FRED Reports

TUTKA LAGOON HATCHERY 1981
ADULT RETURN EVALUATION

by
Larry Boyle
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Number 61

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Enhancement and Development (FRED)

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ABSTRACT

Marine survival rates of fed and unfed hatchery pink salmon, *Oncorhynchus gorbuscha*, were evaluated by excising the adipose fins of a representative sample of fry and by recovering them as marked adults the following summer. Hatchery contribution to the total pink salmon return was then estimated by analyzing the recovery data of these marked fish. The fed fry were held in saltwater net pens and fed commercial fish food for 30-40 days before their release. Upon their emergence from the incubators, unfed fry were transported and released in Tutka Bay.

Sampling for the marked adult salmon was conducted during the commercial seine fishery in Tutka Bay and during spawning at the hatchery. Sampling crews on cannery fish tenders examined the fish as they helped the fishermen off-load their catches. Approximately 16% of the Tutka Bay pink salmon return was inspected for clipped adipose fins.

The estimated marine-survival rates of 12.5% for fed fry and 14.0% for unfed fry were based on an adjustment of the mark-recovery data for possible differential survival of marked and unmarked fish. However, this method could only account for 74% of the return. It is not probable that the wild Tutka Creek stock accounted for the remaining 26% of the return; nor is it probable that the interception or straying of other stocks are responsible for that remainder.

Differential predation on the two groups at the time of release and the likelihood that the marked fish did not adequately represent the unmarked fish in the fed group are possible explanations for the unexpected difference in survivals between these groups.

The 1981 return of 1,080,000 pink salmon to Tutka Bay more than doubles the previous high that occurred in 1979. The Tutka Bay commercial harvest accounted for 29% of the entire lower Cook Inlet pink salmon catch.

KEY WORDS: Pink salmon, fin-excision, survival rate, fed fry, mark-recovery.

INTRODUCTION

The Tutka Bay Lagoon Salmon Hatchery was constructed in the spring of 1976, with a designed production capacity of 10 million salmon eggs. It has since been expanded to its present capacity of over 30 million eggs. Tutka Hatchery is located on the lower Kenai Peninsula within Tutka Lagoon, which is midway along the southwest shore of Tutka Bay, approximately 32 air kilometers from Homer (Figure 1). Pink salmon, *Oncorhynchus gorbuscha* Walbaum, are the primary species produced at the hatchery. Chum salmon, *O. keta* Walbaum, production is still in the initial stages; the first large returns are expected in 1986 and 1987.

The major goal of the hatchery is the enhancement of the pink and chum salmon runs in Tutka Creek. Salmon fry have been produced for both the immediate-release and short-term rearing programs at the hatchery. In addition, hatchery pink salmon fry have been introduced into several barren river systems in lower Cook Inlet. In recent years, the contribution of hatchery-produced pink salmon has been important to the commercial fisheries in the lower Kenai Peninsula.

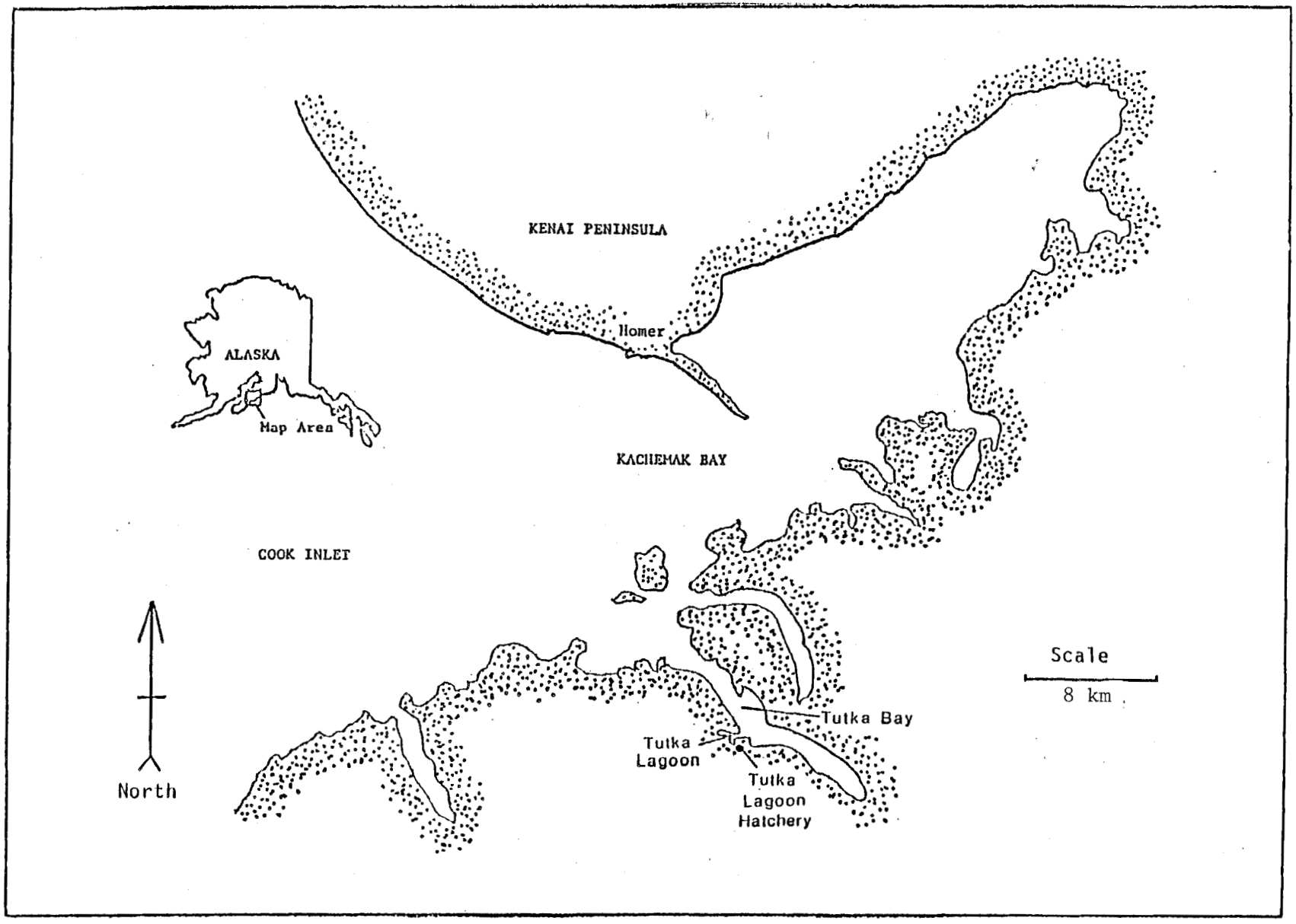

Figure 1. Location of Tutka Bay Lagoon Salmon Hatchery and Tutka Bay Lagoon.

Although the first adult pink salmon return to the hatchery occurred in 1977, the first extensive evaluation of hatchery adult returns to Tutka Bay was initiated in 1979 (Dudiak and Quimby 1979). This study was based on the recovery of adult pink salmon that had been marked as fry by adipose fin excision.

Since 1979 the recovery of marked fish taken during the commercial fishery and hatchery egg-stripping operations have been used to evaluate the adult survival rates of fed fry and "direct release" unfed fry. The marks were also used to estimate the number of hatchery-produced pink salmon adults returning to Tutka Bay. No wild Tutka Creek fry were marked in 1979 or 1980.

The adult pink salmon that returned to the Tutka Bay area in 1981 originated from the 1980 release of Tutka Bay Lagoon Hatchery fry and Tutka Creek wild fry. During this 1981 adult salmon run, an intensive sampling program was conducted by a crew of several fishery biologists and technicians. Much of the commercial catch in the vicinity of Tutka Bay and all of the artificially spawned adults were screened for marked fish.

The purpose of this report is to document the methodology and results of that sampling program, to discuss the estimation of survival rates for the two different hatchery production groups, and to evaluate the numbers of pink salmon contributed by the Tutka Bay Lagoon Hatchery to the total Tutka Bay pink salmon run.

METHODS AND MATERIALS

Fry Marking

Some of the hatchery-released fish were marked by excising a ventral fin from each fish before its release in 1980. The direct-release unfed fry were marked by excising their left-ventral fins, while the short-term reared fry had their right-ventral fins removed. The number of wild fry emerging from Tutka Creek was estimated by the Commercial Fisheries Division (fry pump index). The number of fry marked and the total number released are presented in Table 1.

After the direct-release fry were marked, they were held in the hatchery for 24 hours so that they could be observed for any mortalities. These marked fish were then mixed with the unmarked direct-release group, transported by boat out of Tutka Lagoon, and released in Tutka Bay on 15 and 18 May 1980.

The marked short-term reared fry were transported by boat to floating net pens anchored in Tutka Lagoon. To accurately monitor daily mortality until release, the marked fry were held in a pen that was separated from the other fed fry. All of the short-term reared fry were fed for 30-40 days. Prior to release, marked fry were mixed proportionally with the unmarked fry. The short-term reared fish were released on 31 May and 3 and 4 June when the plankton levels and water temperatures in Tutka Bay were increasing. In an attempt to minimize predation, they were released in the evening during an ebbing tide.

Table 1. Tutka Hatchery fry marking, 1980.

Group	Number marked	Mark	Total number released	Average release size
Direct Release Unfed	30,060	Left Ventral	878,000	0.21 g
Short-term Reared Fed	28,196	Right Ventral	5,391,000	0.41 g
Tutka Creek Wild Fry	0	0	1,368,000[a/]	0.21 g[b/]
Total	58,256		7,636,963	

a/ Estimate of wild fry based on the Commercial Fisheries Division fry pump index:

b/ Size based on samples collected from the FRED Division wild fry traps in Tutka Creek.

Return of Adults

The seine fishery in the Tutka Bay statistical area (241-16) was monitored during the entire run by checking the catches collected by commercial fish tenders in the area. FRED Division staff boarded the tenders to look for marked fish as the boats were unloaded. The set-net catch was not monitored because it represented only a small proportion of the total harvest. Special emphasis was placed on monitoring the harvest of surplus salmon during the "emergency openings" held in the normally closed waters of Tutka Lagoon.

As the fish were being sorted by species into the tender's weighing brail, each was examined for fin clips. Since fish delivered to tenders are counted, this examination did not appreciably delay unloading.

All marked fish were weighed to the nearest 0.1 kg, measured from mid-eye to fork of tail (mm), and the mark and sex recorded. For each vessel sampled, the total number and weight of pink salmon caught as well as the number of marked fish (left and right ventral) were recorded. Fish from a random sample of 117 unmarked fish taken at various times throughout the run were also weighed, measured, and sexed. Marked fish recovered during spawning operations were not used in determining mean weights and lengths because of their deteriorated physical condition.

As in the previous 2 years, the 1981 mark-recovery sampling was carried out over the entire salmon seining season, which began on 25 June. This was done because the adult salmon resulting from the fed or unfed fry might return at different times. We examined approximately 16% of the pink salmon run for fish with

excised fins, including the twice weekly fishing periods, the emergency lagoon openings, and the hatchery spawning operations.

Hatchery Contribution

The mark-recovery data were summarized at the end of the run and used to estimate survival rates for the hatchery-release groups. These survival rates were estimated by expanding the mark recoveries to account for the facts that only a portion of the release was marked and only a portion of the run was sampled for marks (Appendix A). A differential mortality rate for marked and unmarked fish was estimated (Appendix B), and it was used to adjust the survival estimates for hatchery-release groups. The hatchery contribution of each group to the total pink salmon run was estimated by using these survival rates. The number of wild Tutka Creek pink salmon in the return was also estimated from a linear-regression analysis (Draper and Smith 1981) of returns to Tutka Bay and to subdistricts adjacent to Tutka for the years 1966-1977 (Appendix C).

RESULTS

Total Return

The estimated total pink salmon run to the Tutka Bay statistical area 241-16 (Figure 2) was 1,080,000. Table 2 partitions the 1981 run into its various components.

Commercial Harvest

A new commercial harvest record for lower Cook Inlet (Figure 3) was set in 1981: 3,296,000 pink salmon. The previous record of 2,980,000 was set in 1979. The commercial pink salmon harvest

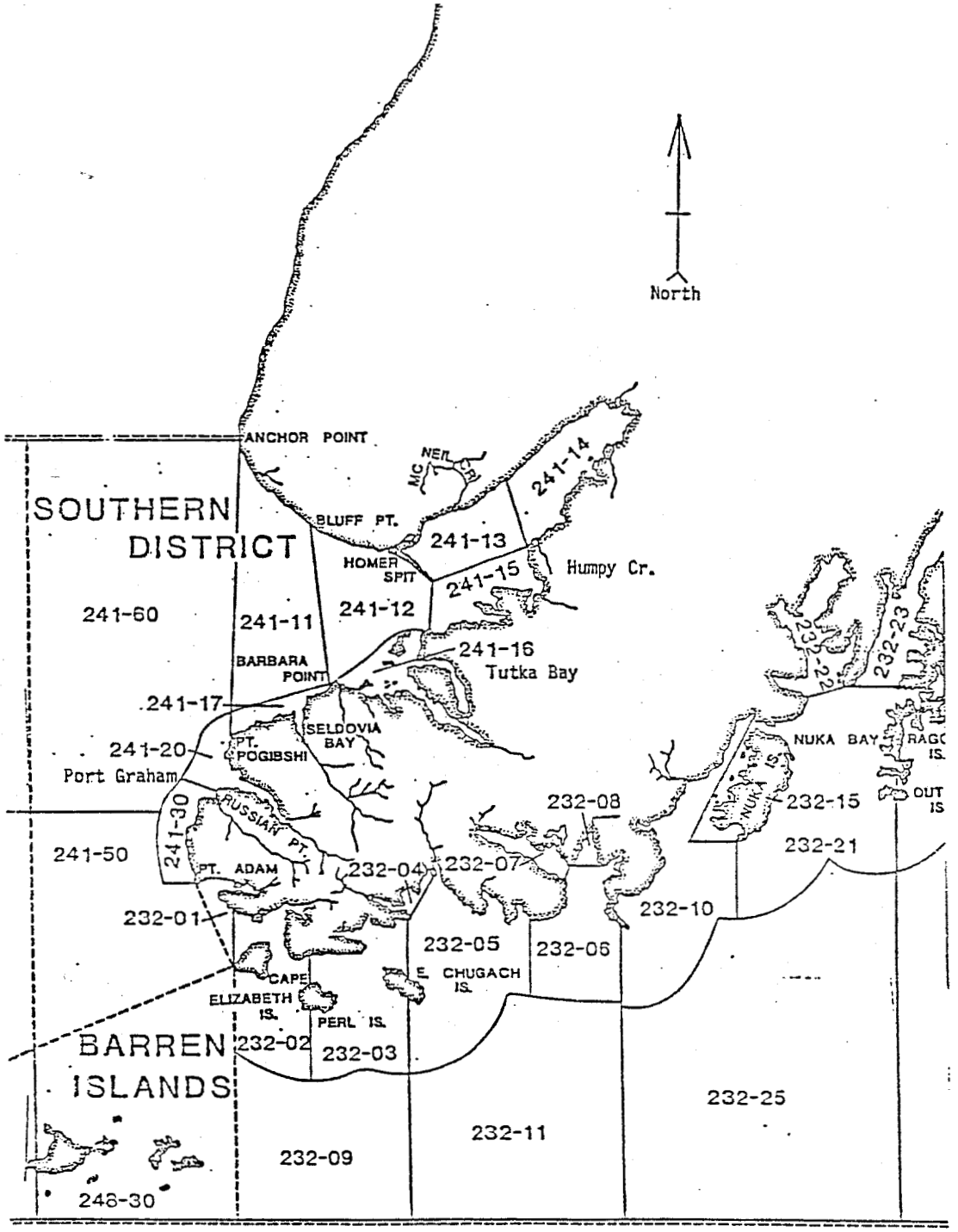

Figure 2. Statistical harvest areas, Southern District, lower Cook Inlet.

Table 2. Estimate of the total adult pink salmon return to Tutka Bay and Lagoon, 1981.[a/]

Commercial Harvest	
Seine	997,000
Set net	27,000
Total	1,024,000
Sport Catch	6,000
Escapement	
Tutka Creek & Channel	28,000
Hatchery-spawners	22,000
	50,000
Total Return	1,180,000

[a/] Estimate based on Commercial Fisheries Division harvest statistics and escapement surveys.

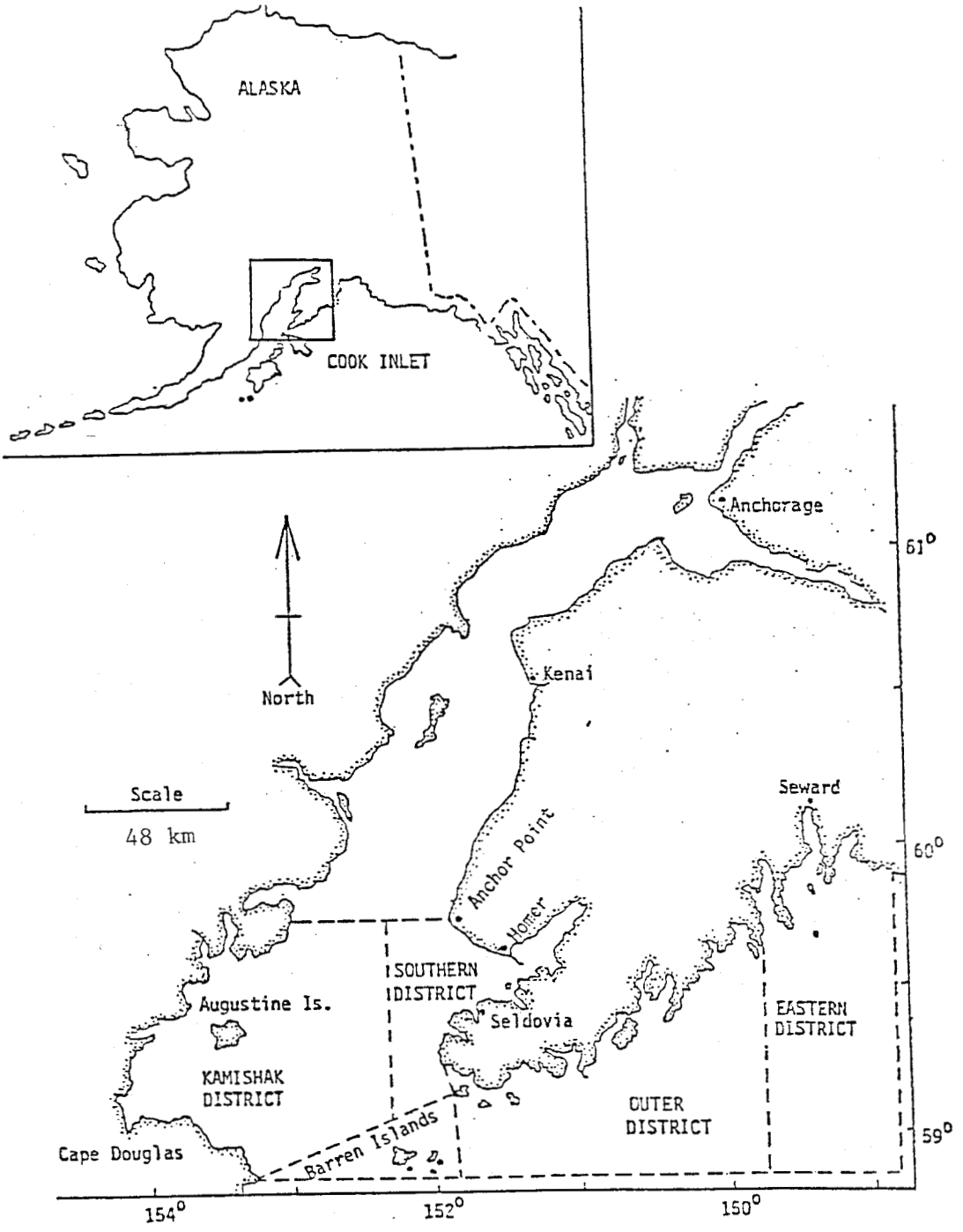

Figure 3. Lower Cook Inlet commercial fishing districts.

from Tutka Bay (1,024,000) was a major component of the new lower Cook Inlet harvest record.

Sport Harvest

The Tutka Lagoon sport fishery has continued to grow in popularity. As many as 35 sport boats have been observed fishing in the lagoon at one time. In 1981, as in previous years, sport fishing started in mid-June and continued through the first week of August; based on limited creel census data and occasional counts of fishermen, an estimated 6,000 pink salmon were taken by sport fishermen.

Mark-Recovery Data

The number of fish sampled, the marks recovered, and the total catch during each sampling period are summarized in Table 3. The relative numbers of right-ventral and left-ventral finclips recovered on the nine recovery occasions were different, as verified by a chi-square test ($X^2 = 28.4$, d.f. = 8, $p < .005$); therefore, the recoveries were divided into three strata for analysis: (1) the commercial fishery from 1 June through 18 July, (2) the commercial fishery from 20 July through 17 August, and (3) the hatchery brood fish. Chi-square analysis indicated that within each of these strata the relative numbers of left-ventral and right-ventral marks recovered were constant.

The average lengths and weights of recovered marked fish are summarized in Table 4. There was no evident difference between lengths and weights of the marked short-term reared females and that of the direct-release females (Table 4). A summary of average sizes of marked fish returning in previous years to Tutka Hatchery is shown in Appendix D.

Table 3. Tutka Hatchery pink salmon mark-recovery effort, 1981.

Fishing Period	Number sampled	Marked fish recovered: Direct release	Marked fish recovered: Short-term reared	Period catch
HARVEST				
06/01-07/01	0	-	-	44,187
07/02-07/03	967	2	1	59,656
07/04	0	-	-	9,701
07/06-07/08	49,734	73	82	166,144
07/09-07/11	7,976	12	21	82,411
07/13-07/15	25,795	36	31	158,817
07/16-07/18 Lagoon Opening 07/17	32,094	42	58	149,537
(Subtotal)	116,566	165	193	520,453
07/20-07/22	0	-	-	50,692
07/23 Lagoon Opening & Tutka Bay Fishery	13,769	36	16	81,539
07/24-07/25	0	-	-	38,876
027 Tutka Bay & Lagoon Opening	11,377	19	4	29,693
07/28-07/29 Lagoon Opening 07/28	13,788	16	6	22,570
07/30-08/17	0	-	-	129,700
(Subtotal)	38,934	71	26	302,378
Sport Catch	0	-	-	6,000
Subtotal	155,500	236	219	1,030,000
ESCAPEMENT				
Tutka Creek & Channel	0	-	-	28,000
Hatchery-spawners 07/31-08/31	18,715	39	29	22,000
Total	174,215	275	248	1,080,000

Table 4. Mean sizes of pink salmon in the Tutka Bay return, 1981.

	Marked Direct release		Marked Short-term reared		Unmarked random	
	Male	Female	Male	Female	Male	Female
Weight (kg)	1.39	1.38	1.53	1.41	1.56	1.41
N	120	132	108	111	58	59
Length (mm)	438	445	451	448	456	452
N	120	132	120	111	58	59

Hatchery Contribution

A simple expansion of the numbers of recovered marks yielded an estimate of 48,000 adult fish from the directly released group and 264,000 from the short-term reared group in the 1981 Tutka pink salmon run (Table 5). Because the proportion of fish with excised fins in the hatchery brood was much smaller than the proportion of juvenile fish originally marked, these estimates were adjusted for possible differential mortality of marked fish (Appendix B). The adjusted estimates are 123,000 adult pink salmon from the directly released component and 674,000 from the short-term reared component (Table 5). These estimates translate to an estimated survival rate from release to return of 14.0% for the directly released fish and 12.5% for the short-term reared group. These estimates do not include any possible contribution to the sport fishery or to stream escapement, because these areas were not sampled for marks.

Subtracting the 797,000 estimated hatchery contribution from the 1,080,000 estimated pink salmon returning to the Tutka area leaves an estimate of 283,000 wild Tutka Creek fish in the run. This number exceeds (by more than twice) the greatest return to Tutka in the years between 1966 and 1977, when hatchery fish began to make up a part of the run (Table 6). An estimate of the wild Tutka Creek run was obtained by using linear-regression analysis of historic returns to Tutka on returns to Seldovia, an adjacent subdistrict (Appendix C). The linear-regression estimate was 54,800 wild Tutka Creek fish. The latter estimate is within the range of 50,000-55,000 returning pink salmon predicted by the Homer, Commercial Fisheries Division, area management biologist, Tom Schroeder (pers. comm. 1981). Therefore, in addition to the direct estimates based on mark-recovery, something on the order

Table 5. Summary of estimates of the contribution of Tutka Hatchery pink salmon to different components of the run.

Stratum	Total fish	Estimated hatchery fish			
		Unadjusted		Adjusted[a/]	
		Direct	Reared	Direct	Reared
Commercial Fishery					
6/01-7/18	670,000	28,000	212,000	71,000	541,000
7/20-8/17	353,000	19,000	45,000	49,000	115,000
Sport	6,000				
Escapement	28,000	0	0	0	0
Eggtake	22,000	1,000	7,000	3,000	18,000
Overall	1,080,000	48,000	264,000	123,000	674,000

[a/] Estimate based on Commercial Fisheries Division harvest statistics and escapement surveys.

Table 6. Historic pink salmon returns in thousands of fish for Humpy, Tutka, Seldovia, and Port Graham streams in the Southern District from 1966 to present.

Year	Humpy	Tutka[a/]	Seldovia	Port Graham
1966	72.0	66.0	145.0	31.0
1967	65.0	43.0	67.0	6.0
1968	70.7	36.9	109.2	43.4
1969	6.4	43.5	91.0	6.0
1970	169.2	51.5	52.0	27.6
1971	56.4	27.0	58.4	14.2
1972	16.4	6.7	6.0	3.5
1973	81.2	26.5	33.9	20.9
1974	52.8	8.1	17.2	7.3
1975	404.9	110.2	481.6	45.6
1976	102.1	40.3	28.6	10.4
1977	128.7	42.4	83.3	65.4
1978	64.6	205.0[b/]	49.6	10.7
1979	458.0	455.5[b/]	213.8	142.7
1980	90.0	370.7[b/]	132.0	50.0
1981	350.0	1,079.5[b/]	165.0	52.0

a/ Overall average return 1966-1977 was 38,300 adults.

b/ Includes estimated hatchery contribution.

of 228,000 fish (283,000 minus 55,000) can be attributed to hatchery production.

DISCUSSION

Total Return

The pre-earthquake record total for pink salmon returns to Tutka Bay was 309,500 in 1962, and the post-earthquake record was 455,000 pinks in 1979. The 1981 total return of 1,080,000 pink salmon substantially surpasses both of these previous record returns.

Commercial Harvest

The 1981 commercial fishery management strategy was much more successful in reducing the build-up of fish in the lagoon than it had been for the previous 2 years. Six emergency-order commercial-fishing openings were required in Tutka Lagoon to harvest the excess concentrations of pink salmon that had avoided the Tutka Bay fishery. Approximately 120,100 fish were harvested from the lagoon (Table 7). However, the harvest accounted for only 12% of the total Tutka Bay commercial catch, while the 1979 and 1980 emergency commercial harvests were 36% and 25%, respectively, of the total Tutka Bay harvest (Dudiak and Quimby 1979; Boyle et al. 1980).

Mark-Recovery Data

Based upon adjusted mark-recoveries, the importance of sampling for marks during the entire return was again evident during the 1981 return. As in previous years (Dudiak and Quimby 1979), recovery rates of the different marks varied throughout the return.

Table 7. Emergency Tutka Lagoon openings for pink salmon, 1981.

Date	Duration	Boats	Fish
Jul 17	1.0 hour	34	44,000
Jul 23	1.5 hours	17	33,400
Jul 27	2.0 hours	6	12,000
Jul 28	1.5 hours	4	10,000
Aug 11	7.0 hours	2	13,500
Aug 17	4.0 hours	2	7,200
Total	17.0 hours	65	120,100

Hatchery Contribution

The estimated number of pink salmon contributed by Tutka Hatchery and Tutka Creek probably accounted for at least 797,000 of the estimated 1,080,000 pink salmon in the total Tutka Bay (241-16) return. However, the remaining 283,000 pink salmon in the total return may also have been largely of hatchery origin for the following reasons:

1. The pink salmon run to the Tutka Bay subdistrict is characteristically different in timing and/or harvest locations from runs to other nearby pink salmon streams. This precludes an overlapping with other runs or harvests (Schroeder 1979, pers. comm.). Therefore, it is probable that all pink salmon harvested in the Tutka Bay subdistrict originated from Tutka Creek or from Tutka Hatchery releases.

2. A natural-stock return of this size to Tutka Creek is unlikely. The highest post-earthquake natural return was 110,200 pink salmon in 1975 (Table 6). Consequently, it is likely that many of the 283,000 pink salmon unaccounted for originated from Tutka Hatchery releases. However, the 1962 run was greater than this figure, so natural runs of this magnitude are possible.

3. The linear-regression estimate of the Tutka natural run (54,800 fish) was consistent with predictions made by the Commercial Fisheries Division. This estimate, based on natural runs to subdistricts adjacent to Tutka, would be plausible if the introduction of hatchery fish did not influence the relationship between the Tutka natural stock and the natural stocks that return to adjacent subdistricts.

However, if the introduction of hatchery fish to Tutka has changed the basic relationships involved, then we must view this independent estimate with caution.

This was the first year that the estimated survival of directly released fish was greater than the estimated survival of the short-term reared group. For the 1979 and 1980 return years, the survival of short-term reared fish was estimated to be 1.7 and 2.5 times greater, respectively, than that of the directly released fish (Dudiak and Quimby 1979; Boyle et al. 1980). Differential predation is one factor that could account for this difference.

The direct-release fry were transported by boat out of Tutka Lagoon and released in Tutka Bay in mid-May. The release of these fish took place during ebbing tides that occurred in the evening and early morning. The fish were not exposed to predation by Pacific herring, *Clupea harengus pallasi*, in the lagoon or by Dolly Varden, *Salvelinus malma*, in the channel or in Tutka Creek. Hatchery personnel remained in the area for 30-45 minutes after the releases; no apparent predation was observed. However, the short-term reared fry were exposed to obvious Pacific herring predation in the lagoon during their releases. We observed Pacific herring actively feeding during the first release of short-term reared fry on the evening of 31 May 1980. After the release of 0.98 million fry, a gill net was deployed briefly to determine the extent of herring predation.

Stomachs of Pacific herring that had been caught in the vicinity of the release site contained numerous pink salmon fry. More extensive test gill netting was conducted before the 3 June

release of 2.01 million short-term reared fry. Approximately 500 Pacific herring (140-250 mm long) were collected in 30 m of gill net that had been fished during a 10-hour set. It was not possible to analyze the stomach contents of these fish. During the release, however, no predation was observed. Consequently, the remaining 2.36 million short-term reared fry were released the following evening. However, after the fry were released, large numbers of Pacific herring were again observed pursuing and feeding on the fry. Test gill netting conducted during the final release revealed that two size classes of herring (160 mm and 210 mm) were present in the lagoon. Stomach analyses indicated that the two size classes were consuming approximately 10 and 20 fry/fish each, respectively. We estimate that more than 10,000 herring were in the lagoon on the 4 June release.

The unexpected differences in the estimated survival rates between the two mark groups could also be because the marked fish representing the reared group were held separately from that group's unmarked fish before release. Thus, it is quite possible that the RV marked fish may not have represented the unmarked short-term reared fish adequately. Any differences between the marked and the unmarked short-term reared fish in their conditions of rearing, amount of food fed, and density could have resulted in differences in survival rates from release to adult return. In future studies, it will be important to mix marked and unmarked fish as soon as possible after marking.

The survival rates of the 1979 brood may have been the highest in the history of the Tutka Bay Lagoon Hatchery. The estimated hatchery survival rates were approximately twice that of the 1977 brood and approximately four times that of the 1978 brood (Dudiak and Quimby 1979; Boyle et al. 1980). Appendices E and F

summarize the short-term reared and direct-release programs, respectively, to date.

The factors leading to the record return of pink salmon to the Tutka subdistrict are not clear. When these fish were released as fry during the spring of 1980, plankton densities and water temperatures were not as great as those that yielded the previous record run in 1979 (Dudiak and Quimby 1979). Estuarine conditions during the spring of 1978, 1979, and 1980 are graphically depicted in appendices F, G, and H, respectively. Early marine-life conditions, ocean predation, and other unknown factors also influenced the survival rates.

Summary

A substantial increase in numbers of pink salmon returning to the Tutka Bay area was observed several years after construction of Tutka Bay Lagoon Hatchery in 1976. The highest return to date occurred in 1981 when an estimated 1,080,000 pink salmon returned to the Tutka Bay system.

Commercial fishermen harvested an estimated 1,024,000 pink salmon from the total Tutka Bay return in 1981. This was instrumental in setting a harvest record of 3.3 million pink salmon in lower Cook Inlet. Also, sport fishermen caught an estimated 6,000 pink salmon from Tutka Lagoon.

Mark-recovery sampling yielded a higher estimated survival rate for the direct-release group than for the short-term reared group for the first time in the history of the project. Observed predation by Pacific herring on short-term reared fry was thought to have caused a greater initial loss of juvenile fish than that

of the direct-release group.

Linear-regression analysis of pink salmon returning to Tutka Bay and adjacent streams was used to estimate the number of wild Tutka Creek pink salmon. The estimated number of wild pink salmon returning was within the range of the Commercial Fisheries Division's prediction. The regression analysis was useful, since no wild fry were marked for the evaluation program.

The recoveries of marks from hatchery releases were unable to account for 283,000 pink salmon in the total run.

The overall survival rates for the direct-release and short-term reared groups were estimated to be 14.0% and 12.5%, respectively. These are the highest survival rates yet achieved for the Tutka Bay Lagoon Hatchery and are probably among the highest recorded for hatchery salmon that have been released on a large scale in the Pacific Northwest.

The location of Tutka Hatchery, the timing of the Tutka Bay pink salmon run, and the historic salmon run information for lower Cook Inlet allowed for a comprehensive evaluation of hatchery production. The proximity of the hatchery to the Gulf of Alaska prevented the interception of Tutka salmon by "Cape fisheries". Timing and harvest of the Tutka salmon run had little overlapping with other runs from nearby areas; these factors minimized the interception of those runs in the Tutka Bay fishery.

Historic information on run strengths for Tutka Bay and nearby streams was valuable in estimating the numbers of fry in the wild run, especially in a year when wild fish had no marks.

Recommendations

1. Evaluation of hatchery contributions that rely solely on mark-recovery data can underestimate hatchery returns. Mark-recovery data must incorporate an estimated differential mortality or mark loss (handicap factor) for marked fish as compared to the unmarked fish that they are supposed to represent.

2. The timing of the run can vary between mark groups; therefore, sampling for marks in the fishery should be stratified over the entire run.

3. When possible, wild fry should be captured and marked so that adult quality as well as survival rates of the returning fish can be compared to those fish resulting from hatchery production.

4. Marked fish should be mixed with unmarked fish as soon as possible after marking so that the assumption that they represent the unmarked fish will be more tenable.

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REFERENCES

Boyle, L.R., N.C. Dudiak and A.J. Quimby. 1980. Tutka Lagoon Hatchery 1980 Adult Return Evaluation. Unpublished Report. Alaska Department of Fish and Game, FRED Division; Homer, Alaska.

Draper, N.R. and H. Smith. 1981. Applied Regression Analysis, 2nd ed. John Wiley and Sons, New York, NY.

Dudiak, N.C. and A.J. Quimby. 1979. Tutka Lagoon Hatchery 1979 Adult Return Evaluation. Unpublished Report. Alaska Department of Fish and Game, FRED Division; Homer, Alaska.

Schroeder, T.R. 1979. Personal Communication. Alaska Department of Fish and Game, Commercial Fisheries Division; Homer, Alaska.

_____. 1981. Personal Communication. Alaska Department of Fish and Game, Commercial Fisheries Division; Homer, Alaska.

Zar, J.H. 1974. Biostatistical analysis. Prentice-Hall, Inc., Englewood Cliffs, NJ.

APPENDIX A

Estimating the Contribution of Hatchery Fish to the Return Based on Mark-recovery Data

For analyzing the Tutka mark-recovery data, the adult run was divided into three components, or strata (*see* test).

The contribution (number of fish) from a single release group to a single stratum of the adult return may be estimated from recoveries of marked fish by a two-step process. First of all, since marks are recovered from only a portion of the adult run, the total number of marks must be estimated in the following way:

$$M = m\ (N/n),$$

where M is the estimated number of marks in the stratum,
m is the number of marks recovered in the sample that were derived from the given release group,
N is the total number of fish in the stratum, and
n is the number of fish in sample is the stratum.

Next, the estimated marks in the stratum must be expanded to account for the fact that only a fraction of the released fish were marked:

$$C = M\ (R/r),$$

where C is the estimated hatchery contribution,
R is the number of fish released in the group, and
r is the number of fish marked in the group.

As an example of the above procedure, consider the contribution of the short-term reared group to the stratum that includes the commercial fishery from 1 June through 18 July. For this computation we have (Table 3):

m = 193 RV marks recovered between 1 June and 18 July
N = 670,456 fish caught in the period
n = 116,566 fish sampled for marks in the period
M = (193) X (670,456) / (116,566) = 1,110

and (Table 1):

R = 5,391,000 short-term reared fish released
r = 28,196 short-term reared fish marked
C = (1,100) X (5,391,000) / (28,196) = 212,245.

So, the unadjusted estimate of the contribution of short-term reared hatchery fish to the commercial fishery from 1 June through 18 July is 212,000 fish (where the final number has been rounded off to reflect its true precision). All of the unadjusted estimates in Table 5 were computed in this manner.

APPENDIX B

Adjustment of Mark Recoveries to Account for Possible Differential Survival of Marked and Unmarked Fish

Two characteristics of a good mark are that it remain unaltered during the lifetime of the fish and that it not adversely affect the survival of the fish. A chi-square test (Zar 1974) was used to compare the proportion of marked fish in the 1980 releases (including wild fish) with the proportion of marked fish in the 1981 hatchery brood fish. Assuming no dilution of the brood fish by other stocks, the significant difference in the two proportions (chi-square = 40.4, d.f. = 3, $p < .001$) indicated that marked fish did not survive as well as their unmarked counterparts or that some marks were lost to regeneration. A second chi-square indicated there was no significant difference (chi-square = 4.9, d.f. = 2, $p < .05$) in the proportion of marks recovered for reared or direct-release fry. Thus, a single differential mark-loss rate was estimated for the 1980 mark releases by comparing the actual marks recovered during egg stripping with the expected marks recovered, provided the marked fish had returned in the same proportion as released. From the data we estimated that the marked fish survived at 39% of the rate of unmarked fish. Inverting this quantity gives an expansion factor of 2.56, which was used to adjust the estimates of hatchery contribution.

APPENDIX C

LIST OF APPENDIX C TABLES

Linear regression analysis of the relationship of Tutka pink salmon returns to the returns to nearby subdistricts.[a/]

This analysis is based on the idea that there might be a relationship between the size of the natural pink salmon run to Tutka Bay and the sizes of the runs to adjacent subdistricts. If there were a relationship, an equation for it could be estimated using data from the period before the beginning of hatchery operations. Then, after the hatchery is operating, the runs to the nearby subdistricts could be used as independent variables in the equation, and an estimate of the natural run to Tutka could be obtained. This would provide auxiliary information on the hatchery contribution to the Tutka run.

Linear-regression analysis was used to estimate the relationship between the Tutka returns and the returns to adjacent subdistricts. Three adjacent subdistricts, along with Tutka, account for most of the pink salmon returns to the Southern District. These districts are Humpy, Seldovia, and Port Graham. The most general linear-regression model of the relationship would be:

$$T = b_0 + b_1 H + b_2 S + b_3 P, \qquad (1)$$

where T, H, S, and P represent the total wild returns to Tutka, Humpy, Seldovia, and Port Graham respectively, and b_0, b_1, b_2, and b_3 are constant coefficients. Another possible linear-regression model would use the sum of the returns to the adjacent subdistricts as the independent variable, i.e.:

$$T = a + b(H + S + P) \qquad (2)$$

[a/] By Kit Rawson, Regional Biometrician, FRED Division, ADF&G, Anchorage

The constant coefficients in (1) or (2) may be estimated using data from before the initiation of hatchery operations. The estimation of the coefficients in a multiple-regression model, such as (1), must be done with care, especially if the results are to be used with further data. Draper and Smith (1981) discuss methods of estimating multiple linear-regression coefficients. One method, backward elimination, is appropriate when there are a small number of independent variables, and that was the method used in this study. The rationale behind this method and its application are discussed fully by Draper and Smith and will not be discussed in detail here.

This analysis uses the data on pink salmon returns to the far subdistricts of the southern district for the years 1966-1977 (Table 6). Information is available on the pink salmon runs in the southern district before 1966, but it was not used because the March 1964 earthquake might have damaged the area available for spawning; therefore, the relative run strengths are likely to have been different for brood years before 1964. The years after 1977 were not used because the first fish returned to the Tutka Hatchery in 1978.

The results of the backward-elimination procedure applied to the model (1) regression of the southern district data are summarized in Table C-1. Essentially, this procedure consists of first estimating the coefficients b_1, b_2, and b_3 for the "full model" with all three independent variables in the equation. Then an "F to remove" is calculated for each independent variable, and the variable with the smallest F to remove is eliminated from the equation provided that the F to remove is less than some predetermined value (*see* Draper and Smith 1981). The criterion used in this analysis was that the F to remove be smaller than the 95% point of the F-distribution with the appropriate degrees

Table C-1. Results of the backward elimination procedure applied to the linear regression of Tutka returns on Humpy, Seldovia, and Port Graham returns for 1966-1977.

Step No.	Variables in equation	Mean Square		F Ratio	F to remove		
		Regression	Residual		H	S	P
1	H, S, P	2,255.0	180.6	12.5	.29	5.84	.16
2	H, S	3,367.9	163.8	20.6	.51	6.50	
3	S	6,651.9	155.8	42.7		42.7	

H = Humpy
S = Seldovia
P = Port Graham

of freedom. New coefficients are estimated from the reduced set of independent variables, and the procedure continues until no more independent variables can be removed. As Table C-1 shows, in this case, both Humpy and Port Graham were removed from the equation, and the final model (1) solution uses just Seldovia as the single independent variable.

The results of the linear regression of Tutka pink salmon returns on Seldovia returns are summarized in Table C-2. The estimated equation follows:

$$T = 22.96 + .1231(S), \qquad (3)$$

where T and S represent, respectively, the Tutka and Seldovia returns in thousands of fish.

The mean square of the residuals (MSR) from this equation is 155.817, with 10 degrees of freedom. From this the standard errors of the coefficients, the r squared, and the standard errors of any estimate derived from the equation may be determined (Table C-2). Based upon the results of this particular analysis the formula for the standard error of an estimate of Tutka wild returns (see Draper and Smith 1981, equation 1.4.10) as follows:

$$s.e.(T) = 12.48\left[\frac{1}{12} + \frac{(S - 97.77)^2}{178310.8}\right]^{\frac{1}{2}}, \qquad (4)$$

where S is the value of Seldovia returns for the particular year and $\hat{T}$ is the estimate of Tutka wild returns for the particular year, calculated from (3). Equation (4) was used to calculate the confidence intervals for the estimated 1981 Tutka wild return given in the body of this report.

Table C-2. Results of linear regression of Tutka returns on Seldovia returns for 1966-1977.

Estimated Equation: $T = 22.96 + .1931\ (S)$

R Squared = 0.81

Mean Square of Residuals = 155.817

$\hat{\alpha} = 22.96$ standard error = 4.62

$\hat{\beta} = 0.1931$ standard error = .0296

Finally, as discussed above, it is possible to calculate a different regression based on comparing Tutka returns with the sum of Humpy, Seldovia, and Port Graham returns (equation [2]). The results of this regression are presented in Table C-3. The mean square of the residuals from this regression is only slightly larger than that obtained by regressing Tutka on Seldovia alone. This indicates that model (2) is as good a candidate for the preferred model in this kind of analysis as model (1). Further investigations into the relationship between Tutka returns and those from nearby subdistricts are necessary before a final decision can be made.

Table C-3. Results of linear regression of Tutka returns on the sum of Humpy, Seldovia, and Port Graham returns for 1966-1977.

Estimated Equation: $\hat{T} = 18.56 + .1042\ (H + S + P)$

R Squared = 0.81

Mean Square of Residuals = 156.57

$\hat{\alpha} = 18.56$	standard error =	5.08
$\hat{\beta} = 0.1042$	standard error =	.0160

APPENDIX D

Table D-1. Mean lengths and weights of marked fish in the Tutka Bay return 1979, 1980, and 1981.

Return Year	MALE			FEMALE		
	Direct Release	Short-term Reared	Random Unmarked	Direct Release	Short-term Reared	Random Unmarked
1979	mean wt = 1.49 kg	1.48	1.54	1.49	1.37	1.43
	$N_{\bar{x}}$ = 116	76	112	159	112	132
	mean lth = 457.1 mm	452.2	462.2	457.4	452.6	459.4
	$N_{\bar{y}}$ = 125	91	124	184	122	144
1980	mean wt = 1.28 kg	1.29	1.41	1.21	1.28	1.34
	$N_{\bar{x}}$ = 32	39	67	38	57	77
	mean lth = 433.6 mm	437.1	450.5	431.3	443.2	443.3
	$N_{\bar{y}}$ = 33	43	67	38	58	77
1981	mean wt = 1.39 kg	1.53	1.56	1.38	1.41	1.41
	$N_{\bar{x}}$ = 120	108	58	132	111	59
	mean lth = 438.6 mm	451.7	456.2	445.2	448.1	452.7
	$N_{\bar{y}}$ = 120	120	58	132	111	59

APPENDIX E

Table E-1. Summary of Tutka Lagoon Hatchery pink salmon short-term rearing program, 1978-1980.

Release Data	1978	1979	1980
Release Date	10, 11 June	3, 4 June	31 May
Length of rearing	42 days	39 days	36 days
Number released	2.9 million	4.6 million	5.4 million
Survival in Pens	95%	96%	95%
Size at release	0.53 g	0.40 g	0.41 g
Estuarine Conditions			
Surface water temperature	10°C - 12°C	7°C - 9°C	8°C - 10°C
Plankton density	10,000 - 42,000/m^3	1,500/m^3	1,500/m^3
Organisms	Copepods:Calanoid 80% Harpacticoid 10%	Copepods:Calanoid 80% Harpacticoid 10%	Copepods:Calanoid 80% Harpacticoid 10%
Hatchery Adult Return Data			
Total return	455,000 (1979)	371,000 (1980)	1,080,000 (1981)
Estimated adults (hatchery)	270,000 (1979)	230,500 (1980)	674,000 (1981)
Survival rate	9.2%	4.9%	12.5%
Size male	1.48 kg 452.2 mm	1.29 kg 437.1 mm	1.53 kg 451.7 mm
female	1.37 kg 452.5 mm	1.28 kg 443.2 mm	1.41 kg 446.1 mm

APPENDIX F

Table F-1. Summary of Tutka Lagoon Hatchery pink salmon direct fry release program, 1978-1980.

Release Data	1978	1979	1980
Release Date	March - mid-May	April - early June	15, 18 May
Number released	1.9 million	4.8 million	0.88 million
Size at release	0.24 g	0.23 g	0.21 g
Release site	Tutka Bay: 105,000 Tutka Creek: 1,828,100	Tutka Creek	Tutka Bay
Estuarine Conditions			
Surface water temperature	5°C - 8°C	4.6°C - 8.0°C	5.5°C - 6.0°C
Plankton density	330 - 2,900/m^3	300 - 1,500/m^3	439 - 1,500/m^3
Organisms	Copepods:Calanoid 80% Harpacticoid 10% Calanoid Nauplii 10%	Copepods:Calanoid 70% Harpacticoid 10% Barnacle Nauplii 20%	Copepods:Calanoid 60% Harpacticoid 5% Barnacle Nauplii 35%
Hatchery Adult Return Data			
Total return	455,000 (1979)	371,000 (1980)	1,080,000 (1981)
Estimated adults (hatchery)	101,000 (1979)	99,000 (1980)	123,000 (1981)
Survival rate	5.3%	2.1%	14%
Size male	1.55 kg 459.46 mm	1.28 kg 433.55 mm	1.39 kg 438.60 mm
female	1.47 kg 458.12 mm	1.21 kg 431.32 mm	1.38 kg 445.59 mm

APPENDIX G

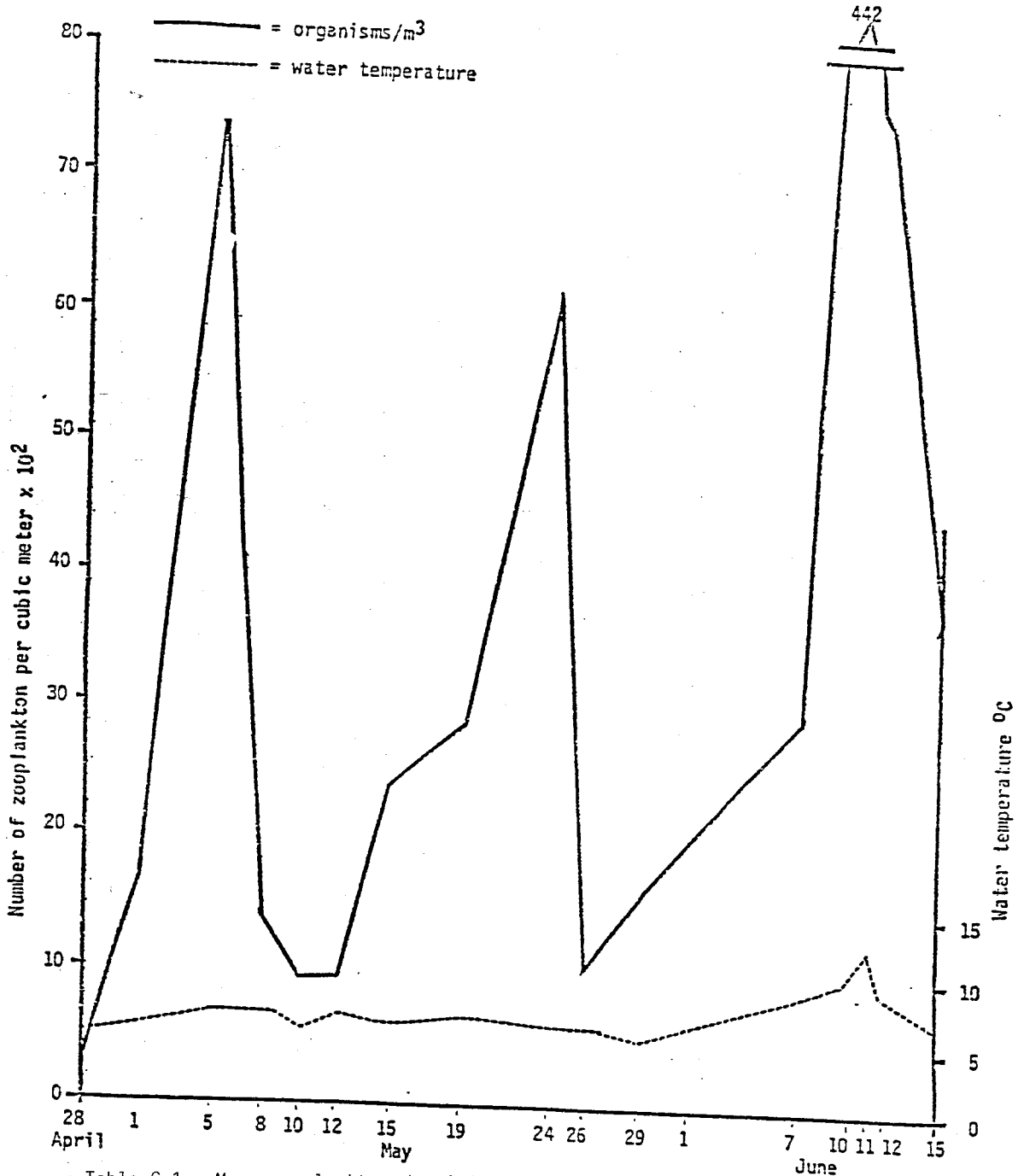

Table G-1. Mean zooplankton densities and surface water temperatures from all stations, Tutka Bay and Lagoon, Spring, 1978.

APPENDIX H

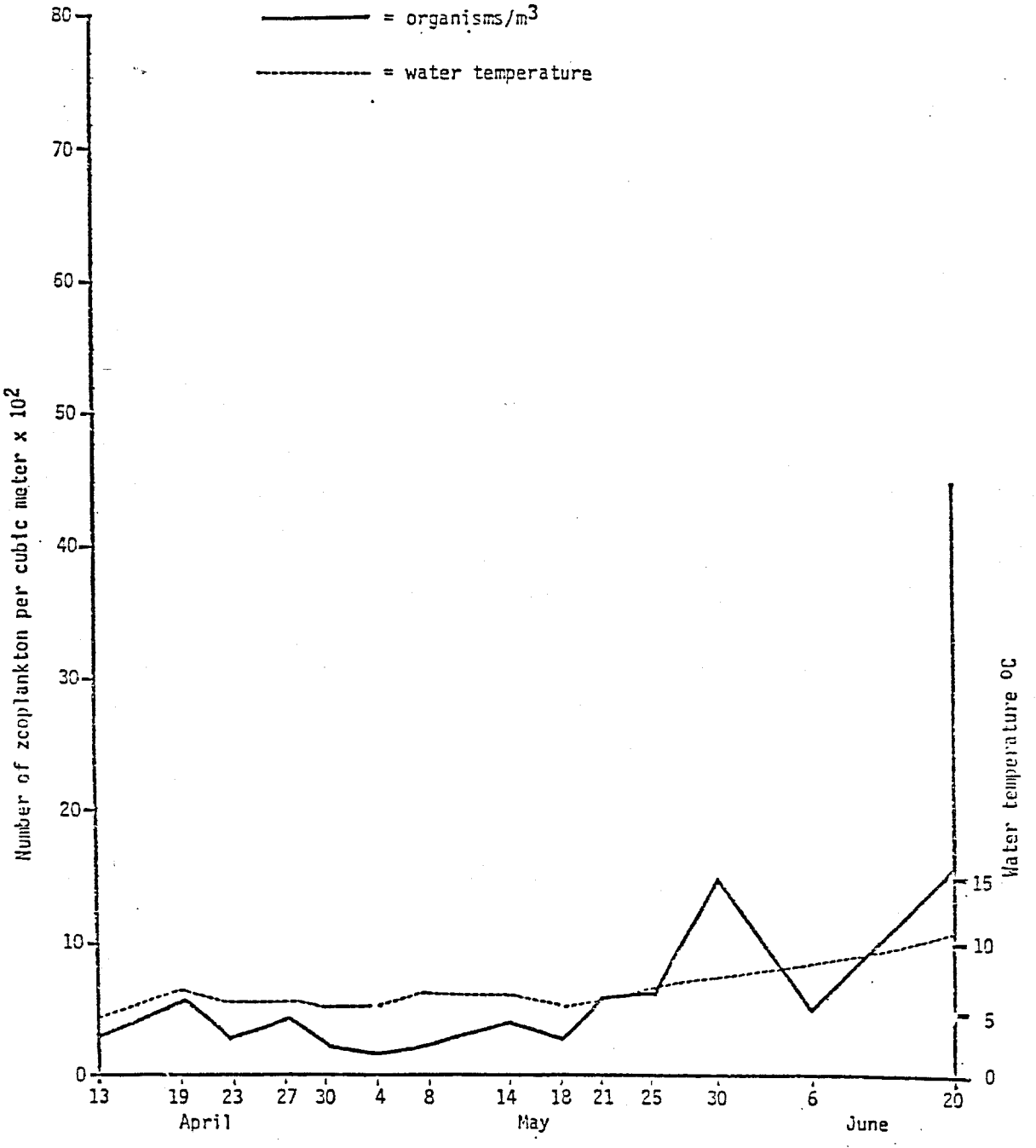

Table H-1. Mean zooplankton densities and surface water temperatures from all stations, Tutka Bay and Lagoon, Spring, 1979.

APPENDIX I

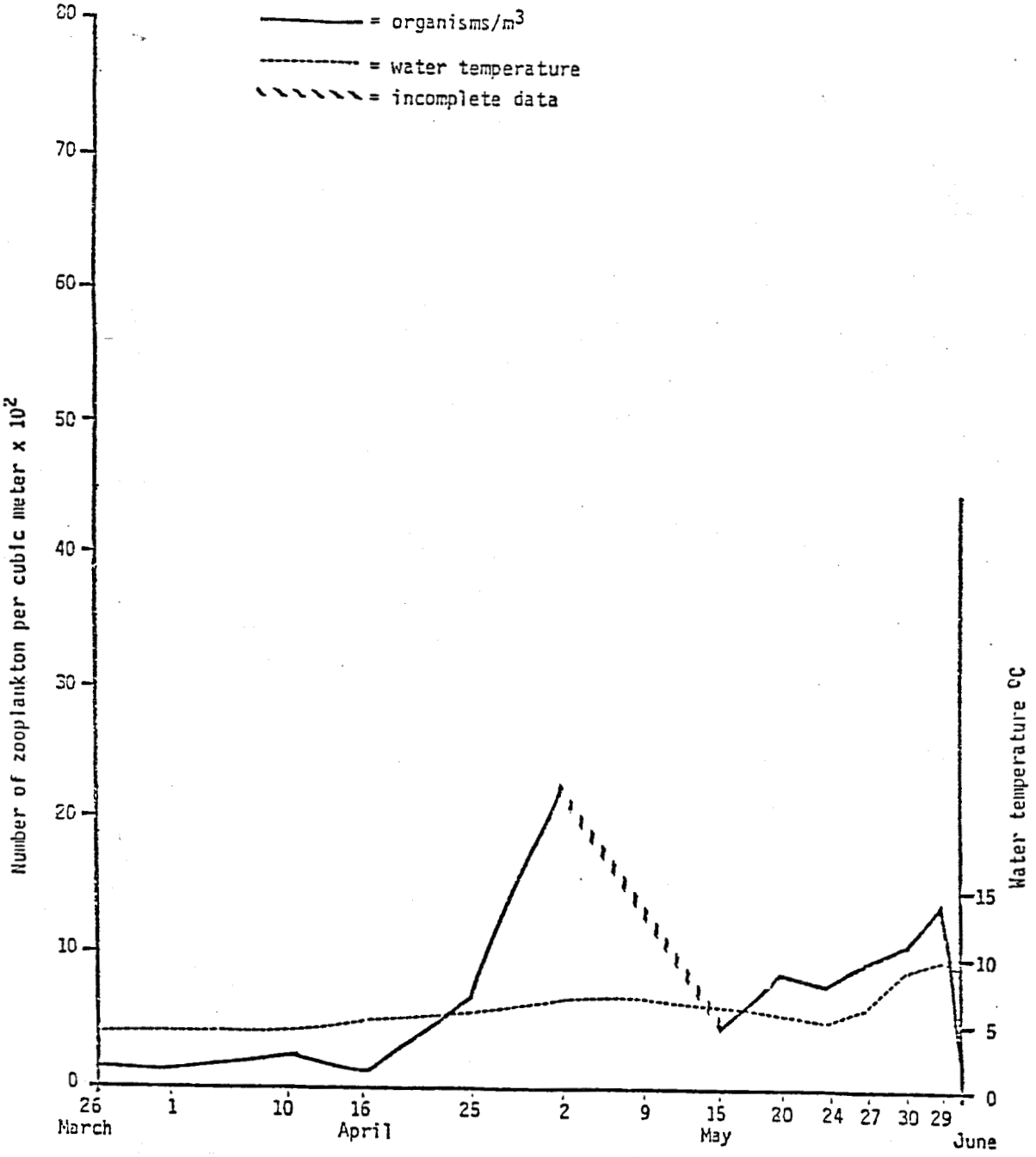

Table I-1. Mean zooplankton densities and surface water temperatures from all stations, Tutka Bay and Lagoon, Spring, 1980.

APPENDIX J

Table J-1. Pink salmon release and return data from Tutka Lagoon Hatchery, 1977-1981.

Brood year/ Release date	Number stocked	Year return	Hatchery Fish Total adults	Hatchery contribution	Hatchery Commercial	Hatchery Sport	Egg-take Escapement	Percent ocean survival
Tutka Creek 1976/77	4,299,100 D.R.	1978	151,000 205,000	74%	164,862	1,500	21,000 15,000	3.5[a/]
Tutka Creek 1977/78	1,933,000 D.R.[b/] 2,933,800 S.T. 1,412,800 W.F.	1979	370,000 455,000	81%	421,816	2,000	21,000 10,600	5.0 D.R. 9.0 S.T. 6.0 W.F.
Tutka Creek 1978/79	4,796,109 D.R. 4,631,477 S.T. 1,964,800 W.F.	1980	330,000 371,000	89%	321,513	5,000	26,897 17,259	2.1 D.R. 5.0 S.T. 2.1 W.F.
Tutka Creek 1979/80	877,849 D.R. 5,391,114 S.T. 1,368,000 W.F.	1981	797,000 1,080,000	74%	797,000	6,000	22,000 28,000	14.0 D.R. 12.5 S.T. 21-4.7 W.F.
Tutka Creek 1980/81	1,360,849 D.R. 8,487,392 S.T. 778,000 W.F.	1982	N/A	N/A	N/A	N/A	N/A	N/A

[a/] Survival estimate based on comparison to known wild fry data for Tutka Creek.
[b/] D.R. = direct hatchery release
S.T. = short-term reared
W.F. = wild fry