. Description of Klamath River Harvest Rate Model

An age-structured stock-recruitment model was constructed to evaluate long-term impacts of ocean and river harvest rate combinations on landings of naturally produced Klamath River chinook. The Ricker function was used to estimate year-class production (recruits) from estimated spawning escapements of adult (age 3 and older) fish. Fishery impacts on a cohort of salmon were estimated based on assumptions about basic life history characteristics of the fish and selectivities of the fisheries acting upon them. The model is classed as a Type 1 fishery model whereby natural mortality occurs between fishing season (Ricker 1975). Klamath River chinook salmon mature at ages 2 through 5. Ocean fisheries first impact the resource when the fish reach age 2, but generally do not land them until the fish reach age 3 (due to minimum size limit restrictions). Mixed fishery management of chinook salmon stocks is complicated because offshore fisheries simultaneously impact up to four spawning escapements of fish while in-river fisheries impact one escapement per year. Terminal area management is also complicated by size selectivity of the fishing gear. Both ocean and terminal area fisheries have related non-catch losses of fish (e.g. shaker mortality, seal depredation, etc.). The Klamath River harvest rate model takes these factors into account to generate estimates of mixed fishery impacts over a protracted period of years under various combination of continuous ocean and river harvest rates.

Model Construction

Recruitment is defined as the number of age 2 fish alive prior to fishing and is calculated following the Ricker model:

$$R = a P \exp(-bP)$$

where $R = A_2$ = Number of age 2 recruits

a (alpha) = a coefficient that reflects stock productivity

P = the number of parent spawners (ages 3-5)

b (beta) = a coefficient that reflects the carrying capacity of the environment for adult spawners

Fish belonging to a cohort (recruited at age 2) that survive to subsequent years are calculated based on age 2 recruits ($R=A_2$) by

$$A_{i+1} = [A_i - (T_i + S_i + G_i + D_i + E_i)]\ (1 - m_i);\ i=2,\ 3,\ 4,$$

where

A_i = Number of age i fish alive prior to the fishing season,

T_i = Offshore landings of age i fish,

S_i = Offshore shaker deaths at age i,

G_i = In-river (terminal) landings of age i fish,

D_i = Terminal fishery drop-offs (seal losses, etc.) at age i,

E_i = Spawning escapement of age i fish,

m_i = Ocean natural mortality rate between fishing seasons from age i to i+1.

Fish landings, non-catch mortalities, and spawning escapement (all measured as numbers of fish) are calculated using the following formulas:

$$T_i = u_t \cdot A_i \cdot r_i \cdot p_i,$$

$$S_i = s_i \cdot A_i \cdot r_i \cdot (1 - p_i),$$

$$G_i = u_r \cdot q_i \cdot g_i \cdot (A_i - T_i - S_i)\ (1 - d_i),$$

$$D_i = d_i \cdot u_r \cdot q_i \cdot g_i\ (A_i - T_i - S_i),$$

$$E_i = [q_i \cdot (R_i - T_i - S_i)] - G_i - D_i.$$

Definitions for additional parameters used in the above formulas are:

r_i = Offshore fishery contact rate at age i relative to fully vulnerable age 4 and 5 fish,

p_i = Fraction of contacted ocean fish that are legal size at age i,

s_i = Fraction of contacted ocean sublegal fish that suffer shaker mortality at age i,

q_i = Maturity rate at age i,

g_i = In-river (terminal) contact rate relative to fully vulnerable (age 4 and 5) fish,

d_i = In-river drop-off rate for age i fish,

u_t = Offshore exploitation rate for fully vulnerable (age 4 and 5) fish,

u_r = Terminal fishery exploitation rate for fully vulnerable (age 4 and 5) fish.

Model-based calculations sum landings, non-catch mortalities and escapement across cohorts alive in the same years. Escapement in year t was used to generate age 2 recruits in year t+2, and so on, until the stock and fisheries reached rough equilibrium after about 40 years. (Exact analytic expressions for calculating equilibrium landings, mortalities and spawning escapement are also available). The following section describes methods used to arrive at estimates of the above parameters that appear appropriate for Klamath River chinook salmon.

The model output used to develop the harvest rate option is appended as Attachment 1.

Parameter Estimates

Alpha. The Ricker alpha parameter may be interpreted as the recruits produced per adult spawner at extremely low stock sizes. For small stock sizes (relative to stock size at unexploited equilibrium), in fact, recruitment should increase linearly with stock size according to the magnitude of alpha. The Ricker alpha parameter is thus a measure of a chinook stock's underlying productivity and determines harvest rates that produce maximum yield and that would result in stock collapse (Hankin and Healey MS).

The conventional approach to estimating an alpha parameter for a salmon stock consists of log-log fit of recruits/spawner against parent stock size. This procedure is prone to many errors. However, the most serious problem in analyzing data from a heavily exploited population comprised of several contributing stocks stems from dominance in the data of the more productive spawning units. This should be a major concern for Klamath chinook because the stock has been heavily fished. Under reduced harvest rate a lower alpha parameter would be expected for the Klamath owing to greater representation of the less productive units.

We explored two approaches to selecting alpha for use with Klamath River chinook:

(1) Analysis of existing data for Klamath stock which relates recruits to parents.

(2) Search the fisheries literature for other estimates of alpha for chinook stocks and assume that Klamath chinook have a similar alpha.

Klamath River Data. Table III-1 shows that the maximum recruits/spawner ratio of the Klamath chinook as a whole since 1978 has been 4.66 (measuring recruits as age 3 fish prior to ocean fishing). This value may be converted to an approximation of alpha at age 2 by accounting for mortality from age 2 to age 3 (assumed equal to 50 percent) and maturation at age 2 (assumed equal to 7 percent). These adjustments give an approximation of alpha = 4.66/(0.5(1-0.07)) = 10.02. In reality, stock size has probably not been so low as to create a linear relation between parents and recruits. Thus, this approximation is probably too low even for natural spawners.

Many hatchery fish were present in the Klamath River runs during 1978-1982 (Table III-2). The recruits from the 1979

TABLE III-1. Klamath River Fall Chinook Salmon Recruits per Spawner Estimates, 1978-1982 Brood Years in Numbers of fish[a/]

Brood year	Adult spawning escapement	Back calculated age three recruitment	Recruits per spawner
1978	71,451	218,200	3.05
1979	34,273	159,800	4.66
1980	27,994	114,600	4.09
1981	38,282	68,100	1.78
1982	40,528	56,500[b/]	1.39
Averages	42,506	162,280	2.99

a/ Revised from PFMC 1985 based on final exploitation rate estimates.
b/ Projected.

TABLE III-2. Estimated Hatchery Contribution to Klamath River Fall Chinook Salmon Runs, 1978-1984

Return year	Reported escapement		Adjusted escapement[1/]		Percent Hatchery	
	Hatchery	Wild	Hatchery	Wild	Reported	Adjusted
1978	13,000	58,500	19,000	52,500	18.2	26.6
1979	3,600	30,600	4,900	29,300	10.5	14.3
1980	6,500	21,500	10,600	17,400	23.2	37.9
1981	4,400	33,900	6,800	31,500	11.5	17.8
1982	10,400	30,100	12,500	28,000	25.7	30.9
1983	14,100	31,500	19,900	25,700	30.9	43.6
1984	7,200	15,400	9,100	13,500	31.9	40.3

1/ Table assumes 50% of Trinity River Hatchery fish spawned in the wild (CDFG data).

escapement, which had the highest recruits/spawner ratio on record, returned to spawn in 1982 and 1983 as ages 3 and 4 fish, respectively. In these return years, the hatchery component was higher than most of the years on record. Thus the recruits/spawner ratio for the 1979 brood was probably bolstered by a large hatchery component.

Recruits/spawner estimates have been calculated for Klamath River hatchery releases (Table III-3). Weighted means (for fingerling and yearling releases) were 18.2 for Iron Gate Hatchery and 17.3 for Trinity River Hatchery. Considerable variation exist in the component estimates (2.7/1 to 79.1/1), but the data do serve to indicate that hatchery fish "alpha" data are substantially above 10 recruits per spawner.

An alpha estimate for age 2+ recruits of 13.6 for Shasta River chinook of the 1957-1982 broods has been developed by L.B. Boydstun of the CDFG. The Shasta River is the second-most important natural spawning unit in the Klamath basin behind the mainstem Trinity River. Annual escapement counts are available for the Shasta River most years since 1930. In this analysis (Ricker Method) recruits are estimated based on Shasta River grilse (jack) returns to the Klamath River mouth coupled with an assumed age 2 maturity rate (0.125). The alpha estimate represents ocean population size at the end of ocean year 2 (age

TABLE III-3. Klamath River Hatchery Survival Rate and Recruits/Spawner Estimates

	Iron Gate		Trinity River	
Hatchery data (1971-81)				
Number of Females trapped	3,693(59% of adults)		1,278(47% of adults)	
Females spawned	3,291(89%)		1,174(92%)	
Average eggs/year	10,136,00(3,080 ea.)		3,240,000(2,560 ea.)	
Fish released (average)				
Fingerlings	4,376,000		1,210,000	
Yearlings	429,000(90%)[a]		688,000(.90)[a]	
Fingerling estimate	4,853,700		1,974,444	
Age 2 Survival Estimates (%)[1]				
	Mean	Range	Mean	Range
Fingerlings	2.00	(1.09-2.91)	1.62	(0.40-5.37)
Yearlings	6.63	(3.35-11.31)	4.70	(1.75-6.14)
Recruits/Spawner Estimates				
	Mean	Range	Mean	Range
Fingerlings	15.5	(8.5-22.6)	10.9	(2.7-36.3)
Yearlings	46.3	(23.4-79.1)	28.6	(10.6-37.3)
Weighted averages	18.2	-	17.3	-

1/ From Hankin (1985), Appendix B5.
a/ Estimated percent survival from fingerling stage.

2+ on about September 1). Ocean population size at the beginning of the fishing season (about May 1) was probably about 26 percent higher assuming an average monthly mortality rate of about 0.056 (50 percent on an annual basis). Thus this study would indicate an adjusted alpha for age 2 Shasta River chinook of about 17.

Statistical analysis of the Shasta River data indicated a very poor fit between recruits and spawners. Analysis of various environmental indicators did not substantially improve the relationship (Attachment 2). Thus the Shasta River data should be used with caution.

The Shasta River counts for the periods 1955-1964 and 1965-1975 have also been analyzed by Reisenbichler (MS). His approach differed in that the adult returns were separated as to brood year based on assumptions about age composition of the spawning escapements. Fishery contribution estimates were based on assumptions about fishery exploitation rates. Recruits were defined as fishery deaths (adjusted for shaker losses) plus spawning escapement. Thus the alpha parameter in this analysis (16.0 overall) is not age specific. Assuming the average age of fish in the catch and escapement was 3.0, study results would indicate an alpha at age 2 for the Shasta River of about 34 (adjusting for age 2 to 3 natural mortality rate, 0.50, and age 2 maturity rate 0.07). Klamath River hatchery data do not support an age 2 alpha estimate for natural stocks of over about 15. Thus, results from the study do not appear to be applicable to current management considerations for Klamath chinook.

Fisheries Literature

Our review of the fisheries literature revealed that all previous Ricker-type stock recruitment analyses for chinook salmon measured recruits as the sum of fishery landings and escapements. None of the studies was age-specific for alpha. The range in estimates was from 6.4 to 26.4, averaging 12.6 (Table III-4). Assuming these are estimates for age 3.0 recruits, adjusted alpha estimates for age 2 recruits range from about 13 to 53 averaging 25.

Based on Klamath River hatchery data, these alpha estimates appear to be too high for naturally spawning Klamath River chinook.

For modeling purposes we have set alpha for age 2 natural stocks from the Klamath basin at 14.0. Our selection was heavily weighted by available data for Klamath River chinook.

Beta. The beta parameter is a coefficient of capacity of the environment for adult spawners. There is a wide range in

TABLE III-4. Summary of Ricker Alpha Parameter Estimates from Pacific Coast Chinook SAlmon Stock Recruitment Studies

River stock	Reference	Broods	Alpha Estimate	Alpha Ages	Basis for Recruits
Shasta River	1) L.B. Boydstun CDFG, pers. comm.	1957-1982	13.6	2+	Jack returns/assumed maturity rate
	2) Reisenbichler 1980 a)	1955-1964	12.4	All	Catch plus escapement
	b)	1965-1975	20.5	All	Catch plus escapement
Upper Sacramento	Reisenbichler 1980	1950-1975	13.4 a/	All	Catch plus escapement
Feather River	Reisenbichler 1980	1953-1966	10.7	All	Catch plus escapement
American River	Reisenbichler 1980	1945-1955	12.4	All	Catch plus escapement
San Joaquin River	Reisenbichler 1980	1948-1962	14.4	All	Catch plus escapement
South Fork Eel	Reisenbichler 1980	1949-1971	8.9	All	Catch plus escapement
British Columbia (Total)	Healey 1982	1951-1976	7.4 b/	All	Catch plus escapement
Columbia River	Van Hyning 1973	1938-1946	26.4	All	River catch plus escapement
		1947-1959	6.4	All	River catch plus escapement
Rogue River (Springs)	Steve Cramer ODFW, pers. comm.	1960-1979	13.1	All	Catch plus escapement

a/ Mean for four periods of analysis.
b/ Based on discussion in report.

opinion about the capacity of the Klamath basin for adult chinook. Under harvest rate management, beta is unimportant except to develop comparative estimates of offshore and in-river fishery impacts.

Age-Specific Parameter Estimates for Klamath

Age-Specific parameter estimates for Klamath River fall-run chinook and the fisheries acting upon them are described in this section.

(1) Offshore contact rates. Exploitation rates for CWT Klamath River hatchery chinook indicate age 4 fish are more vulnerable to ocean fisheries than age 3, and that age 3 fish are more vulnerable than age 2 fish. Ocean commercial fishery data for Klamath River hatchery CWT chinook that had been released as fingerlings were 80% vulnerable at age 3 to being landed in the troll fishery with its 26-inch minimum size limit (see below). Adjusting the age 3 data for shakers indicates age 3 fish are contacted at 88 percent the rate of age 4 fish. The age 2 contact rate is set at 40% that of the age 4 rate based on troll fishery logbook data (1:1 shaker to legal ratio) and an assumed ocean age structure for a heavily fished chinook population. CWT

data are lacking for age 5 chinook. The rate for this age class has been assumed to be the same as the age 4 rate.

(2) Percent Legal in Offshore Fisheries. These estimates are based on troll fishery data assuming the troll fishery will have the major offshore impact. The minimum size limit in that fishery is assumed to continue to be 26 inches in total length (23.6 inches, 60 cm in fork length). CWT data for Klamath River hatchery chinook released as fingerlings were used to develop these estimates.

Troll and sport landings in northern California and southern Oregon rarely include age 2 fish so the percent legal for age 2 fish was set at 0.10. The troll fishery generally does not land age 2 fish because of their small size. The sport fishery lands very few because of overall low impact on all ages of fish and general unavailability of age 2 fish in the major Klamath River chinook sport fishing area. Length frequency data for ages 3 and 4 fish in the troll fishery have previously been reported (PFMC 1983). They indicated age 4 fish are essentially fully vulnerable to being landed while age 3 fish are generally between 26 and 28 inches in total length. Length frequency analysis of CWT recovery data for Klamath River hatchery chinook of the 1977-79 broods indicated the modal lengths of these fish were well above the minimum size limit. Assuming the modes of these groups (determined by smoothing) also represented group medians, the estimated percent legal at age 3 appeared to be about 70 percent in May and 90 percent each in July and August. An intermediate value of 0.80 is used in the model for age 3 fish. Ages 4 and 5 fish are all assumed to be legal size.

(3) Shaker mortality rate. Probability of death from being caught and released in offshore fisheries due to small size is set at 0.30. This value is in coastwide use and is based on a review by Wright (1972).

(4) Maturity rate. The assumed maturity schedule for Klamath River fall-run chinook is as follows: Age 2, 7%; age 3, 43%; age 4, 89%; age 5, 100 percent. Age 2 maturity rate was based on a cohort analysis using in-river age composition estimates (Tables III-5 and III-6). Maturity estimates for older age classes were based on additional considerations.

TABLE III-5. Ocean Fishery Impact Estimates for Klamath River Fall Chinook of the 1976-1980 Broods (in thousands of fish)

Brood year	Inriver 2's	Age 3 Ocean Impact(T3)	Age 3 Inriver(E3)	Age 4 Ocean Impact(T4)	Age 4 Inriver(E4)	Age 5 Ocean Impact(T5)	Age 5 Inriver(E5)
1976	22.5	68.1(.39) 1/	19.9	49.9(.70) 2/	14.9	2.0(.56) 3/	1.6
1977	8.7	59.5(.45)	13.9	26.3(.56)	12.6	3.6(.56)	2.8
1978	45.2	112.7(.40)	56.3	51.4(.56)	35.7	1.6(.64)	0.9
1979	34.6	124.7(.54)	31.6	38.2(.64)	19.4	0.7(.41)	1.0
1980	28.7	46.5(.32)	33.5	18.6(.41)	23.5	0.5(.20) 4/	2.1 5/

1/ Exploitation rate (u_3) from CWT analysis (Handin 1985) increased by 7½% to account for shaker losses.
2/ Exploitation rate (u_4) from CWT analysis (Hankin 1985).
3/ Exploitation rate (u_5) assumed same as age 4 fish.
4/ Assumed ½ of 1980 exploitation rate.
5/ 9% of age 4 based on 1976-79 brood year average.

Formulas:

$T_5 = (E_5/1-e_5)e_5$

$A_4 = (T_5+E_5/0.80)+E_4$

$T_4 = (A_4/1-e_4)e_4$

$A_3 = (T_4+A_4/0.80)E_3$

$T_3 = (A_3/1-e_3)e_3$

$A_2 = (T_3+A_3/0.50)+E_2$

Table III-6. Maturity rate estimates for Klamath River fall chinook of the 1976-1980 broods based on in-river age composition of ocean fishery impact estimates (in thousands of fish).

Brood Year	Age 2 Alive[1/] (A_2)	Age 2 Mature (q_2)	Age 3 Alive[1/] (A_3)	Age 3 Mature (q_3)	Age 4 Alive[1/] (A_4)	Age 4 Mature (q_4)
1976	371.7	0.06	106.5	0.19	19.4	0.77
1977	140.9	0.06	72.7	0.19	20.7	0.61
1978	608.8	0.07	169.1	0.33	38.8	0.92
1979	496.4	0.07	106.2	0.30	21.5	0.90
1980	302.3	0.09	90.3	0.37	26.8	0.88
Averages		0.07		0.28		0.82

1/ Alive at the end of the ocean fishing season (August 31).

Formulas:

See Table III-5 for E_i and A_i

$q_i = E_i/A_i$

Maturity rates for Klamath River hatchery chinook of the 1977-1980 broods that had been released as fingerlings averaged 0.57 at age 3, 0.96 at age 4 and 1.00 at age 5. These are unweighted averages for the two basin hatchery stocks, Trinity River and Iron Gate. Respective hatchery averages were for Trinity River Hatchery (seven groups): 0.61 at age 3, 0.96 at age 4 and 1.00 at age 5. For Iron Gate returns (two groups) the averages were 0.52 for age 3, 0.96 for age 4 and 1.00 for age 5 (Hankin 1985).

Cohort analysis based on in-river age composition estimates indicated high maturity rates at ages 4 and 5 (0.82 and 1.00, respectively) (Table III-5 and III-6) but a much lower rate at age 3 (0.28) compared to the hatchery CWT data. There are several possible explanations for this difference including (i) faster growth rate of the hatchery fish resulting in earlier age at maturity, or (ii) genetic differences between hatchery and natural stocks.

Our estimates of maturity probability for ages 3 and 4 chinook are intermediate to those indicated from cohort analysis and hatchery CWT data. The age 3 rate also agrees very closely with maturity samples taken at sea off Eureka in the late 1970's (Joe Lesh, CDFG, pers. comm.).

(5) Terminal Fishery Contact Rates. The major in-river user is the gillnet fishery on the Hoopa Valley Indian Reservation. Estimates for terminal fishery contact rates relate to age-specific vulnerability of the fish being caught in the gillnet fishery. Because of net mesh size preferences, the fishery targets on ages 4 and 5 fish. These ages are assumed in the model to be 100 percent vulnerable to capture. Because of their smaller size, the relative vulnerability of ages 2 and 3 fish are set at 0.00 and 0.66, respectively. These values are based on FWS analysis of gillnet fishery data compared to ocean escapement age structure estimates.

(6) Terminal Fishery Noncatch Mortality. In the terminal fisheries, noncatch mortality occurs through pinniped interactions (depredation), through the unmeshing of salmon previously caught in gillnets, and through sport caught fish which escape landing (or are released) and subsequently die. The model assumes for each age class that a total of 6 percent of all salmon impacted by

(killed in) the terminal fisheries does not appear in landings estimates. The 6 percent value comes from estimated 8 and 2 percent noncatch mortality rates in the terminal net and sport fisheries, respectively, and an assumed 75:25 split of harvest between these two fisheries. Derivation of the 8 and 2 percent values follows:

Net Fishery

Pinniped depredation with the net fishery has been observed by CDFG (Herder 1983) and the U.S. FWS (1981, 1982, 1983, 1984, 1985). These studies concluded that while some pinniped damage to netted fish is minor (these fish are kept for consumption and included in harvest estimates), additional fish are either too badly damaged and discarded by fishermen or totally removed and eaten by pinnipeds. On a reservation-wide basis, these studies indicate that approximately 3 percent of all salmon impacted by the net fishery dies through pinniped depredation and does not appear in harvest estimates. The U.S. FWS also estimates that, on a reservation-wide basis, an additional 5 percent of salmon impacted by the net fishery become unmeshed, die and do not appear in harvest estimates (R. Adair, U.S.

FWS, personal communication). A 30 percent mortality rate among all salmon which become unmeshed is assumed. Total noncatch mortality associated with the net fishery through pinniped interaction and the unmeshing of salmon, therefore, approximates 8 percent of the total net fishery impact.

Sport Fishery

Noncatch mortality through pinniped interactions with the sport fishery is known to occur in the lower Klamath River, but is assumed here to be negligible. Some salmon that have been hooked by river sport fishermen manage to escape landing, but subsequently die from the experience. No data are available to estimate the magnitude of this problem. A rate of 2 percent of total sport fishery impact has been assumed here for noncatch mortality in the in-river sport fishery.

(7) Natural Mortality. Age-specific annual natural mortality rates are set at 0.50 for age 2 and 0.20 for ages 3-5. Ocean natural mortality rate appears to decline as the fish increase in weight (Matthews and Buckley 1976). The values used are slightly lower than

those used by the Washington Department of Fisheries for hatchery fingerling releases in their Puget Sound chinook salmon catch allocation model (0.60 for age 2 and 0.25 for all older ages) (WDF 1984).

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Attachment 1. Model Output used to develop Option 4.

```
A>B:PRINT

A>TYPE A:KLAMPARA.DAT
```

Parameters used for Klamath model 1/26/1986

Alpha : 1.4000000000E+01 Beta : 0.00001000

AGE	OSC	%Legal	Shkrs	%Mature	TCR	DOR	MORT	Begin R.
2 :	0.400	0.100	0.300	0.070	0.000	0.000	0.500	400000
3 :	0.880	0.800	0.300	0.430	0.660	0.060	0.200	218200
4 :	1.000	1.000	0.300	0.890	1.000	0.060	0.200	32200
5 :	1.000	1.000	0.300	1.000	1.000	0.060	0.200	2000

```
A>TYPE A:KLAM425.DAT
```

Total Landings

Youngest Age = 2 Oldest Age = 5 1/26/1986

T E R M I N A L M O R T A L I T Y R A T E

		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
O	0.15 :	79723	86805	93834	100701	107245	113232	118313	121964	123378
	0.20 :	90414	96819	103049	108968	114382	119010	122446	124087	123021
S	0.25 :	100434	106026	111305	116102	120186	123228	124756	124083	120182
	0.30 :	109504	114123	118266	121736	124256	125442	124755	121411	114263
R	0.35 :	117261	120711	123503	125398	126075	125089	121821	115390	104519
A	0.40 :	123225	125274	126450	126476	124975	121438	115160	105153	90056
T	0.45 :	126763	127123	126367	124165	120086	113544	103748	89649	70137
E	0.50 :	127023	125347	122268	117405	110261	100181	86353	68037	45697
	0.55 :	122860	118715	112834	104782	94017	79940	62213	41774	22254

```
A>TYPE A:KLAM122.DAT
```

Offshore Landings

Youngest Age = 2 Oldest Age = 2 1/26/1986

T E R M I N A L M O R T A L I T Y R A T E

		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
O	0.15 :	3020	3048	3071	3086	3090	3078	3044	2979	2868
	0.20 :	4077	4102	4117	4119	4102	4061	3984	3858	3663
S	0.25 :	5138	5150	5146	5121	5068	4977	4836	4623	4310
	0.30 :	6180	6165	6128	6059	5951	5788	5554	5221	4752
R	0.35 :	7171	7115	7025	6892	6703	6440	6079	5587	4915
A	0.40 :	8068	7950	7784	7560	7260	6861	6332	5632	4700
T	0.45 :	8811	8604	8334	7984	7534	6954	6207	5241	4006
E	0.50 :	9314	8985	8572	8055	7406	6590	5565	4295	2819
	0.55 :	9458	8965	8361	7621	6715	5606	4282	2815	1459

A>TYPE A:KLAM125.DAT

Offshore Landings

Youngest Age = 2 Oldest Age = 5   1/26/1986

T E R M·I N A L   M O R T A L I T Y   R A T E

		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
O	0.15 :	42097	42494	42813	43022	43076	42913	42442	41533	39986
	0.20 :	55511	55850	56056	56079	55853	55284	54240	52528	49865
S	0.25 :	68304	68457	68402	68071	67368	66166	64280	61451	57295
	0.30 ;	80197	80011	79520	78633	77222	75117	72076	67760	61674
R	0.35 :	90830	90117	88980	87295	84900	81572	77005	70771	62251
A	0.40 :	99726	98261	96220	93446	89734	84803	78272	69613	58107
T	0.45 :	106253	103757	100500	96286	90856	83865	74851	63211	48354
E	0.50 :	109563	105696	100841	94755	87121	77529	65482	50572	33303
	0.55 :	108514	102851	95925	87442	77041	64343	49200	32465	16995

A>TYPE A:KLAM133.DAT

Offshore Landings

Youngest Age = 3 Oldest Age = 3   1/26/1986

T E R M I N A L   M O R T A L I T Y   R A T E

		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
O	0.15 :	24164	24392	24575	24695	24726	24633	24363	23840	22952
	0.20 :	32381	32579	32699	32712	32580	32249	31639	30641	29088
S	0.25 :	40495	40586	40553	40357	39940	39227	38110	36432	33968
	0.30 :	48330	48217	47922	47387	46537	45268	43436	40835	37167
R	0.35 :	55647	55210	54513	53481	52014	49975	47177	43358	38138
A	0.40 :	62120	61207	59936	58209	55896	52824	48756	43362	36194
T	0.45 :	67303	65722	63659	60990	57550	53122	47412	40039	30624
E	0.50 :	70581	68090	64962	61042	56124	49945	42182	32573	21438
	0.55 :	71105	67394	62856	57297	50482	42159	32231	21255	11109

A>TYPE A:KLAM144.DAT

Offshore Landings

Youngest Age = 4 Oldest Age = 4   1/26/1986

T E R M I N A L   M O R T A L I T Y   R A T E

		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
O	0.15 :	13875	14006	14111	14180	14198	14144	13989	13689	13179
	0.20 :	17800	17908	17974	17982	17909	17727	17392	16843	15989
S	0.25 :	21267	21315	21298	21194	20976	20601	20014	19133	17839
	0.30 :	24197	24141	23993	23725	23300	22664	21747	20445	18608
R	0.35 :	26497	26289	25957	25465	24767	23796	22464	20645	18160
A	0.40 :	28056	27644	27070	26290	25245	23858	22021	19585	16349
T	0.45 :	28748	28072	27191	26051	24582	22690	20252	17104	13090
E	0.50 :	28418	27415	26156	24577	22597	20110	16986	13126	8663
	0.55 :	26886	25483	23767	21665	19089	15946	12203	8074	4256

A>TYPE A:KLAM155.DAT

Offshore Landings

Youngest Age = 5 Oldest Age = 5 1/26/1986

T E R M I N A L   M O R T A L I T Y   R A T E

		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
O	0.15 :	1038	1048	1056	1061	1062	1058	1046	1024	986
	0.20 :	1253	1261	1265	1266	1261	1248	1224	1186	1126
S	0.25 :	1404	1407	1406	1399	1384	1360	1321	1263	1177
	0.30 :	1491	1487	1478	1461	1435	1396	1340	1259	1146
R	0.35 :	1516	1504	1485	1457	1417	1361	1285	1181	1039
A	0.40 :	1481	1460	1429	1388	1333	1260	1163	1034	863
T	0.45 :	1391	1359	1316	1261	1190	1098	980	828	634
E	0.50 :	1250	1206	1151	1081	994	885	748	578	383
	0.55 :	1065	1009	941	858	756	632	484	321	171

A>TYPE A:KLAM222.DAT

Shaker Deaths

Youngest Age = 2 Oldest Age = 2 1/26/1986

T E R M I N A L   M O R T A L I T Y   R A T E

		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
O	0.15 :	8153	8230	8292	8332	8343	8311	8220	8044	7744
	0.20 :	11009	11076	11117	11121	11077	10964	10757	10417	9889
S	0.25 :	13873	13904	13893	13826	13683	13439	13056	12481	11637
	0.30 :	16685	16647	16545	16360	16066	15628	14996	14098	12832
R	0.35 :	19362	19210	18967	18608	18097	17388	16415	15086	13269
A	0.40 :	21784	21464	21018	20412	19601	18524	17097	15206	12691
T	0.45 :	23788	23230	22501	21557	20341	18776	16758	14150	10817
E	0.50 :	25146	24259	23145	21748	19996	17794	15026	11596	7611
	0.55 :	25537	24204	22574	20578	18129	15137	11562	7600	3938

A>TYPE A:KLAM233.DAT

Shaker Deaths

Youngest Age = 3 Oldest Age = 3 1/26/1986

T E R M I N A L   M O R T A L I T Y   R A T E

		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
O	0.15 :	1812	1829	1843	1852	1854	1847	1827	1788	1721
	0.20 :	2429	2443	2452	2453	2444	2419	2373	2298	2182
S	0.25 :	3037	3044	3041	3027	2996	2942	2858	2732	2548
	0.30 :	3625	3616	3594	3554	3490	3395	3258	3063	2788
R	0.35 :	4174	4141	4089	4011	3901	3748	3538	3252	2860
A	0.40 :	4659	4591	4495	4366	4192	3962	3657	3252	2715
T	0.45 :	5048	4929	4774	4574	4316	3984	3556	3003	2297
E	0.50 :	5294	5107	4872	4578	4209	3746	3164	2443	1608
	0.55 :	5333	5055	4714	4297	3786	3162	2417	1594	833

A>TYPE A:KLAM325.DAT

Terminal Landings

Youngest Age = 2 Oldest Age = 5   1/26/1986

		TERMINAL MORTALITY RATE								
		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
O	0.15 :	37626	44311	51022	57679	64169	70319	75871	80431	83392
	0.20 :	34903	40969	46993	52889	58529	63726	68206	71559	73156
S	0.25 :	32130	37569	42902	48031	52817	57062	60475	62632	62887
	0.30 :	29307	34112	38746	43103	47033	50326	52679	53651	52589
R	0.35 :	26431	30594	34523	38103	41175	43517	44816	44620	42267
A	0.40 :	23499	27013	30231	33029	35241	36635	36888	35541	31949
T	0.45 :	20510	23366	25866	27879	29230	29679	28897	26438	21783
E	0.50 :	17460	19651	21427	22650	23140	22651	20871	17465	12395
	0.55 :	14346	15864	16909	17340	16976	15596	13013	9309	5259

A>TYPE A:KLAM525.DAT

Drop-off Deaths

Youngest Age = 2 Oldest Age = 5   1/26/1986

		TERMINAL MORTALITY RATE								
		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
O	0.15 :	2402	2828	3257	3682	4096	4488	4843	5134	5323
	0.20 :	2228	2615	3000	3376	3736	4068	4354	4568	4670
S	0.25 :	2051	2398	2738	3066	3371	3642	3860	3998	4014
	0.30 :	1871	2177	2473	2751	3002	3212	3362	3425	3357
R	0.35 :	1687	1953	2204	2432	2628	2778	2861	2848	2698
A	0.40 :	1500	1724	1930	2108	2249	2338	2355	2269	2039
T	0.45 :	1309	1491	1651	1780	1866	1894	1844	1688	1390
E	0.50 :	1114	1254	1368	1446	1477	1446	1332	1115	791
	0.55 :	916	1013	1079	1107	1084	996	831	594	336

A>TYPE A:KLAM635.DAT

Escapement

Youngest Age = 3 Oldest Age = 5   1/26/1986

		TERMINAL MORTALITY RATE								
		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
O	0.15 :	123056	117482	111579	105305	98612	91438	83709	75333	66190
	0.20 :	115172	109649	103803	97594	90974	83885	76254	67992	58986
S	0.25 :	107030	101561	95774	89633	83089	76087	68558	60415	51550
	0.30 :	98608	93194	87471	81400	74936	68025	60602	52582	43864
R	0.35 :	89880	84526	78868	72871	66491	59676	52362	44471	35906
A	0.40 :	80820	75527	69938	64018	57726	51011	43812	36056	27669
T	0.45 :	71394	66166	60649	54811	48610	41999	34923	27329	19251
E	0.50 :	61563	56404	50963	45210	39106	32610	25693	18414	11186
	0.55 :	51284	46196	40837	35176	29186	22868	16333	10018	4846

A>TYPE KLAM622.DAT

Escapement

Youngest Age = 2 Oldest Age = 2 1/26/1986

T E R M I N A L   M O R T A L I T Y   R A T E

		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
O	0.15 :	34447	34772	35033	35204	35248	35115	34730	33986	32720
	0.20 :	34621	34832	34960	34975	34834	34479	33828	32760	31099
S	0.25 :	34636	34714	34686	34518	34162	33552	32596	31161	29054
	0.30 :	34448	34368	34157	33776	33170	32266	30960	29106	26492
R	0.35 :	33997	33731	33305	32674	31778	30532	28823	26489	23300
A	0.40 :	33208	32720	32041	31117	29881	28239	26064	23180	19347
T	0.45 :	31981	31230	30250	28981	27347	25243	22529	19024	14543
E	0.50 :	30185	29120	27782	26105	24002	21359	18037	13920	9137
	0.55 :	27645	26202	24437	22276	19625	16386	12516	8227	4263

A>TYPE KLAM633.DAT

Escapement

Youngest Age = 3 Oldest Age = 3 1/26/1986

T E R M I N A L   M O R T A L I T Y   R A T E

		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
O	0.15 :	69955	67709	65290	62667	59801	56640	53117	49139	44574
	0.20 :	67307	64931	62374	59601	56575	53240	49529	45345	40558
S	0.25 :	64335	61826	59125	56201	53010	49499	45597	41209	36201
	0.30 :	60999	58353	55506	52426	49069	45380	41287	36694	31468
R	0.35 :	57253	54467	51471	48233	44707	40839	36556	31760	26322
A	0.40 :	53046	50116	46969	43570	39875	35828	31355	26363	20733
T	0.45 :	48313	45237	41937	38377	34513	30288	25632	20463	14747
E	0.50 :	42983	39760	36306	32585	28554	24158	19347	14123	8758
	0.55 :	36969	33598	29991	26113	21927	17410	12621	7868	3875

A>TYPE KLAM644.DAT

Escapement

Youngest Age = 4 Oldest Age = 4 1/26/1986

T E R M I N A L   M O R T A L I T Y   R A T E

		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
O	0.15 :	48983	45914	42700	39333	35802	32100	28220	24163	19940
	0.20 :	44357	41440	38393	35208	31878	28398	24766	20987	17076
S	0.25 :	39748	36992	34119	31124	28003	24752	21375	17880	14289
	0.30 :	35175	32586	29895	27098	24193	21180	18064	14860	11593
R	0.35 :	30657	28244	25742	23150	20468	17699	14852	11943	9005
A	0.40 :	26219	23988	21683	19303	16851	14333	11759	9151	6548
T	0.45 :	21890	19849	17747	15586	13370	11107	8812	6512	4272
E	0.50 :	17704	15860	13967	12030	10056	8054	6047	4089	2313
	0.55 :	13705	12062	10384	8677	6950	5225	3554	2058	930

A>TYPE KLAM655.DAT

Escapement

Youngest Age = 5 Oldest Age = 5 1/26/1986

TERMINAL MORTALITY RATE

		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
O	0.15 :	4117	3859	3589	3306	3009	2698	2372	2031	1676
	0.20 :	3509	3278	3037	2785	2522	2246	1959	1660	1351
S	0.25 :	2948	2743	2530	2308	2077	1836	1585	1326	1060
	0.30 :	2435	2255	2069	1876	1674	1466	1250	1028	802
R	0.35 :	1970	1815	1654	1488	1315	1138	955	768	579
A	0.40 :	1555	1423	1286	1145	1000	850	698	543	388
T	0.45 :	1190	1079	965	848	727	604	479	354	232
E	0.50 :	875	784	691	595	497	398	299	202	115
	0.55 :	610	537	462	386	309	233	158	92	42

A>TYPE KEQILB.DAT

Oregon Department of Fish and Wildlife
RESEARCH AND DEVELOPMENT SECTION
303 EXTENSION HALL, O.S.U., CORVALLIS, OREGON 97331

VICTOR ATIYEH
GOVERNOR

September 19, 1985

L. B. Boydstun
California Department of Fish and Game
1701 Nimbus Rd., Ste. B
Rancho Cordova, CA 95670

Dear L. B.:

I completed a multiple regression analysis of the stock-recruitment data for Shasta River fall chinook and I wanted to inform you of the results. Unfortunately, I do not have anything exciting to report. I found no environmental variables that accounted for a substantive amount of variation about the stock-recruitment curve. You may desire to pursue this analysis further with additional data, so I have described here exactly what I did.

I used the following data (1957-82) in my analyses:

1. Adult spawners as listed in Table 3 of your handout from the August 27-28 team meeting
2. Age 3 ocean recruits from the same table as adult spawners
3. Peak daily flow during December-March at Yreka
4. October-November flow at Yreka (mean monthly acre feet)
5. August-October upwelling off Crescent City (sum of monthly Bakun units)
6. April flow at Yreka (acre ft)
7. May flow at Yreka (acre ft)
8. March-June flow at Yreka (total acre ft)

Values for each of these variables are presented in Table 1. Before conducting the regression analysis, I converted variables 3-8 to their standard normal deviates.

First, I regressed $\ln$ recruits on $\ln$ spawners to see if a relationship existed between the two. The correlation between the two was insignificant ($P = 0.091$). However, if I first added March-June flow to the regression, then $\ln$ spawners became nearly significant ($P = 0.057$). No additional variables were significant. The final model of this form accounted for only 32.8% of the variation and is shown in Table 2.

Table 2. Best regression of $\ln$ recruits on $\ln$ spawners and environmental variables.

Independent Variable	Regression Coefficient	P
$\ln$ spawners	-0.466	0.057
March-June flow	-0.387	0.013
Constant	14.042	---

Table 1. Data used in multiple regression of fall chinook recruitment on spawner abundance and environmental factors in the Shasta River.

Year	Spawn	Age 3 Recruits	Peak Flow	Oct.-Nov. Flow	Aug.-Oct. Upwell	Apr. Flow	May Flow	Mar.-Jun. Flow
1957	1,781	12,359	2.7	14.3	118	617	544	2,271
1958	4,694	11,897	0.5	11.1	194	204	159	714
1959	8,619	34,578	1.6	9.5	133	238	212	884
1960	9,489	49,112	0.8	9.1	141	245	232	955
1961	5,250	88,679	0.7	11.3	75	307	199	831
1962	9,907	35,897	1.4	17.9	60	428	398	1,219
1963	22,825	7,626	2.6	12.7	177	276	175	799
1964	30,715	4,438	10.4	9.9	174	336	268	1,252
1965	7,136	18,066	0.6	12.1	223	354	229	963
1966	5,573	9,870	1.0	9.8	178	239	475	1,225
1967	10,478	30,002	0.6	11.3	79	165	146	684
1968	13,039	7,006	2.1	10.0	243	565	487	1,586
1969	10,576	16,226	4.0	11.6	231	179	215	955
1970	12,693	8,256	1.3	13.6	105	643	591	2,141
1971	4,970	48,236	1.6	12.3	199	379	296	822
1972	2,802	26,854	0.3	10.2	223	164	173	638
1973	4,516	41,437	5.8	7.3	214	829	466	2,289
1974	7,376	20,607	1.9	10.8	184	487	560	2,004
1975	11,821	21,144	0.5	11.1	103	367	263	1,582
1976	4,154	64,880	0.6	9.4	115	67	93	300
1977	5,478	11,954	1.6	8.2	114	197	190	751
1978	12,024	41,773	0.4	10.1	50	164	276	798
1979	7,111	53,210	2.4	11.3	205	245	234	978
1980	3,762	24,872	0.4	9.9	92	160	119	535
1981	7,890	7,154	4.0	6.5	65	576	349	1,787
1982	6,531	4,968	3.0	6.0	107	639	616	2,629
$\bar{X}$			1.9	11.0	146	348.8	306	1,215
S			2.22	2.20	59.9	194	158	624

This result indicates there is poor evidence of any relationship between recruits and spawners. Thus, the Ricker curve may be inappropriate for these data. The R^2 value of 0.61 when ℓn recruits per spawner is regressed on spawners is largely a spurious correlation from having spawners on both sides of the equation. The Ricker equation can be reduced to a form similar to that which I tested first as follows:

$$\ell n\ R/S = a - BS$$
$$\ell n\ R = a - BS + \ell n\ S$$

However, I found for the regression in Table 2 that if both ℓn spawners and spawners were included, that the partial correlation of ℓn spawners became insignificant ($P = 0.33$). Thus, there is no statistical evidence that a Ricker model is appropriate for these data.

I proceeded anyway with a standard Ricker analysis by regressing ℓn recruits/spawner on spawners. The only environmental variable that improved the regression was March-June flow (Table 3), which increased the R^2 from 0.61 to 0.71. Addition of March-June flow to the regression had no effect on the value of a.

Table 3. Best regression of ℓn recruits/spawner on spawners and environmental variables.

Independent Variable	Regression Coefficient	P
Spawners	-0.1505×10^{-3}	0.000
March-June Flow	-0.3797	0.009
Constant	2.3218	---

I was surprised that peak winter flows and August-October upwelling did not work out in the regression. Obviously, there are other factors influencing recruitment that we have not accounted for. River temperature is a likely candidate. Abundance of predators might be another. What are the chances that there are substantial errors in the estimated abundance of spawners or recruits? Perhaps the regression of age 3 on age 2 abundance will fall apart with additional data.

The results of this analysis are disappointing and give us little direction for managing harvest of Klamath fall chinook. I have attached copies from portions of my computer printout. Let me know if you have further data or ideas I can work with.

Sincerely,

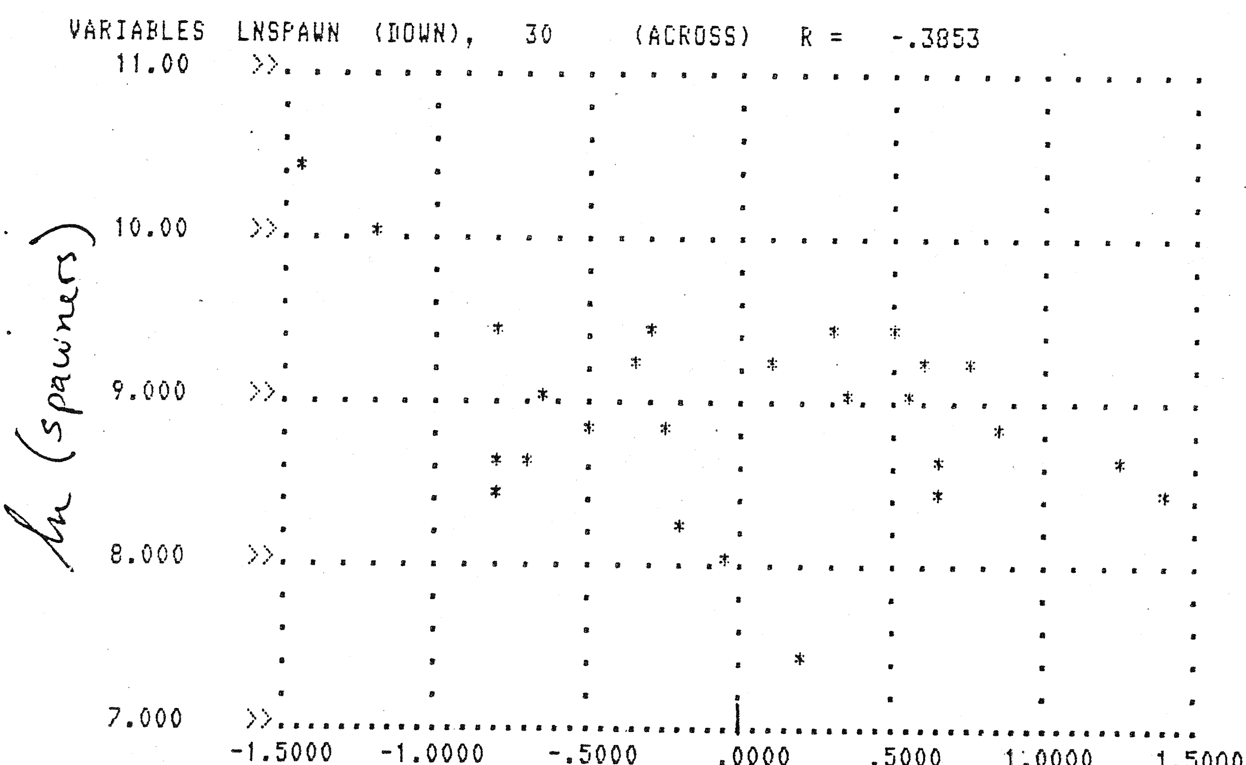
Steven P. Cramer

SPC/sd

cc: Dave Hankin
Jim Martin

Attachment

```
 ** WRONG TYPE IN SUBLIST
    IN REGRESS
? ADD,LNSPAWN,MJFLSN


 LNRECRT =
    14.0424      (CONSTANT)
   -.387453      MJFLSN
   -.466106      LNSPAWN
? AVTABLE


              ANALYSIS OF VARIANCE TABLE

 SOURCE        DF   SUM OF SQUARES         MEAN SQUARE
 TOTAL         25       17.5512            .702049
 REGRESSION     2       5.76331            2.88166
 RESIDUAL      23       11.7879            .512518

               R SQUARED =  .3284
? DROP,LNSPAWN


 LNRECRT =
    9.89076      (CONSTANT)
   -.384922      MJFLSN
? RESIDUAL,30
? SCATTER,30,LNSPAWN
 LOWER BOUND OF X=    -1.46997       UPPER BOUND OF X=     1.40368
 LOWER BOUND OF Y=     7.48493       UPPER BOUND OF Y=     10.3325
```



residuals from ln(recruits) vs Mar-June flow

```
?
 END
 ** LEAVING REGRESS **
? EXIT
     4.565 CP SECONDS EXECUTION TIME.
/BYE
UN=CMWA2C   LOG OFF  10.16.29.
```

ln(recruits/spawner)

LNRPS =
2.32182 (CONSTANT)
-.150474E-03 SPAWN
-.379713 MJFLSN
? TVALUES

Best model. Addition Flow has no influence R^2 without March-June

VARIABLE	S.E. OF REGR. COEF	T	P
CONSTANT	.23134	10.036	.0000
SPAWN	.21455E-04	-7.013	.0000
MJFLSN	.13337	-2.847	.0091

VARIABLE	PARTIAL CORRELATION	T	P
PKFLOW	.17883	.853	.4027
ONFLOW	.23451	1.132	.2695
UPWELL	-.11732	-.554	.5849
APFLOW	.23111	1.114	.2767
MAYFLOW	-.13781	-.653	.5205
MJFLOW	0.	.000	1.0000
PKFLSN	.17883	.853	.4027
ONFLSN	.23451	1.132	.2695
UPWLSN	-.11732	-.554	.5849
MAYFLSN	.87746E-01	.413	.6833
AMFLSN	.87746E-01	.413	.6833
LNRECRT	.92110	11.097	.0000
LNSPAWN	-.18941	-.905	.3749

? AVTABLE

ANALYSIS OF VARIANCE TABLE

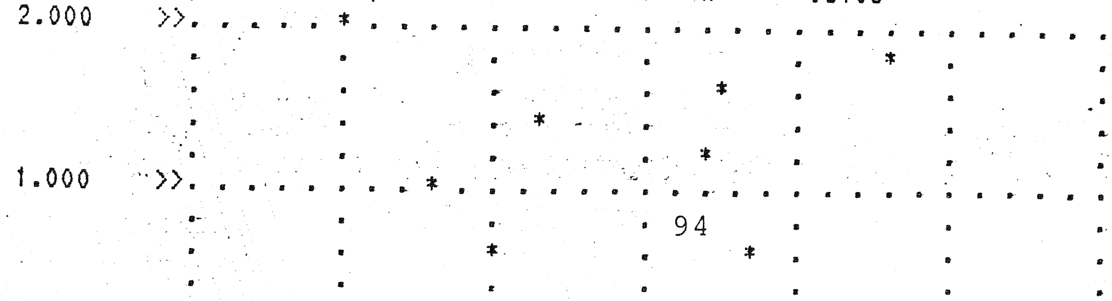
SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
TOTAL	25	35.7319	1.42928
REGRESSION	2	25.4955	12.7477
RESIDUAL	23	10.2364	.445063

R SQUARED = .7135

? DROP,MJFLSN

LNRPS =
-2.32165 (CONSTANT)
-.150459E-03 SPAWN
? RESIDUAL,30
? SCATTER,30,MJFLSN
LOWER BOUND OF X= -1.61254 UPPER BOUND OF X= 1.29506
LOWER BOUND OF Y= -1.46635 UPPER BOUND OF Y= 2.26603

VARIABLES MJFLSN (DOWN), 30 (ACROSS) R = -.5105



LNRECRT =
14.0424 (CONSTANT)
-.387453 MJFLSN
-.466106 LNSPAWN
TVALUES

ARIABLE	S.E. OF REGR. COEF	T	P
ONSTANT	2.0776	6.759	.0000
JFLSN	.14312	-2.707	.0126
NSPAWN	.23272	-2.003	.0571

This model shows a very we[ak]
relationship between recruits a[nd]
Note that more spawners pr[oduce]
fewer recruits, according to th[e]
Lower flows during spring prod[uce]
more recruits. This is consist[ent]
$R^2 = 0.33$

ARIABLE	PARTIAL CORRELATION	T	P
KFLOW	-.19838	-.949	.3523
NFLOW	.16032	.762	.4539
PWELL	-.19337	-.924	.3649
PFLOW	.20555	.985	.3348
AYFLOW	-.34368E-01	-.161	.8733
LOW	0.	.000	1.0000
KFLSN	-.19838	-.949	.3523
NFLSN	.16032	.762	.4539
PWLSN	-.19337	-.924	.3649
AYFLSN	.13572	.643	.5269
HFLSN	.13572	.643	.5269

DVAR,2
NAME,2,*DEL*
ALUES,2

RIABLE	S.E. OF REGR. COEF	T	P

RIABLE	PARTIAL CORRELATION	T	P
AWN	-.40345	-2.068	.0501

DD,2

RECRT =
5.17959 (CONSTANT)
.107615E-03 SPAWN
.382234 MJFLSN
.524097 LNSPAWN
VALUES

RIABLE	S.E. OF REGR. COEF	T	P
STANT	4.2700	1.447	.1619
WN	.52035E-04	-2.068	.0506
LSN	.13392	-2.854	.0092
PAWN	.52597	.996	.3299

IABLE	PARTIAL CORRELATION	T	P
OW	.10149	.467	.6447
LOW	.22568	1.062	.2999
EL	-.14831	-.687	.4991
LO	.23032	1.085	.2898
FLOW	-.11402	-.526	.6042
LOW	0.	.000	1.0000
SN	.10149	.467	.6447
LSN	.22568	1.062	.2999
LSN	-.14831	-.687	.4991
FLSN	.10381	.478	.6372

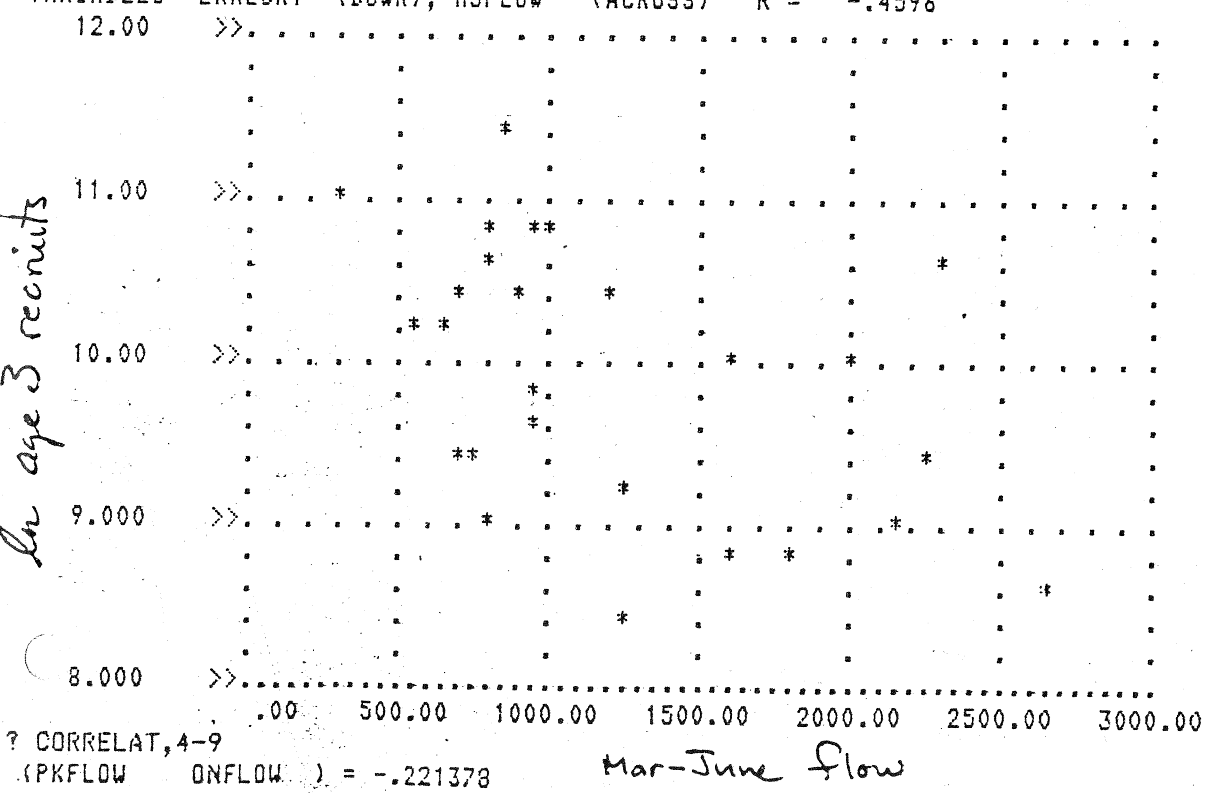
```
? SET,17=LN(2)
? SET,18CLN(3/2)
        *
 ** SHOULD BE VARIABLE =
? SET,18=LN(3/2)
? REGRESS,16,17,4-15
 **ENTERING REGRESS SUBSYSTEM**

 LNRECRT = 9.8907
? TVALUES
```

VARIABLE	S.E. OF REGR. COEF	T	P
CONSTANT	.16432	60.191	.0000

VARIABLE	PARTIAL CORRELATION	T	P	
PKFLOW	-.44177	-2.412	.0235	Peak winter flow
ONFLOW	.16455	.817	.4215	Ave Oct-Nov Flow
UPWELL	-.14474	-.717	.4802	Ave Aug-Oct upwelling -Crecent City
APFLOW	-.35091	-1.836	.0783	Ave April Flow
MAYFLOW	-.42524	-2.302	.0300	Ave May flow
MJFLOW	-.45960	-2.535	.0179	~~Ave~~. March-June flow (Total)
PKFLSN	-.44177	-2.412	.0235	Peak winter Flow (stand. normal deviate)
ONFLSN	.16455	.817	.4215	Ave Oct-Nov Flow " " "
UPWLSN	-.14474	-.717	.4802	Ave Aug-Oct Upwell. " " "
APFLSN	-.45960	-2.535	.0179	Ave April Flow " " "
MAYFLSN	-.40142	-2.147	.0417	Ave May Flow " " "
MJFLSN	-.40142	-2.147	.0417	Ave Mar-June Flow " " "
LNSPAWN	-.33818	-1.760	.0906	ln_e(spawners)

```
? SCATTER,9,16
 LOWER BOUND OF X=     300.000        UPPER BOUND OF X=     2629.00
 LOWER BOUND OF Y=     8.39796        UPPER BOUND OF Y=     11.3928
```

VARIABLES LNRECRT (DOWN), MJFLOW (ACROSS) R = -.4596




```
? CORRELAT,4-9
 (PKFLOW    ONFLOW  ) = -.221378
 (PKFLOW    UPWELL  ) =  .234578
 (PKFLOW    APFLOW  ) =  .382282
 (PKFLOW    MAYFLOW ) =  .225218
```