Canadian Technical Report of

Fisheries and Aquatic Sciences No. 1620

May 1988

THE INFLUENCE OF TIME AND SIZE AT RELEASE OF JUVENILE COHO SALMON (*Oncorhynchus kisutch*) ON RETURNS AT MATURITY; RESULTS OF STUDIES ON THREE BROOD YEARS AT QUINSAM HATCHERY, B.C.

by

R. B. Morley, H. T. Bilton, A. S. Coburn, D. Brouwer,

J. Van Tine[1], and W. C. Clarke

Department of Fisheries and Oceans

Fisheries Research Branch

Pacific Biological Station

Nanaimo, British Columbia V9R 5K6

[1]Salmon Enhancement Program
Operations Branch
Quinsam Hatchery
Campbell River, British Columbia
V9W 5C1

Cat. No. Fs 97-6/1620E ISSN 0706-6457

Correct citation for this publication:

Morley, R. B., H. T. Bilton, A. S. Coburn, D. Brouwer, J. Van Tine, and W. C. Clarke. 1988. The influence of time and size at release of juvenile coho salmon (Oncorhynchus kisutch) on returns at maturity; results of studies on three brood years at Quinsam Hatchery, B.C. Can. Tech. Rep. Fish. Aquat. Sci. 1620: 120 p.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT'D)

ABSTRACT

Morley, R. B., H. T. Bilton, A. S. Coburn, D. Brouwer, J. Van Tine, and W. C. Clarke. 1988. The influence of time and size at release of juvenile coho salmon (Oncorhynchus kisutch) on returns at maturity; results of studies on three brood years at Quinsam Hatchery, B.C. Can. Tech. Rep. Fish. Aquat. Sci. 1620: 120 p.

Juvenile one year old coho salmon (Oncorhynchus kisutch) were released from Quinsam Hatchery on April 20, May 10, May 30, and June 19 in both 1980 and 1981 and on May 30, 1983; fish of each release were graded to three size categories and coded wire tagged. The resulting returns to the catch and escapement were examined for influences of time of release and size of juveniles at release. While there were differences in total survival among studies (i.e. brood years), the relative differences associated with time and size at release were quite consistent within studies. Time of release strongly influenced survival. Response surface analysis indicated maximum adult returns from juveniles released on June 5; returns increased gradually until this date and then decreased sharply. The effect of juvenile size on adult returns was minor, with slightly higher returns from smaller juveniles indicated, especially for early releases. The incidence of jacks increased with earlier release and was strongly affected by juvenile size, the incidence being higher for larger juveniles; the size-associated differences observed in the adult returns appear to have been largely attributable to these differences in the incidence of jacks and their effect on production of adults. Maximum adult biomass was indicated for releases made 3 - 5 days in advance of the date for maximum adult returns, reflecting the larger size of adults from earlier releases. Geographic and gear type distribution in the adult fishery was quite consistent between years; the most notable feature was the increasing proportion of the catch taken in the southern area sport fishery associated with later releases. Seawater challenge tests indicated that differences in return rate among the four release dates did not result from changes in seawater adaptability of the smolts, which was at its optimum about seven weeks in advance of the optimum release date; rearing at lower temperatures to delay smolting is suggested as a possible means of further increasing survival.

Key words: coho, size at release, time of release, survival, precocious males, jack, salmon fisheries, sex ratios, seawater challenge, blood sodium

RÉSUMÉ

Morley, R. B., H. T. Bilton, A. S. Coburn, D. Brouwer, J. Van Tine, and W. C. Clarke. 1988. The influence of time and size at release of juvenile coho salmon (Oncorhynchus kisutch) on returns at maturity; results of studies on three brood years at Quinsam Hatchery, B.C. Can. Tech. Rep. Fish. Aquat. Sci. 1620: 120 p.

À la piscifacture Quinsam on a remis à l'eau le 20 avril, le 10 mai, le 30 mai et le 19 juin 1980 et 1981 et le 30 mai 1983 de jeunes saumons cohos (Oncorhynchus kisutch) âgés d'un an à chaque remise à l'eau, les poissons étaient classés dans trois catégories de taille puis étaient marqués à l'aide d'étiquettes métalliques codées. On a examiné les taux de retour consécutifs dans les prises et dans la remonte pour déterminer l'influence du moment de remise à l'eau et de la taille des jeunes relâchés. Bien qu'on ait observé des différences dans la survie totale entre les études (c.-à-d. les années de génération), les différences relatives liées au moment et à la taille lors de la remise à l'eau ont été assez constantes dans les études. Le moment de la remise à l'eau a influé considérablement sur la surive. L'analyse superficielle des réactions a montré qu'il y avait des remontes maximales d'adultes avec les jeunes libérés le 5 juin; les remontes ont augmenté graduellement jusqu'à cette date puis ont diminué nettement. L'effet de la taille des jeunes sur les remontes di adultes a été mineure, des remontes légèrement plus élevées étant enregistrées pour les jeunes plus petits, particulièrement les remises à l'eau précoces. La fréquence des jeunes saumons mâles a augmenté lorsque la remise à l'eau était précoce et dépendait beaucoup de la taille des jeunes, la fréquence étant plus élevée pour les jeunes de taille plus grande; les différences liées à la taille observées dans les remontes d'adultes semblent. Avoir été grandement imputables à ces différences dans la fréquence des jeunes saumons mâles et à leur effet sur la production d'adultes. La biomasse maximale des adultes a été enregistrée pour les remises à l'eau faites de 3 à 5 jours avant la date des remontes maximales d'adultes, ce qui reflète la taille plus grande des adultes provenant de remises à l'eau precoses. La distribution géographique et des types d'engins pour la pêche des adultes a été tout à fait constante d'une année à l'autre; la caractéristique la plus remarquable a été la proportion croissante des prises réalisées dans le secteur sud de pêche sportive qui était liée aux remises à l'eau tardives. Les tests de provocation a l'eau de wer ont montré que les différences observées dans le taux de remonte entre les quatre dates de remise à l'eau ne résultaient pas de changement dans la capacité d'adaptation à l'eau de mer des saumoneaux, qui était optimale environ sept semaines avant la date optimale de remise à l'eau; on propose que l'élevage s'effectue à des temératures inférieures pour retarder le passage au stade de saumoneau ce qui serait un moyen possible d'accroître davantage la survie.

Mots-clés: saumon coho, taille à la remise à l'eau, moment de la remise à l'eau, survie, mâles précoces, jeune saumon mâle, pêcheries de saumon, rapports des sexes, provocation à l'eau de mer, sodium du sang

INTRODUCTION

A study at Rosewall Creek experimental hatchery, Vancouver Island, British Columbia, showed that both the time of release and size at release of juvenile coho salmon influenced their subsequent growth, survival, and age at maturity. Substantial increases in production could be achieved by releasing fish at optimal times and sizes (Bilton and Jenkinson 1976; Bilton 1978; Bilton 1980; Bilton et al. 1982). As part of a Federal-Provincial Salmonid Enhancement Program, similar studies were undertaken at two production hatcheries in British Columbia: Quinsam Hatchery, on north-east Vancouver Island, and Capilano Hatchery, on the southern mainland. The objective of these studies was to determine whether the Rosewall results could be applied to improve the effectiveness of existing or proposed salmonid enhancement facilities or whether site specific and/or annual (i.e. brood year) variation in the the effects of time and size at release could be expected. The studies were conducted on multiple brood years at each location to examine for annual variability. Quinsam and Capilano were selected since they differ in culture methods as well as location - Quinsam Hatchery uses ground water over the winter and is therefore considered a "warm-water" hatchery; rearing temperatures during this period are much warmer than they are at Capilano, a "cold-water" hatchery, where ground water is not available.

This report deals with the studies at Quinsam Hatchery. These studies consisted of a series of releases in 1980 (1980 study) and in 1981 (1981 study) designed to examine the simultaneous effects of both time and size at release. An additional single release of three size categories was made in 1983 (1983 study) to further examine the effects of size at release only. The 1980 study has been reported by Bilton et al. (1984) and the reader is referred to that source for a full description of the study and detailed results. Descriptions and results of the 1981 and 1983 studies are presented in Parts I and II, respectively, of this report. The combined results of the three studies are discussed in Part III. The studies at Capilano Hatchery were begun one year later than the Quinsam studies and have been reported to the release stage only (Bilton et al. 1982c, Bilton et al. 1983).

PART I. RELEASES MADE IN 1981

MATERIALS AND METHODS[1]

DONOR STOCK AND REARING

A part of the production stock of 1979 brood Quinsam Hatchery coho was used for the experiment. Fish were reared in four Burrows ponds at standard production densities using normal hatchery water; Oregon Moist Pellets (OMP) were fed according to routine hatchery schedules.

EXPERIMENTAL DESIGN

Three size groups of juveniles were released at each of four times, using fish from a different pond for each release. Size groups were replicated three times within each release, giving 9 groups per release, 36 groups in total. Each group was tagged distinctively using coded wire nose tags (CWT's) and all tagged fish were marked externally by removal of the adipose fin. Size groups were obtained by grading into small, medium, and large length categories (details follow). The design is outlined below:

	Release date and approximate number of fish			
Size Category	Apr 20	May 10	May 30	June 19
Small	4,000	4,000	4,000	4,000
	4,000	4,000	4,000	4,000
	4,000	4,000	4,000	4,000
Medium	4,000	4,000	4,000	4,000
	4,000	4,000	4,000	4,000
	4,000	4,000	4,000	4,000
Large	4,000	4,000	4,000	4,000
	4,000	4,000	4,000	4,000
	4,000	4,000	4,000	4,000

[1]Details of this study up to and including release have been previously reported (Bilton et al. 1982b); the reader is referred to that source for more detailed information.

MARKING, TAGGING AND RELEASE

Fish for all releases were marked and tagged during November, 1980. Fork length-frequency distributions for fish from each pond were used to establish size categories at the time of tagging. Five percent from each tail of the distribution was rejected (to remove extreme values) and the remaining distribution divided into three 30% portions classified as small, medium, or large.

Fish were anaesthetized before marking and tagging. The adipose fin was first removed, fish were then graded to size category and the appropriate nose tags applied. They were then returned to the pond from which they originated and remained there until release. Approximately one-half of the fish in each pond was marked and tagged; unmarked fish were left in the ponds and released along with the marked fish. All marked mortalities between time of marking and release were examined for CWT's, which were extracted and read; release figures were adjusted accordingly.

Releases were made at approximately 1800 h on Julian days 110 (April 20), 130 (May 10), 150 (May 30), and 170 (June 19), 1981. A sample of 1,000 marked fish was removed from each pond on the day of its release. These fish were killed and frozen; the CWT's were later removed and read and the fork length, weight, and sex of each fish was determined. Tag retention was estimated from the proportion of marked fish in the sample lacking tags and the estimates of numbers of tagged fish released were adjusted accordingly. Other samples were collected for health evaluation, histopathological studies, proximate analysis, and seawater adaptability tests. Estimates of size, sex composition, and numbers released for each of the 36 groups are given in Tables I-1a to I-1d. Analysis of sex ratios and results of health evaluation and seawater adaptability tests are summarized below.

HEALTH, SEAWATER ADAPTABILITY, AND SEX RATIO OF JUVENILES

Health

This information was provided by the Diagnostic Services Unit of the Pacific Biological Station, based on results of health evaluation of juveniles just prior to release. Eye damage was evident to some degree (2% to 10% of randomly sampled fish) in fish of all releases; this was judged to be primarily a result of physical damage. Bacterial kidney disease was detected in fish of the April 20 and May 10 releases, but at a low incidence. Fish health tended to deteriorate the longer fish were held, as evidenced by a greater degree of eye damage and a light myxobacterial infection in fish of the last release. Microhematocrit values (a general indicator of fish health) were all within normal ranges.

Seawater adaptability

Seawater challenge tests were performed on fish sampled from March until early August, and included tests at the time of each release. In these tests, blood plasma sodium levels after 24 h exposure to seawater were used as a measure of ability to osmoregulate (Blackburn and Clarke 1987). Adaptability varied considerably with season but somewhat less with fish size (fork length or weight). During the period of the four releases, all groups had good seawater adaptability; there was only a slight change in performance during this time and no correlation between fork length or weight and plasma sodium after challenge. Response surface analysis of the plasma sodium data from all tests indicated that seawater adaptability reached a maximum during mid-April, just prior to the first release.

Sex ratios

The sex ratios observed in the release samples were examined for both equality between groups and for deviations from a 50:50 male to female ratio. The actual numbers of males and females in the sample from each replicate are given in Tables I-1a to I-1d; the proportion of males in each sample is given in the following table (values in parentheses are for pooled replicates):

	Size			
Release	Small	Medium	Large	Combined
April 20	.4634	.4914	.4634	.4735
(1)	.4538	.4286	.5644	.4811
	.4792	.5370	.4891	.5034
	(.4646)	(.4876)	(.5032)	(.4856)
May 10	.5413	.4922	.5042	.5112
(2)	.4904	.5048	.5833	.5289
	.4938	.5259	.5437	.5233
	(.5102)	(.5072)	(.5439)	(.5208)
May 30	.4779	.4828	.4779	.4795
(3)	.4505	.4331	.5180	.4695
	.4429	.4220	.5467	.4646
	(.4592)	(.4460)	(.5107)	(.4717)
June 19	.4153	.5043	.5625	.4928
(4)	.3902	.4909	.5051	.4578
	.4717	.5053	.5631	.5132
	(.4236)	(.5000)	(.5446)	(.4873)
Combined	.4627	.4848	.5258	.4915

A 2-way (time x size) ANOVA was first performed, using the proportion of males in each of the 36 groups as a single observation[1]:

Source of variation	Degrees of freedom	Sum of squares	Mean square	F	P
Releases	3	0.0109	0.0036	3.10*	0.0455
Sizes	2	0.0244	0.0122	10.43***	0.0006
Releases x sizes	6	0.0099	0.0017	1.41	0.2511
Error	24	0.0281	0.0012		
Total	35	0.0733			

The effect of size was highly significant; the lack of interaction indicates the uniformity of size effects between releases, the proportion of males increasing with increasing fish size. Release effect was only marginally significant and was insignificant when interaction was pooled with error (F=2.87; d.f.=3,30; p=.053).

Next, the sex ratios were examined for deviations from a 50:50 male to female ratio using heterogeneity G-tests (Sokal and Rohlf 1981), which included further tests of equality of ratios between groups. These tests were done twice, once to test ratios within and between sizes (using the total male and female counts for each size) and once to test ratios within and between releases (using total male and female counts for each release).

a) <u>Size effects</u>

Size	Male	Female	n	Proportion male		d.f.	G	p
Small	570	662	1232	(.4627)		1	6.8765**	0.01
Medium	652	693	1345	(.4848)		1	1.2500ns	0.26
Large	683	616	1299	(.5258)		1	3.4573ns	0.06
					Total	3	11.5838**	0.01
Sum	1905	1971	3876	(.4915)	Pooled	1	1.1239ns	0.28
					Heterogeneity	2	10.4599**	0.01

[1]In this analysis testing is for equality of sex ratios only, it is not a test of a 50:50 sex ratio.

b) Release effects

Release	Male	Female	n	Proportion male	d.f.	G	p
1	454	481	935	(.4856)	1	0.7798ns	0.38
2	513	472	985	(.5208)	1	1.7071ns	0.19
3	459	514	973	(.4717)	1	3.1106ns	0.08
4	479	504	983	(.4873)	1	0.6359ns	0.43
					Total 4	6.2334ns	0.18
Sum	1905	1971	3876	(.4915)	Pooled 1	1.1239ns	0.28
					Heterogeneity 3	5.1095ns	0.16

The heterogeneity G-tests indicated the population as a whole (pooled G) did not differ significantly from a 50:50 male to female ratio. However, there were significantly fewer males than females in small category fish. Pairwise comparisons of the sex ratios among sizes (unplanned tests of homogeneity, Sokal and Rohlf 1981) indicated a significant difference in ratios between small and large fish only ($p<.01$), small fish having a lower proportion of males. The sex ratios observed for each release were not significantly different from a 50:50 and ratios did not differ significantly between releases.

RECOVERY OF JACKS (AGE 1.0) AND ADULTS (AGE 1.1, 1.2)[1]

Escapement

Jacks

In the fall of 1981, 98.5% of the jacks returning to the Quinsam hatchery were examined for adipose fin clips and CWT's. Hypural length and/or round weight were recorded for 96% of the tagged fish; sampling was conducted throughout the run. All fish recovered were precocious males.

River spawners were not examined; the returns presented and analysed in this report are for the hatchery only and are therefore conservative. Hatchery records indicate the hatchery fish represented approximately 69.7% of the total (i.e. hatchery plus river) escapement.

Adults

All adult coho returning to Quinsam hatchery in the fall of 1982 (age 1.1) were examined for adipose clips and CWT's. The sex of all tagged

---

[1]European system of age designation; the first digit indicates the number of annuli formed while in fresh water, the second those formed while in the ocean (Koo 1962). A 1.0 fish returns in its 2nd yr (from hatching) after spending 1 yr in freshwater and part of 1 yr in the ocean, a 1.1 fish returns in its third year after 1+ yr in the ocean, and a 1.2 fish in its 4th year after 2+ yr in the ocean.

fish was recorded and hypural length and/or round weight recorded for 66% of fish from throughout the run. It was estimated that hatchery returns represented 76.2% of the total adult escapement; the remainder spawned in the river and were not examined. As with the jack recoveries, the escapement returns presented and analyzed in this report are for the hatchery only and are therefore conservative.

A similar recovery program was conducted in the fall of 1983; no age 1.2 fish were observed in the hatchery escapement.

Catch

Estimates of the numbers of tagged coho taken in the 1981, 1982, and 1983 commercial and sport fisheries were obtained through the coastwide Mark Recovery Program (MRP) supported by government agencies in British Columbia, Alaska, Washington, Oregon, and California.

In British Columbia, commercial catches were sampled at a target intensity of 20%; the numbers of tags recovered (observed recoveries) were then expanded by adjusting for the actual sampling rate for each catch to give estimated recoveries. Estimates of the numbers taken in the sport fishery were based on voluntary returns of heads from adipose clipped fish. Returns were expanded using "awareness factors" derived from estimates of the proportions of the clipped fish caught which were recognized and reported. Georgia Strait monthly awareness factors were calculated from year round creel census surveys conducted by the Fisheries Branch of the Department of Fisheries and Oceans, averaging between adjacent months or the same month in adjacent years to obtain estimates if necessary. For all other areas an awareness factor of .252 (i.e. 25.2% of the clipped fish caught were reported) was used; this is the average awareness factor from an early (1980-81) Georgia Strait Creel Survey (DPA 1982), weighted by catch for region.

Estimates of the numbers recovered in United States fisheries were provided by the various American agencies; these agencies use similar sampling and estimation procedures.

Very few fish were taken in the 1983 fishery (age 1.2); these were all taken in the sport fishery and it is possible they were simply late voluntary returns of fish caught in 1982 (i.e. actually age 1.1). They were included with the 1982 adult recoveries for purposes of analysis.

DATA ANALYSIS AND RELIABILITY

Fishery recoveries in the year of release

An important aspect of the study was the incidence of jacks in the various groups. It was therefore desirable to classify the 1981 fishery recoveries as maturing jacks or as potential adults (immatures). Since information on the sex or maturity of these fish was not available it was necessary to estimate the numbers of each type. Assuming the 1981 catches to have been un-biased samples of the population at that time, the jack: potential adult ratios of the fish caught would have been the same as those of survivors of the fishery. The latter were estimated for each group using 1) the 1981 jack escapement returns, and 2) the 1982 adult returns (catch plus escapement) expanded backward to allow for estimated natural mortalities during the year subsequent to the 1981 fishery.[1] The ratios determined from these two figures were used to divide the 1981 catches into jacks and potential adults. Those designated as jacks were then added to the 1981 jack recovery figures; those designated as potential adults were added to the 1982 adult recoveries after subtracting estimated natural mortalities for an additional year in the ocean. Although this method requires numerous assumptions and estimates, the results appear reasonable and affect the analysis less than designating all recoveries as either jack or adult, or omitting them completely.

Percentage returns

Percentage returns (% returns) were calculated based on the numbers of tagged juveniles released. Returns to the escapement are considered conservative (since they do not include river spawners) but reliable. Returns to the commercial fisheries were calculated by adjusting the observed recoveries for differing catch sample rates and are considered to be fairly accurate but less reliable than the escapement counts. Estimates of returns to the sport fishery are considered less reliable than other estimates because of possible inaccuracies in the awareness factors used.

Biomass of returns

Biomass estimates of returning fish were calculated using the average weights of jacks and adults for each group as determined from sampling of hatchery returns. For comparative purposes, the estimates were standardized to kilograms per 100,000 juveniles released, based on the observed percent returns. Final weights as observed at the hatchery were used since little biological information was available for the fishery recoveries. Biomass is probably slightly overestimated since fish taken early in the fishery would not have reached final weight. It is also possible that size selectivity of the fishery could have created differences in size distribution between the catch and escapement.

Statistical analyses

The relationships between dependent variables (e.g. percentage returns, weights of adults) and weight at release were examined separately for

---

[1]Any fish surviving the 1981 fishery would have either suffered natural mortality or contributed to one of these returns. Estimates of natural mortality were made using monthly instantaneous rates derived from a Puget Sound study, as described by Ricker (1976).

each release using polynomial regression analysis (BMDP Statistical Software 1981); data was tested for fit to both linear and quadratic models. Response surface analysis was used to examine the relationships between dependent variables and both independent variables (time of release and weight at release) simultaneously. This approach enables one to predict responses of the dependent variable for any combination of time and weight (Schnute and McKinnell 1984). Equations for significant regressions and response surface model parameters are given in Appendix Tables 1 and 2, respectively.

Most statistical tests are from Sokal and Rohlf (1981). A minimum significance level of 5% (α=0.05) was used in all tests. When calculating weights of returning fish, replicates were pooled, if necessary, to give a minimum sample size of 10 for any group. Other analytical methods and statistical tests are described where they occur in the text.

RESULTS

Equations for significant regressions and response surface model parameters are given in Appendix Tables 1 and 2, respectively.

RETURNS OF JACKS AND ADULTS (Tables I-1a to I-1d)

Jack returns

Total return of jacks was 940. Of these, 932 were recovered in the escapement to the hatchery and 8 were estimated to have been taken in the fishery. The few taken in the fishery came mainly from larger size category groups.

Highest total return (catch plus escapement) for a common release date was for the May 10 release, 464 fish or 1.33%. This was followed in decreasing order by the May 30 (281 fish, 0.83%), April 20 (156 fish, 0.48%) and June 19 (39 fish, 0.11%) releases.

For the May 10, May 30, and June 19 releases, there were significant linear correlations between jack % returns (catch plus escapement) and smolt weight, larger smolts producing higher % returns (Figure I-1; r^2=.847, .914, and .697 respectively; $p<.01$ for all). Addition of a quadratic term (x^2) did not significantly improve the fit for any release, the quadratic curve shown for the April 20 release represents a line of best fit only (i.e. higher r^2 than the linear).

Response surface analysis of jack % returns is shown in Figure I-2. Strong effects of both size at release and time of release are indicated. Percentage returns increase with advancing date until about day 130 (May 10)

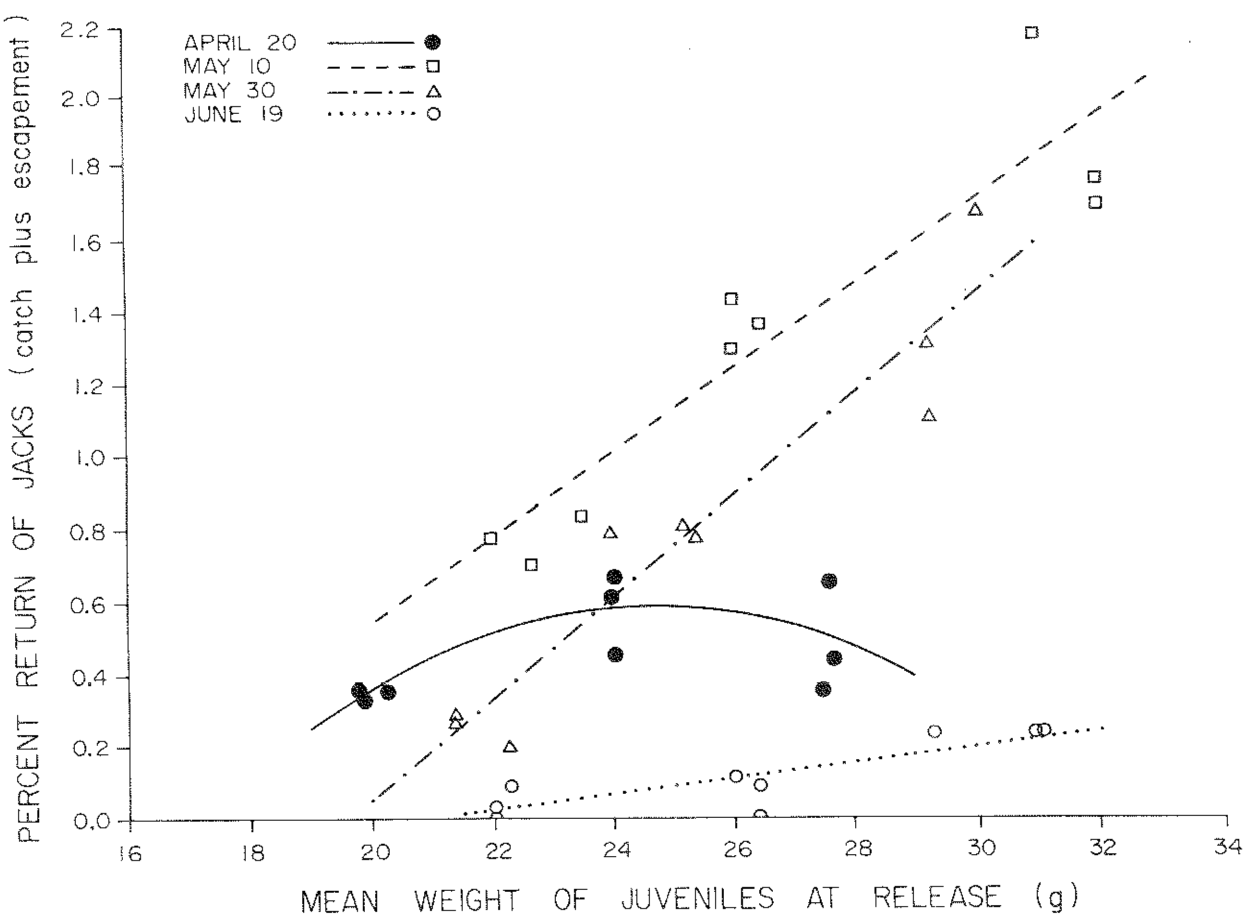

Fig. I-1. 1981 releases. Mean weights of juveniles (sexes combined) at time of release and total returns of jacks (catch plus escapement) as percentages of juveniles released.

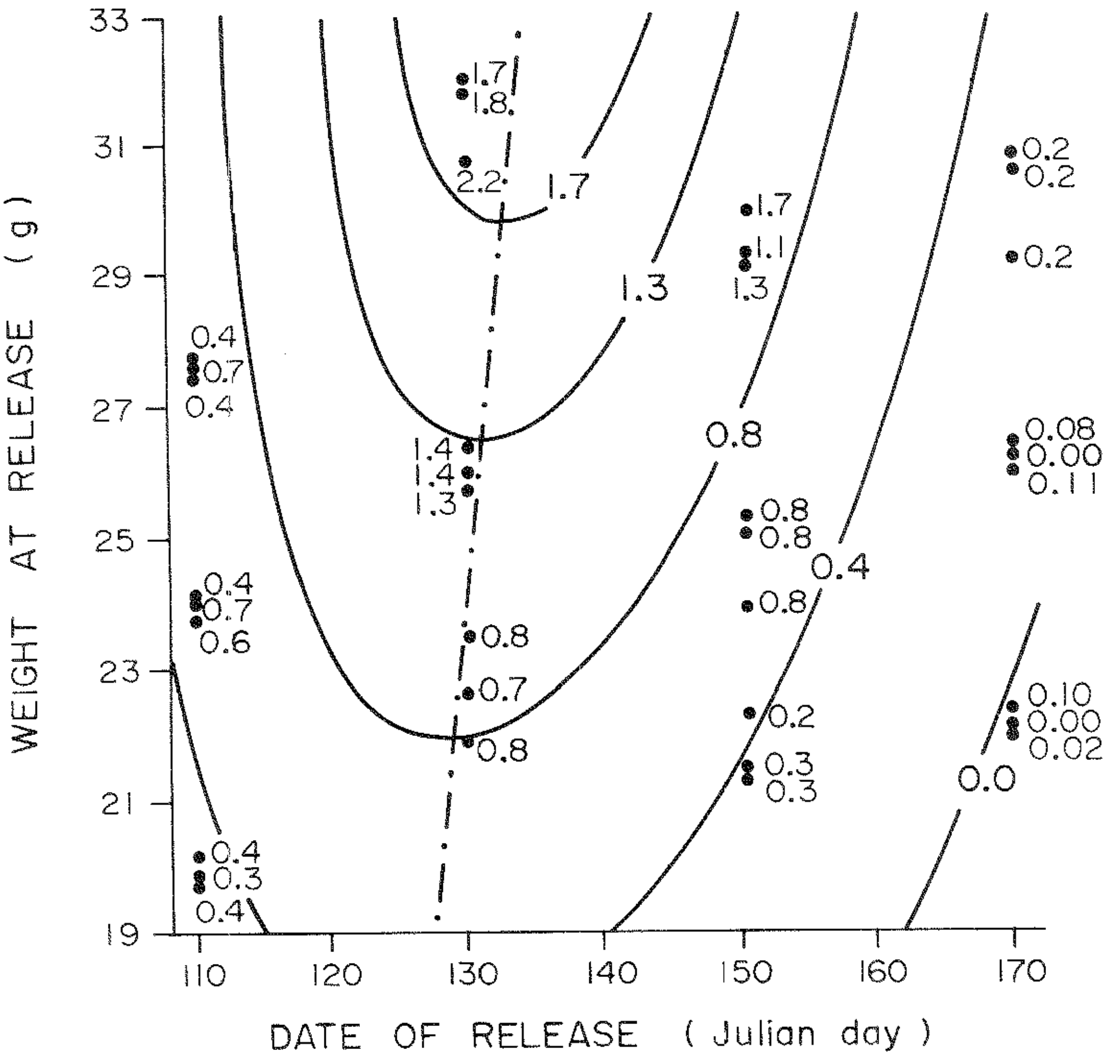

Fig. I-2. 1981 releases. Response surface showing the relationship of returns of jacks in the catch plus escapement (as percentages of juveniles released) to mean weight of juveniles at release and time of release. Contours represent estimated returns, individual points are the observed values for each group.

then begin to decrease at about the same rate. There is an increase in % returns with increasing size throughout the period of the releases; however, size effects are strongest around day 130. The broken line represents the line of optimum release date; for juveniles of any given weight (y axis intercept) the corresponding date (x axis intercept, as determined by the line) is the date for which maximum % returns are predicted; the optimum date advances very slightly with increasing juvenile weight. The manner in which the contours ascend toward the top center of the figure suggest a theoretical maximum % return somewhere in this area but beyond the tested range.

Adult returns (sexes combined)[1]

Escapement

A total of 1,728 adults were recovered in the escapement to the hatchery. Highest return for a common release date was for the May 30 release, 919 fish or 2.72%. This was followed in decreasing order by the May 10 (393 fish, 1.13%), June 19 (248 fish, 0.72%), and April 20 (168 fish, 0.51%) releases.

There were no significant linear correlations between juvenile weight and adult % returns within any of the releases. Addition of a quadratic term improved the fit for the June 19 release significantly ($p<.01$), giving an r^2 value of 0.719 and suggesting slightly higher % returns from medium sized juveniles (these relationships are not illustrated).

Catch

Adult contribution to the combined fisheries (sport plus commercial) was estimated at 5,545 fish. Highest return for a common release date was for the May 30 release, 2,891 fish, or 8.55%. This was followed in decreasing order by the May 10 (1,233 fish, 3.55%), June 19 (990 fish, 2.88%), and April 20 (431 fish, 1.32%) releases. The order of these returns is the same as that observed in escapement returns.

There were no significant linear correlations between juvenile weight and adult % returns within any of the releases. Inclusion of a quadratic term marginally improved the fit for the May 10 release ($p=.05$), giving an r^2 value of .614 and suggesting slightly higher % returns from small smolts.

Catch plus escapement

An estimated total of 7,273 adults were recovered in the catch plus escapement. Highest return for a common release date was for the May 30 release, 3,810 fish or 11.27%. This was followed in decreasing order by the May 10 (1,626 fish, 4.68%), June 19 (1,238 fish, 3.60%) and April 20 (599 fish, 1.83%) releases. This order is the same as that observed for the catch and escapement independently.

---

[1]Returns discussed here are for males plus females. Escapement returns by sex are discussed in a later section; sex observations on catch were not sufficient to allow separate analyses.

There were no significant linear correlations between juvenile weight and adult % returns within any of the releases (Fig. I-3). Addition of a quadratic term did not significantly improve the fit for any release and the curves shown are lines of best fit only.

Response surface analysis of adult % returns (catch plus escapement) is shown in Figure I-4.[1] The vertical nature of the contours indicates the effects of juvenile size are relatively minor, since in ascending the weight axis on a given date the level of predicted % returns (contour) tends to remain constant. The contribution of size to the model was statistically insignificant ($p=.27$); however, there is some suggestion of slightly higher % returns from smaller juveniles for earlier releases. Strong effects of time of release are evident. Initially the % return contours are quite widely separated and indicate a gradual increase in % returns with advancing date, reaching an optimum as indicated by the broken line. This line is almost vertical and predicts optimum returns of about 12.5% on about day 157 (June 6) regardless of juvenile weight, at least within the range of weights tested near this date (approximately 21 to 31 g); caution should be used in extrapolating beyond this range. Percentage returns decline rapidly beyond the optimum date.

Jack plus adult returns

Escapement

A total of 2,660 jacks plus adults were recovered in the escapement to the hatchery. Highest return for a common release date was for the May 30 release, 1199 fish or 3.55%. This was followed in decreasing order by the May 10 (853 fish, 2.45%), April 20 (321 fish, 0.98%) and June 19 (287 fish, 0.83%) releases.

There were significant linear correlations between juvenile weight and % returns for the May 10 and May 30 releases (Fig. I-5, $r^2=.589$, $p<.05$ and $r^2=.861$, $p<.01$, respectively), with higher % returns from larger juveniles; neither of these fits was improved significantly by addition of a quadratic term. Addition of a quadratic term significantly improved the fit for the June 19 release ($p=.05$) giving an r^2 value of .589 and suggesting slightly lower % returns from smaller juveniles. The quadratic curve shown for the April 20 release is a line of best fit only.

The juvenile weight to % return relationships for the May 10 and May 30 releases are more similar to the relationships observed for jack % returns (Fig. I-1)[2] than to those observed for adult % returns, and reflect the high jack production from larger juveniles of these releases.

Catch

Only 8 jacks were estimated to have been taken in the catch. Jack plus adult catch was therefore negligibly different from that already

---

[1]The minor effect of size created problems of model instability in trying to estimate certain parameters. This necessitated the fixing of these parameters as noted in Appendix Table 2.

[2]Figure I-1 includes jack returns to both escapement and catch but differs negligibly from that for escapement alone, since only 8 jacks were estimated to have been taken in the catch.

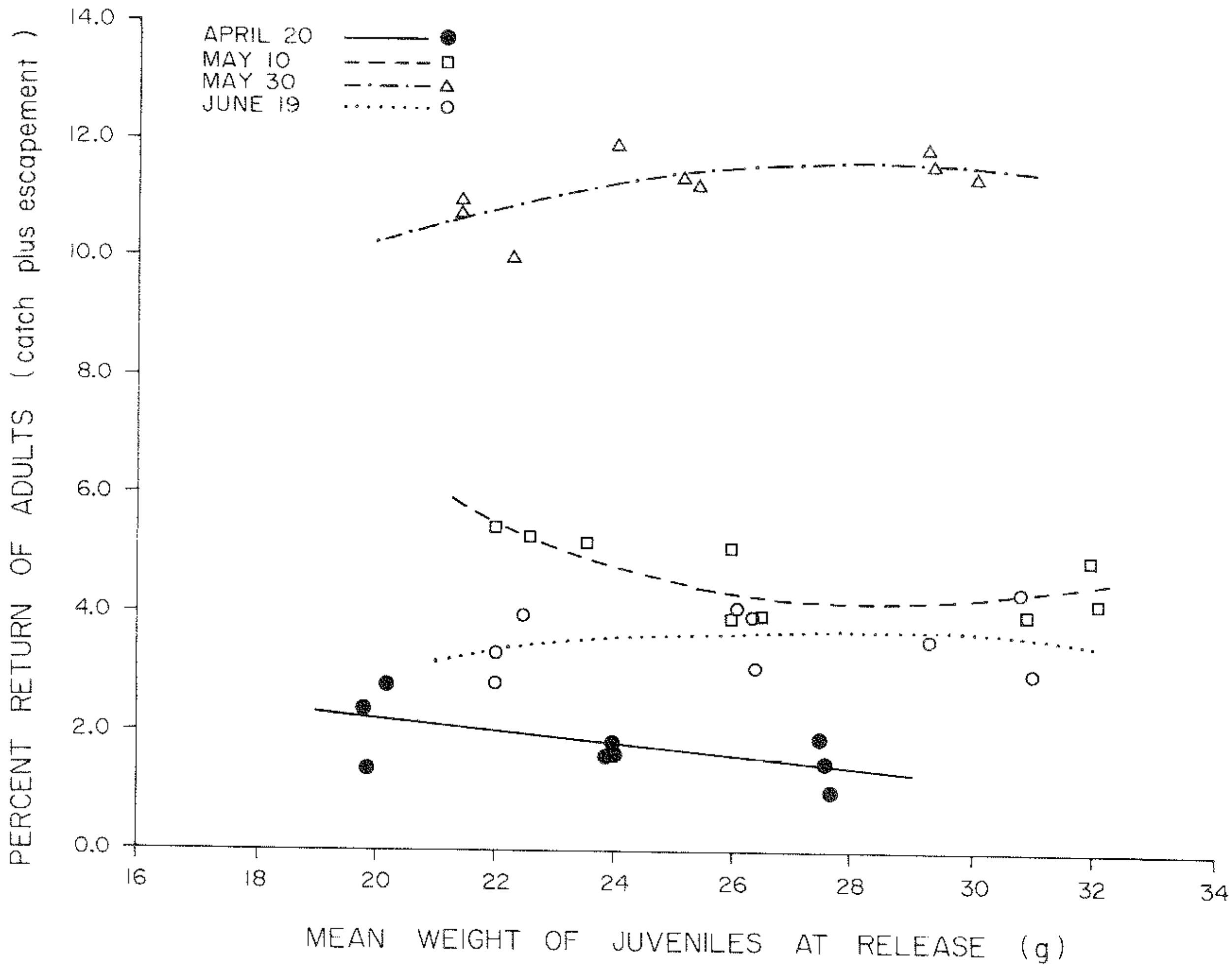

Fig. I-3. 1981 releases. Mean weights of juveniles (sexes combined) at time of release and total returns of adults (sexes combined, catch plus escapement) as percentages of juveniles released.

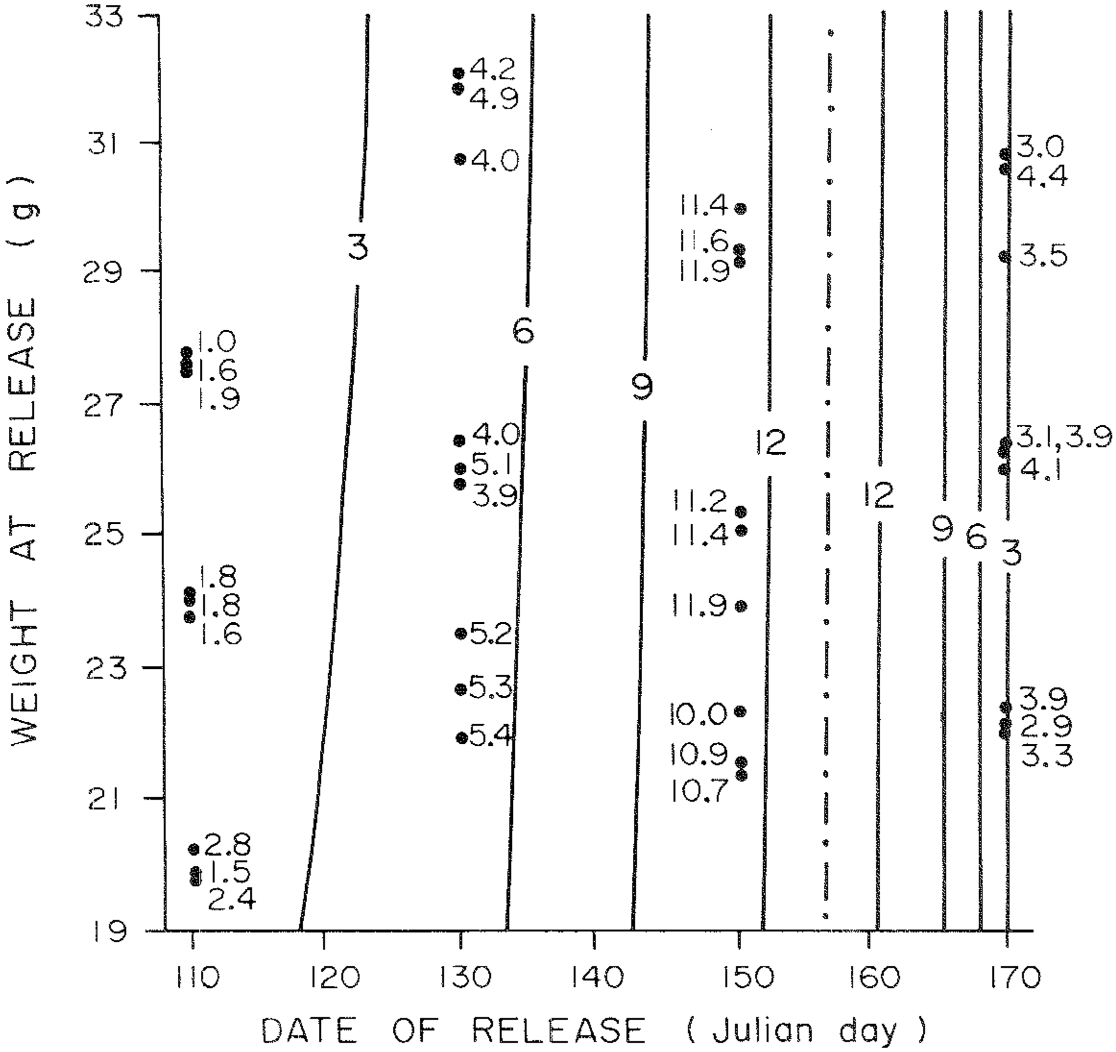

Fig. I-4. 1981 releases. Response surface showing the relationship of returns of adults in the catch plus escapement (as percentages of juveniles released) to mean weight of juveniles at release and time of release. Contours represent estimated returns, individual points are the observed values for each group.

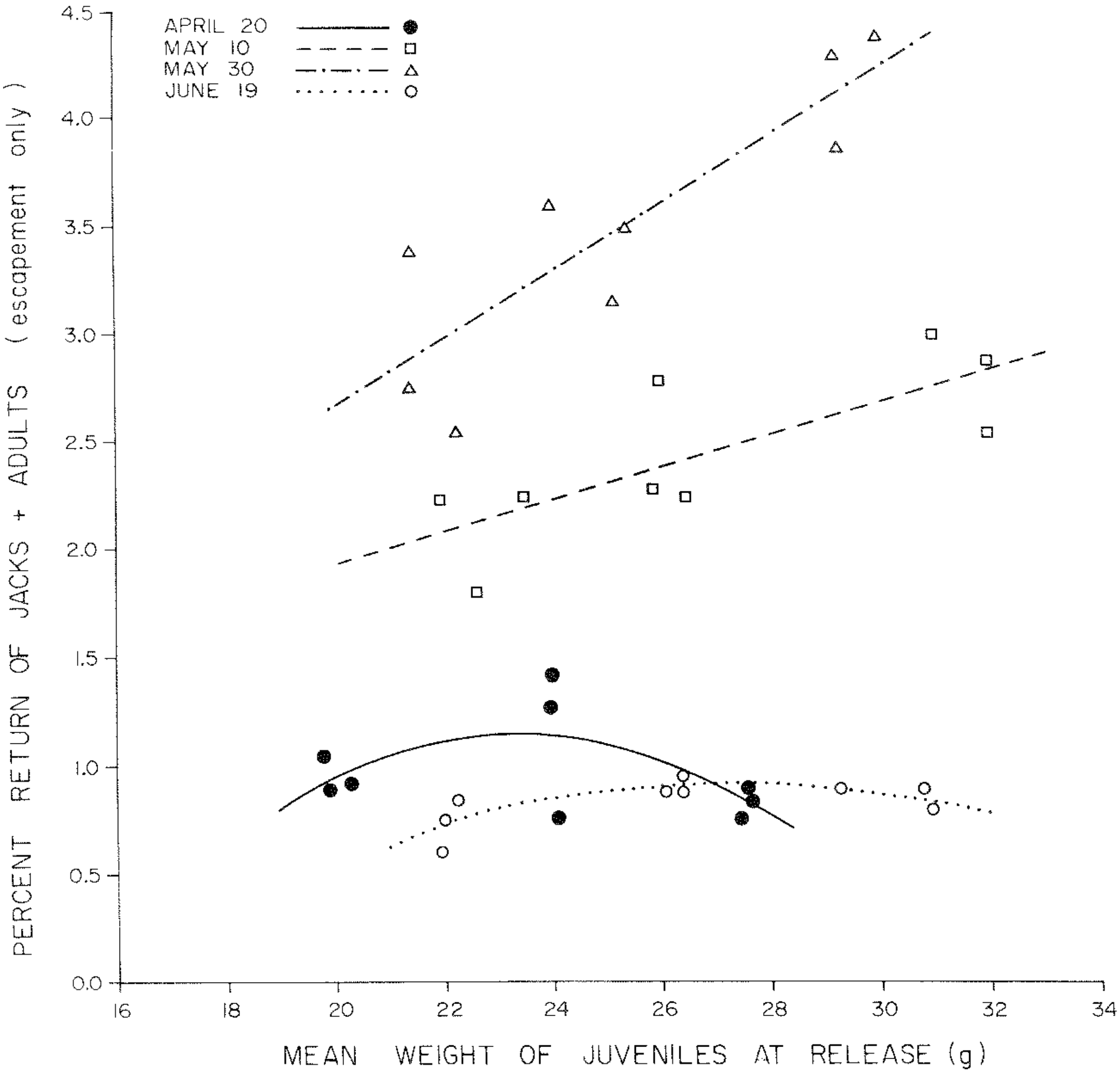

Fig. I-5. 1981 releases. Mean weights of juveniles (sexes combined) at time of release and escapement returns of jacks plus adults (sexes combined) as percentages of juveniles released.

described for adults alone.

Catch plus escapement

A total of 8,204 jacks plus adults were recovered. Highest return for a common release date was for the May 30 release, 4,091 fish or 12.1%. This was followed in decreasing order by the May 10 (2,090 fish, 6.01%), June 19 (1,277 fish, 3.71%), and April 20 (755 fish, 2.31%) releases.

There was a significant linear correlation between juvenile weight and % returns for the May 30 release with higher returns from larger smolts (Fig. I-6, r^2=.719, p<.01); fit was not improved significantly by addition of a quadratic term. There were no significant linear or quadratic relationships for the other releases and the lines shown are lines of best fit only.

Response surface analysis of jack plus adult % returns is shown in Figure I-7. The surface is very similar to that observed for adults alone (Fig. I-4), with very slight, statistically insignificant (p=.21), size effects but strong time effects.[1] Returns increase gradually with advancing date, peak, and then decline sharply. Optimum time of release in this case, however, is day 154-155 (June 3-4) versus 157 for adults alone. As with the adults alone, the optimum date is essentially the same for any size of juvenile, at least within the range of weights tested close to this date.

Incidence of jacks (jacks as a proportion of total returns)

To examine the influence of time and size at release on the incidence of jacks, jacks (catch plus escapement) as a percentage of total returns (jacks plus adult, catch plus escapement) was calculated for each group. Numbers of jacks and adults are given in Tables I-1a to I-1d, the relationships of % jacks to juvenile weights within each release are shown in Figure I-8.

For each release there was a significant linear correlation between % jacks and juvenile weight, with higher percentages from larger smolts. The r^2 values for the April 20, May 10, May 30, and June 19 releases are .467, .768, .916, and .684 respectively; the June 19 correlation is significant at p<.05, all others are significant at p<.01. Addition of quadratic terms did not significantly improve any fit. The relative heights of the regression lines show that for juveniles of a given size the percentage of jacks decreases with later release. For example, the predicted percentages of jacks in returns from 24 g fish released on each of the 4 dates are: April 20 - 21.7%; May 10 - 17.1%; May 30 - 5.0%; and June 19 - 1.6%.

---

[1]As with the adults it was necessary to fix certain parameters to allow for the minor effects of size. See Appendix Table 2.

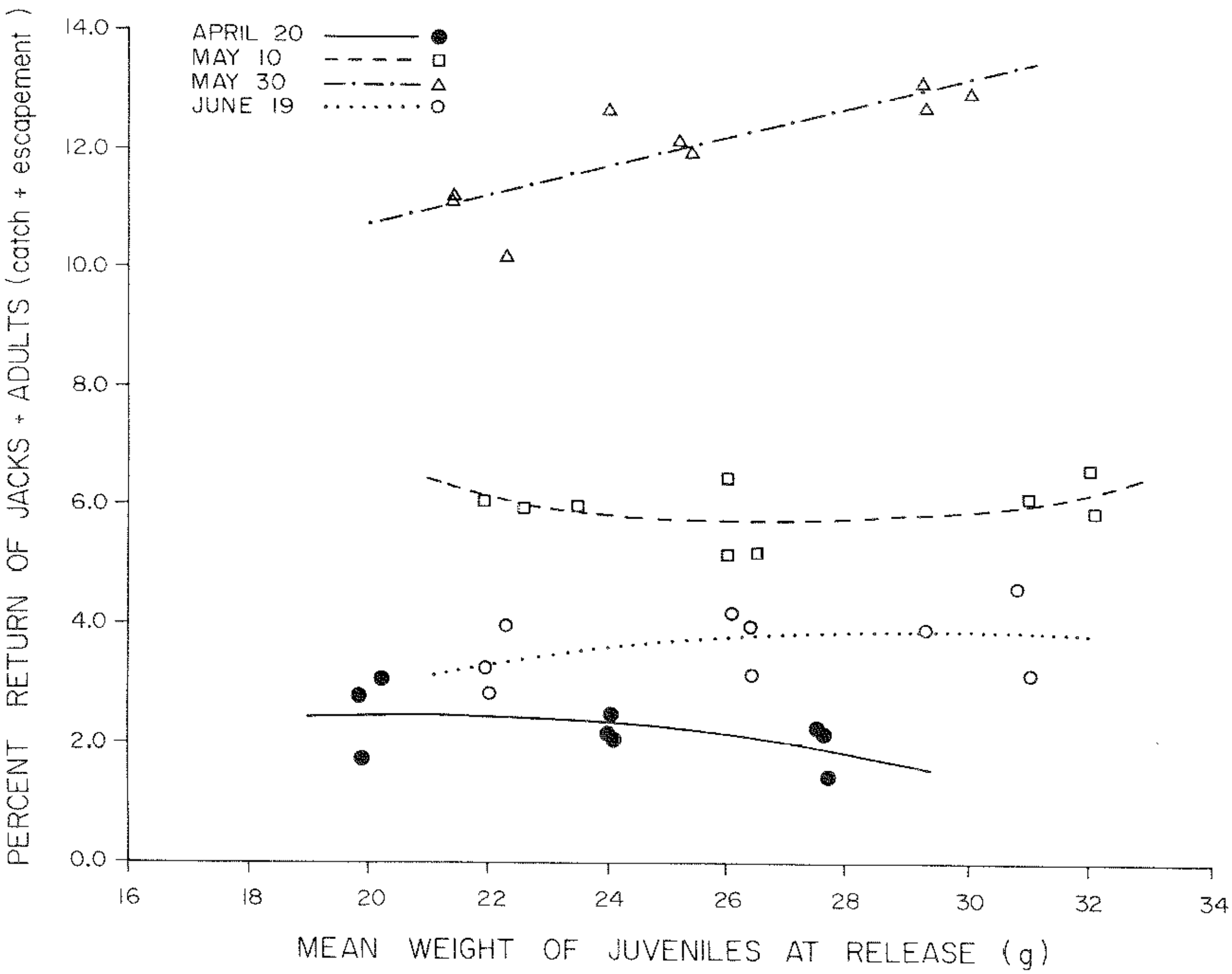

Fig. I-6. 1981 releases. Mean weights of juveniles (sexes combined) at time of release and total returns of jacks plus adults (sexes combined, catch plus escapement) as percentages of juveniles released.

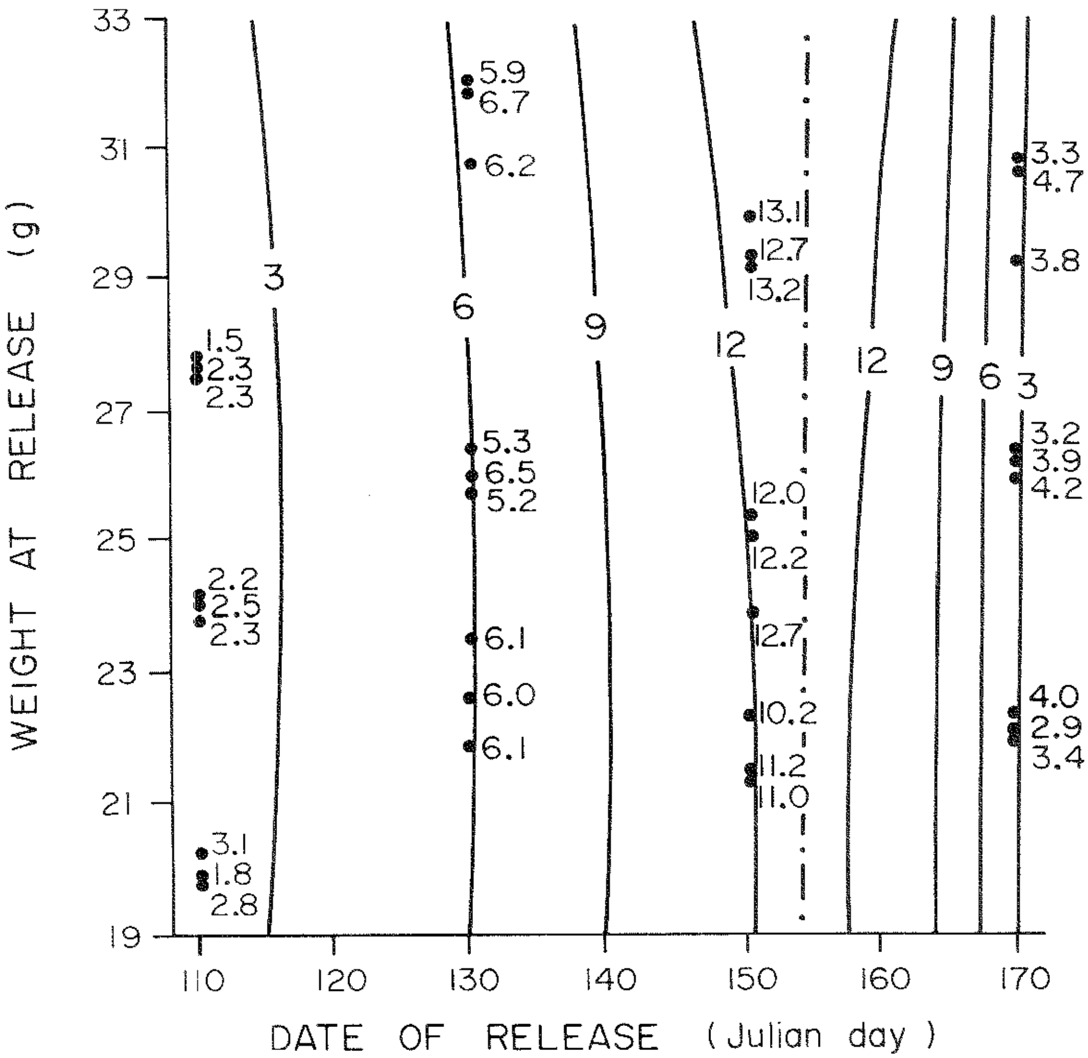

Fig. I-7. 1981 releases. Response surface showing the relationship of returns of jacks plus adults in the catch plus escapement (as percentages of juveniles released) to mean weight of juveniles at release and time of release. Contours represent estimated returns, individual points are the observed values for each group.

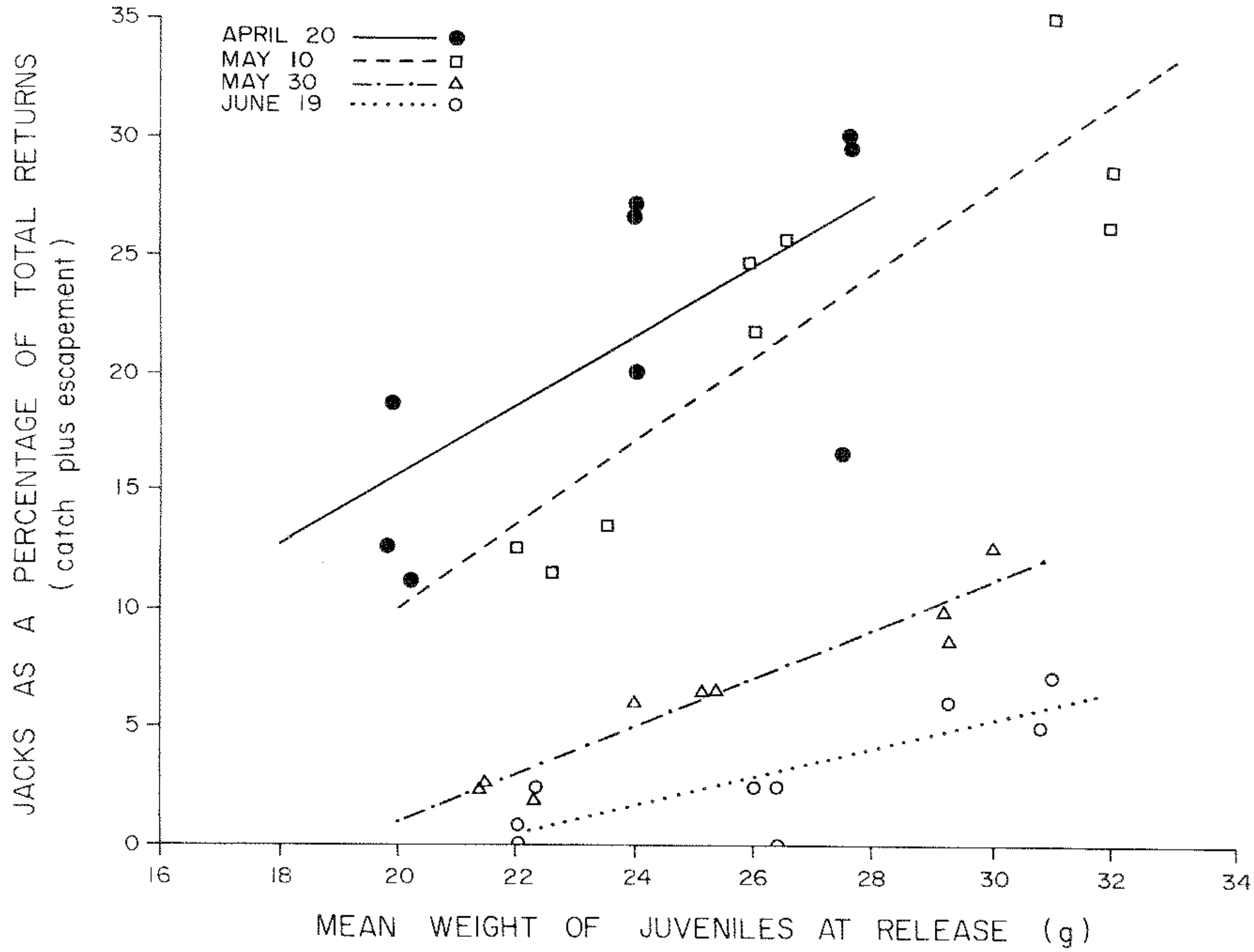

Fig. I-8. 1981 releases. Mean weights of juveniles (sexes combined) at time of release and jacks as a percentage of total returns (i.e. jacks plus adults of both sexes) to the catch plus escapement.

BIOLOGICAL OBSERVATIONS ON ESCAPEMENT RETURNS (INCLUDING PERCENTAGE RETURNS BY SEX)

Percentage returns of adult males and females

The relationships between juvenile weights and % returns to the escapement were analyzed separately for males and females for each release. Returns by sex and juvenile weights by sex can be found in Tables I-1a to I-1d. No illustrations are presented due to the lack of correlations, the only significant correlation being for the April 20 release, with slightly higher % returns of males indicated from release of smaller male juveniles (linear fit, r^2=.49, $p<.05$). Addition of quadratic terms did not significantly improve any fit.

For males, the highest return for a common release date was for the May 30 release (2.44%), followed in decreasing order by the June 19 (0.78%), May 10 (0.75%), and April 20 (0.40%) releases. The order for females was slightly different: May 30 (2.91%), May 10 (1.50%), June 19 (0.63%), and April 20 (0.61%); this order is the same as was observed for the combined sexes, presented earlier.

Sex ratios of adult escapement returns

The sex ratios of the adult escapement returns for each group (replicates combined) are summarized in the following table. Values in parentheses include an adjustment for the number of additional adult males which might have resulted had the jacks (all males) matured as adults.[1] This was done to assess the importance of jacks in explaining the reduced proportions of males observed in the adult escapement returns relative to those observed in the juveniles at release; tests of these differences in proportion follow.

		Sex			
Release	Size	Male	Female	Male & female	Proportion male
a) Totalled by release					
April 20	Small	32 (38)	33	65 (71)	.49 (.54)
	Medium	13 (26)	49	62 (75)	.21 (.35)
	Large	18 (26)	20	38 (46)	.47 (.57)
	Total	63 (90)	102	165 (192)	.38 (.47)

[1]Estimates of additional adult males were made by subtracting estimated mortalities for an additional year of ocean residence from the numbers of jacks recovered for each group; the escapement portions of the resulting theoretical numbers of adult males were calculated using the observed catch: escapement ratios. Mortalities were estimated using instantaneous rates derived from a Puget Sound study as described by Ricker 1976.

May 10	Small	57 (70)	97	154 (167)	.37 (.42)
	Medium	43 (67)	81	124 (148)	.35 (.45)
	Large	36 (65)	73	109 (138)	.33 (.47)
	Total	136 (202)	251	387 (453)	.35 (.45)
May 30	Small	117 (121)	157	274 (278)	.43 (.44)
	Medium	123 (135)	174	297 (309)	.41 (.44)
	Large	151 (175)	186	337 (361)	.45 (.48)
	Total	391 (431)	517	908 (948)	.43 (.45)
June 19	Small	40 (41)	36	76 (77)	.53 (.53)
	Medium	55 (56)	41	96 (97)	.57 (.58)
	Large	37 (40)	33	70 (73)	.53 (.55)
	Total	132 (137)	110	242 (247)	.55 (.55)
	Grand totals	722 (860)	980	1702 (1840)	.42 (.47)
b) Totalled by size category					
	Small	246 (270)	323	569 (593)	.43 (.46)
	Medium	234 (284)	345	579 (629)	.40 (.45)
	Large	242 (306)	312	554 (618)	.44 (.50)

<u>Comparisons of juvenile and adult sex ratios (using unadjusted data)</u>

Heterogeneity G-tests (Sokal and Rohlf 1981) were conducted comparing the adult escapement sex ratio for each release (sizes pooled) with a juvenile ratio of .4915 (statistically common to all releases, see earlier section on sex ratio of juveniles). Tests are summarized below.

Release	Male	Female	n	Proportion male		df	G	p
April 20	63	102	165	.38		1	8.03**	.005
May 10	136	251	387	.35		1	30.90***	.000
May 30	391	517	908	.43		1	13.52***	.000
June 19	132	110	242	.55		1	ns 2.82	.093
					Total	4	55.26***	.000
Sum	722	980	1702	.42	Pooled	1	30.98***	.000
					Heterogeneity	3	24.28***	.000

For the pooled population and 3 of the 4 releases the proportion of males was significantly lower in the adult escapement than in the juveniles at release. The significant G for heterogeneity indicates differences among the adult ratios for the various releases.

Similar tests were conducted comparing the adult sex ratio for each size category with the juvenile ratio for the same category. Large and medium category adult ratios (releases pooled) were compared with a juvenile estimate of .4848 male. This ratio was common to both these sizes of juvenile. The sex ratio of small category adults was tested separately against the statistically distinct ratio of .4627 male observed for small juveniles (G-statistic, 2-waytest of independence, Sokal and Rohlf 1981). Results are given below.

a) Medium and large category fish.

Size	Male	Female	n	Proportion male		df	G	p
Medium	234	345	579	.40		1	15.20***	.000
Large	242	312	554	.44		1	5.12*	.024
					Total	2	20.32***	.000
Sum	476	657	1133	.42	Pooled	1	19.08***	.000
					Heterogeneity	1	1.24ns	.256

b) Small category fish

Stage	Male	Female	n	Proportion male
Smolt	570	662	1232	.46
Adult	246	323	569	.43
Sum	816	985	1801	

G (adjusted)=1.45, d.f.=1, p=.23 (n.s.)

The proportions of males in both medium and large category adults were significantly lower than in the juveniles but did not differ significantly from each other. The ratio for small category adults was not significantly different from that of the juveniles.

Comparisons of smolt and adult sex ratios with adjustment for jacks

No statistical tests were performed on the adjusted data because of the questionable accuracy of the adjustment procedure. However, examination of the table shows the adjusted adult sex ratios are much closer to the juvenile ratios than the unadjusted, although the male proportions are still generally slightly lower.

Size of returning fish (Tables I-2a to I-2d)[1]

Jacks

The average weight of jacks resulting from each release was

[1]Length observations are included in Tables I-2a to I-2d but are not discussed here.

inversely related to time of release. These weights were: April 20 - 0.503 kg; May 10 - 0.449 kg; May 30 - 0.357 kg; and June 19 - 0.291 kg. Pairwise t-tests of these weights (all possible comparisons using Bonferroni probabilities to adjust for multiple tests, BMDP Statistical Software 1981, program 7D) showed all to be significantly different from each other at $p<.001$.

The relationship of jack weight to male juvenile weight was examined for the first three releases, data on jack weights for the fourth release was not sufficient to permit this. There was some suggestion of slightly heavier jacks from larger juveniles for each release; however, this relationship was significant for the second release only (linear correlation, $r^2=.367$, $p<.05$); fit was not improved significantly by addition of a quadratic term.)

Adults

As with the jacks, the average weight of male adults was inversely related to time of release. Average weights for each release were: April 20 - 3.355 kg; May 10 - 3.250 kg; May 30 - 2.491 kg; and June 19 - 1.809 kg. Pairwise t-tests showed no significant difference between the first and second release, all other differences were significant at levels ranging from $p<.05$ to $p<.001$.

For female adults the average weights for each release were: April 20 - 3.368 kg; May 10 - 3.458 kg; May 30 - 2.857 kg; June 19 - 2.307 kg. The average weight for the first release was in this case slightly lower than that of the second release; average weights for the last three releases were again inversely related to time of release. Pairwise t-tests showed the first and second release did not differ significantly, all other differences were significant at $p<.001$.

For the combined sexes the adult weights for each release showed the same order as that for females, the average weight for the first release being slightly lower than that of the second and those for the last three releases being inversely related to time of release. Average weights were: April 20 - 3.363 kg; May 10 - 3.377 kg; May 30 - 2.699 kg; June 19 - 2.045 kg. Pairwise t-tests showed the weights for the first and second releases did not differ significantly; all other differences were significant at $p<.001$.

Average weights for females were greater than those of males in each release. The average weight of females for the combined releases was 2.972 kg, that of males 2.568 kg. This difference was highly significant (t-test, $p<.001$).

The relationships of adult weights to juvenile weights within each release were also examined, both for the combined sexes and for males and females separately (using juvenile weight of the combined sexes, male juvenile weights, and female juvenile weights, respectively). There were no apparent relationships for the first release (there were too few observations on male adults to permit examination of the male relationship for this release). For males of the second release there was no linear correlation; however, addition of a quadratic term significantly improved the fit, giving an r^2 value of .701 and suggesting slightly heavier male adults from medium sized juveniles. For the remaining cases in the second release (combined sexes and females only) and for all cases in the third and fourth releases there was some suggestion of heavier adults from larger juveniles. These relationships were significant for the third (May 30) release only, however, with significant linear correlations for males (r^2 =.4662, $p<.05$), females (r^2 =.6679, $p<.01$), and the combined sexes (r^2 =.6035, $p<.05$). None of these fits was improved by addition of a quadratic term.

Sample sizes likely affected the ability to demonstrate significant relationships between juvenile and adult weights, since sample sizes (as well as adult returns) were considerably larger for the May 30 releases. The same is possibly true for the jack relationships, since the only significant correlation was for the May 10 release, which similarly gave highest returns and largest samples.

BIOMASS OF RETURNS (CATCH PLUS ESCAPEMENT, Table I-3)

Jacks

For a common release date the greatest average biomass (yield of flesh per 100,000 juveniles released) was for the May 10 release, 600.9 kg. This was followed in decreasing order by the May 30 (287.5 kg), April 20 (240.1 kg), and June 19 (33.1 kg) releases.

The relationships of biomass to juvenile weight (male plus female) for each release are shown in Figure I-9. For the May 10, May 30, and June 19 releases there were positive linear correlations, larger juveniles producing greater biomass (r^2 =.857, .918, and .694 respectively; $p<.01$ for all). No fit was improved significantly by addition of a quadratic term; the quadratic curve shown for the April 20 release is a line of best fit only.

Adults (sexes combined)

Greatest average biomass for a common release date was for the May 30 release, 30,239 kg. This was followed in decreasing order by the May 10 (15,751 kg), June 19 (7,330 kg), and April 20 (6,138 kg) releases.

For the May 30 releases there was a significant positive linear correlation between juvenile weight and biomass (Fig. I-10; r^2 =.617, $p<.05$); fit was not improved significantly by addition of a quadratic term. There were no significant linear or quadratic relationships for the other releases and the lines shown are lines of best fit only.

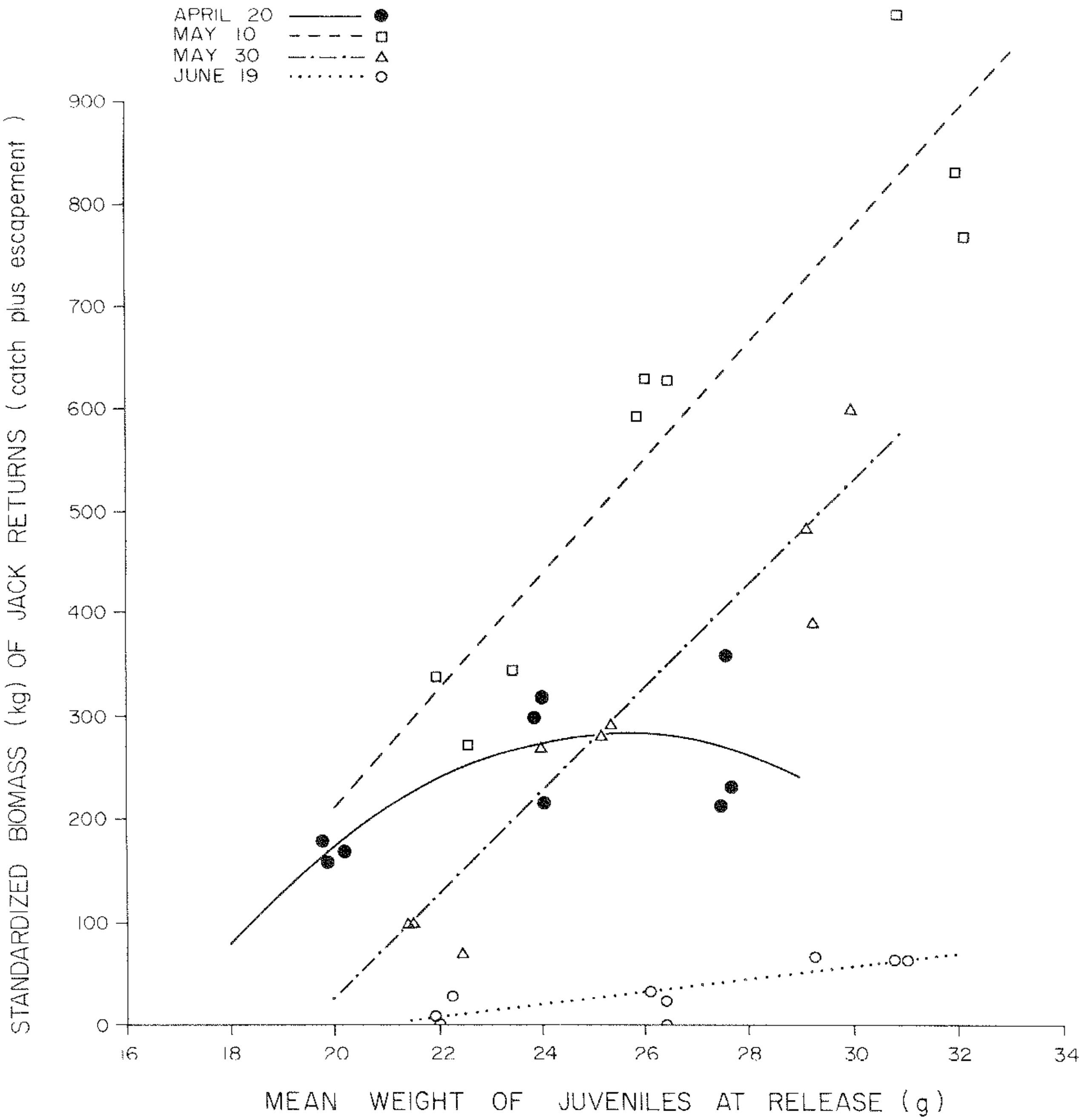

Fig. I-9. 1981 releases. Mean weights of juveniles (sexes combined) at time of release and standardized biomass of jack returns (Kg per 100,000 juveniles released) to the catch plus escapement.

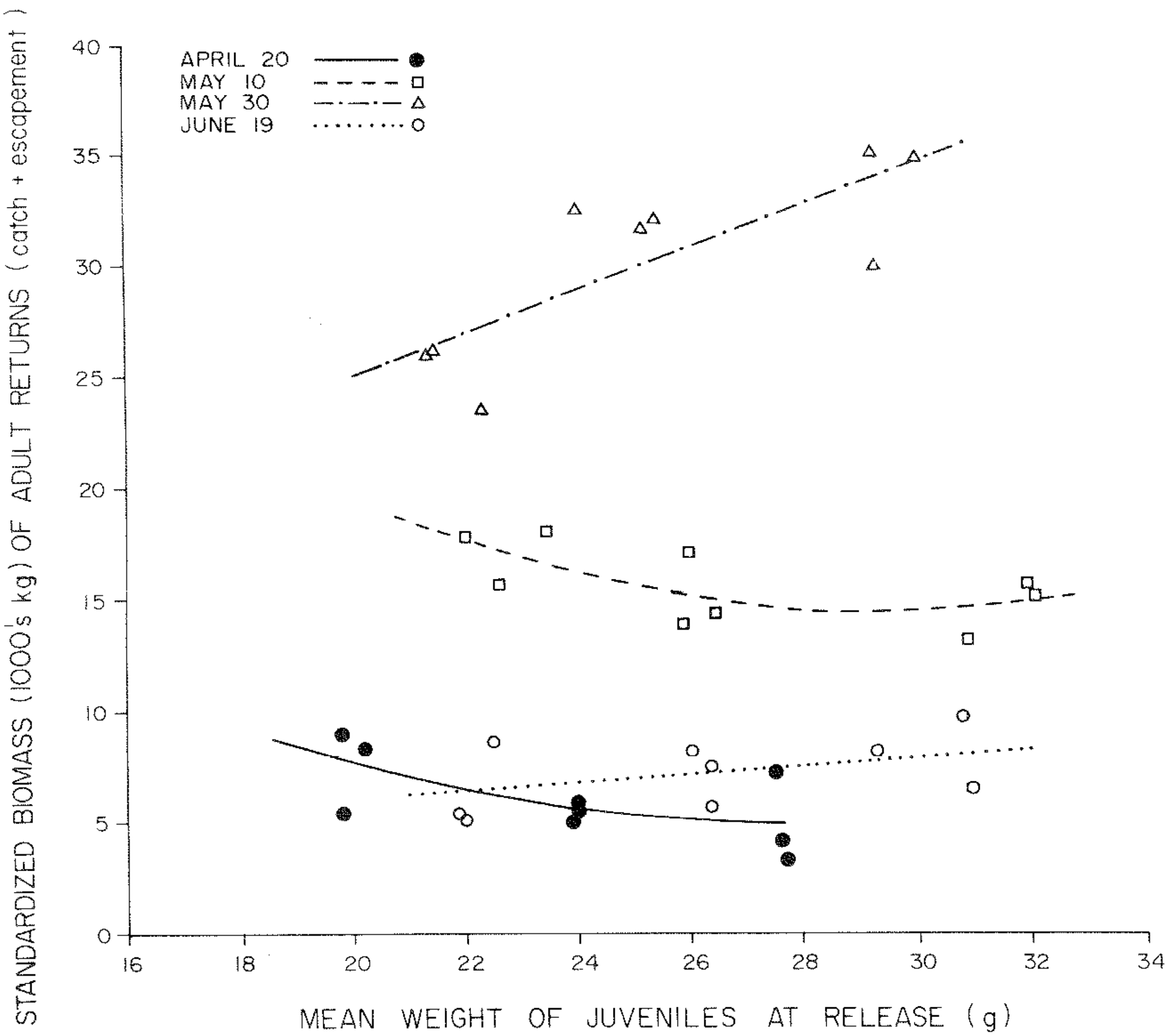

Fig. I-10. 1981 releases. Mean weights of juveniles (sexes combined) at time of release and standardized biomass of adult returns (Kg per 100,000 juveniles released) to the catch plus escapement.

Jacks plus adults

Biomass of jacks plus adults was very similar to that of adults alone. Greatest average biomass for a common release date was for the May 30 release, 30,527 kg. This was followed in decreasing order by the May 10 (16,352 kg), June 19 (7,364 kg), and April 20 (6,378 kg) releases.

The relationships of biomass to juvenile weight for each release were almost identical to those for adults alone and are therefore not illustrated. As with the adults the only significant correlation was for the May 30 release (linear fit, $r^2 = .797$, $p < .05$), with greater biomass from larger smolts.

Response surface analyses

Response surface analysis of adult biomass is shown in Figure I-11.[1] The almost vertical nature of the contours reflects the minor effect of juvenile size (marginally non-significant; $p = .07$). Biomass of returns increases gradually with time and reaches a maximum in the region of days 151 to 153 (May 31 to June 2), as shown by the broken line indicating optimum time of release; this line indicates that the optimum date advances slightly as juvenile weight increases. It is also suggested that biomass increases with increasing juvenile size in the region of optimum time for release and a theoretical optimum time/size combination somewhere beyond the range of the data is indicated.

The response surface analysis for jack plus adult biomass was almost identical to that for adults alone and the same comments on the effects of time and size apply; the surface is not illustrated here.

ANALYSIS OF CATCH[2]

Year of catch

An estimated 5,587 fish were taken in the combined fisheries (Tables I-1a to I-1d). Of this total, 5,506 were taken as age 1.1 adults in 1982. Nine age 1.2 adults were caught in 1983; however, all were taken in the sport fishery and it is possible these were late voluntary returns of fish caught in 1982 (i.e. actually age 1.1). Only 72 fish were caught in 1981, the year of release; it was estimated that eight of these were maturing jacks, the remainder immature adults.

---

[1]As with some percentage return analyses, it was necessary to fix certain model parameters to allow for the minor effects of size. See Appendix Table 2.

[2]Catch figures discussed in this section are observed recoveries expanded for sampling rate and sportsman awareness, as discussed in MATERIALS AND METHODS. Theoretical numbers of adults projected from estimates of immature fish caught in 1981 are not included (see MATERIALS AND METHODS, fishery recoveries in year of release).

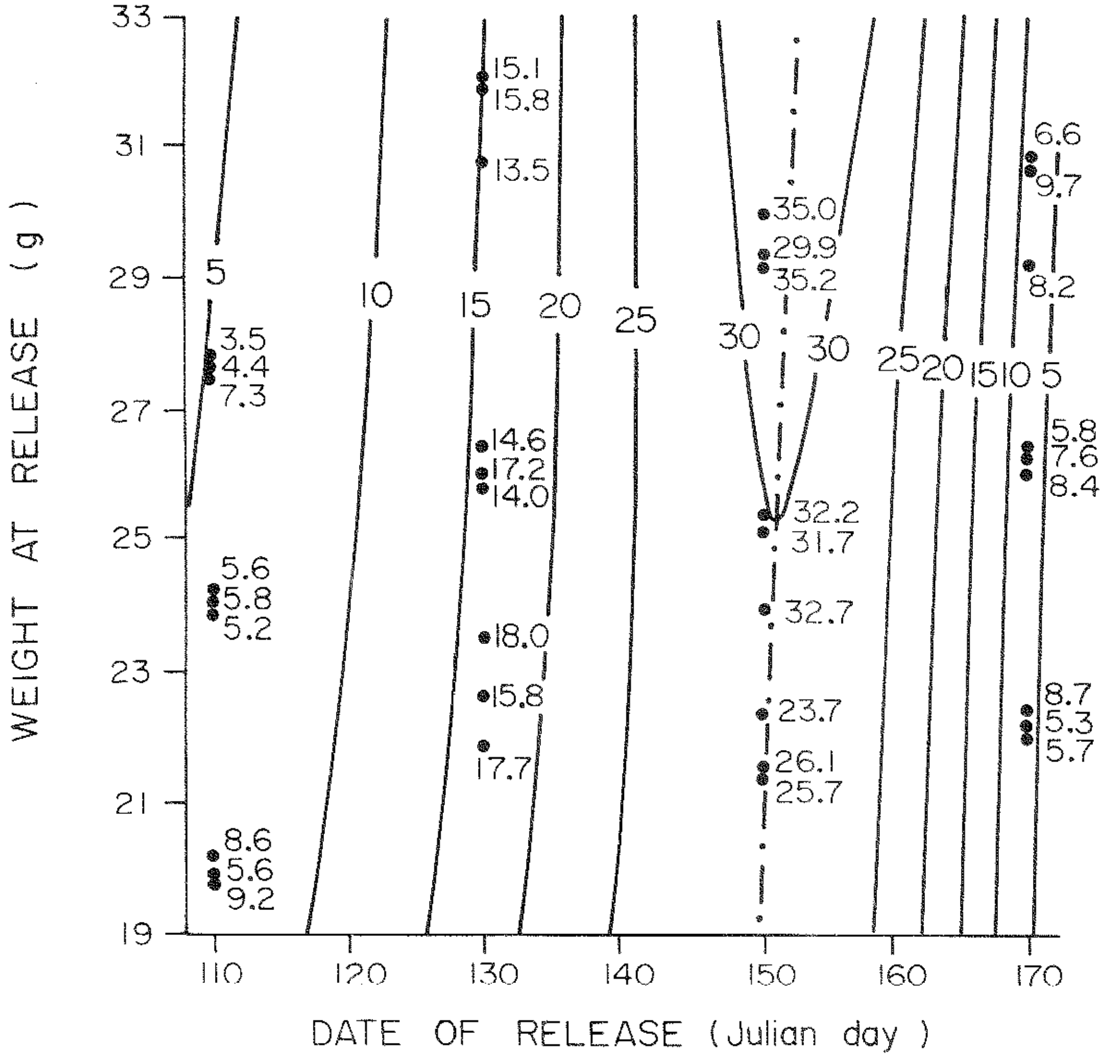

Fig. I-11. 1981 releases. Response surface showing the relationship of adult biomass in the catch plus escapement (standardized to Kg per 100,000 juveniles released and shown in 1000's of Kg) to mean weight of juveniles at release and time of release. Contours represent estimated returns, individual points are the standardized observed values for each group.

Type of fishery (gear type)

Contributions of the various groups to the 1982 commercial troll, net, and sport fisheries are given in Table I-4 (the nine adults taken in 1983 are excluded). Overall, the net fishery took the highest proportion of the catch (36.1%) followed by the commercial troll (33.4%) and sport fisheries (30.6%).

Time of release markedly influenced the distribution of the catch among the gear types. The proportion taken in both the commercial troll and net fisheries decreased with later release while the sport component increased from 15.5% to 41.9%. Size of juveniles also had an influence; for all releases the proportion taken in the net fishery was considerably higher for adults from small category juveniles than for adults from medium or large juveniles. The differences in distribution among gear types associated with both time of release and with juvenile size were highly significant ($p<.001$) when tested using 3-way contingency table analysis (time of release x size category x type of fishery) and Chi-square (Sokal and Rohlf 1981).

Harvest rates

Total adult catch as a percentage of total adult returns for each group is given in Tables I-1a to I-1d, results are summarized in the following table (replicates combined):

Release	Juvenile Size	Area of return			Catch as a percentage of total returns
		Catch	Escapement	Total	
a) Totalled by release					
April 20	Small	173	65	238	72.7
	Medium	124	63	187	66.3
	Large	123	38	161	76.4
	Total	420	166	586	71.7
May 10	Small	461	154	615	75.0
	Medium	373	125	498	74.9
	Large	388	110	498	77.9
	Total	1222	389	1611	75.9
May 30	Small	818	275	1093	74.8
	Medium	1014	303	1317	77.0
	Large	1051	339	1390	75.6
	Total	2883	917	3800	75.9

June 19	Small	316	81	397	79.6
	Medium	326	96	422	77.3
	Large	348	71	419	83.1
	Total	990	248	1238	80.0
Total		5515	1720	7235	76.2
b) Totalled by size category					
Combined	Small	1768	575	2343	75.5
	Medium	1837	587	2424	75.8
	Large	1910	558	2468	77.4

To test for differences in catch:escapement ratio, i.e. harvest rate, the values in the above table were subjected to a 3-way contingency table analysis (time of release x size category x area of recovery; Sokal and Rohlf 1981). There were no significant differences in harvest rate associated with juvenile size, either within releases or overall. There were, however, significant differences among releases ($p<.01$). The values in the table indicate harvest rate was lowest for the first release and highest for the last, with rates for the two middle releases intermediate and equal to each other. These differences were tested by comparing: a) releases 2 and 3, b) release 1 versus 2 and 3 combined, and c) release 4 versus 2 and 3 combined. For these comparisons adjusted significance levels of $\alpha' = .017$ and $\alpha' = .0033$ were used, corresponding to experimentwise levels of $\alpha = .05$ and $\alpha = .01$ respectively. (This was done to allow for non-orthogonality of the comparisons, Sokal and Rohlf 1981, p. 242). The rates for releases 2 and 3 did not differ significantly ($p=.58$), nor was the rate for release 1 significantly different from 2 and 3 combined ($p=.026$, close to significance at $\alpha = .05$). The rate for release 4 was significantly higher than for 2 and 3 combined ($p=.0032$, significant at $\alpha = .01$). These tests indicate the differences are attributable to the high catch for fish of the fourth release relative to other releases.

Geographic distribution

The numbers of fish caught in various areas in 1982 for each type of fishery are shown in Tables I-5, I-6, and I-7 (the estimated nine adults recovered in 1983 are excluded). Table I-8 shows results for the combined fisheries.

In the commercial troll (Table I-5) the largest number of fish were caught in the Central area (27.9%). Most of the remainder were divided fairly evenly amongst the Georgia Strait, Southwest Vancouver Island, and Northwest Vancouver Island fisheries (22.7%, 22.1%, and 18.2%, respectively). The Northern troll accounted for 1.0%; very small numbers were taken in Alaska, Washington, and Oregon (combined total of .9%). The only obvious trend in the pattern of recoveries was the increase in the proportion taken by the Georgia Strait fishery associated with later release, from 11.9% to 38.7%. There were no obvious effects associated with size of juvenile.

Most net-caught fish (Table I-6) were taken in Johnstone Strait (90.1%). The Juan de Fuca and Washington fisheries each accounted for a small proportion (3.4% and 3.8%, respectively). The remaining 2.7% were caught mainly in the Central Coast area with very small numbers taken in Georgia Strait, South West Vancouver Island, and Alaska. There were no obvious effects associated with either time of release or size of juvenile.

The majority of the sport-caught fish (Table I-7) were taken in Georgia Strait (93.5%). A substantial number were taken in the Central Coast area (4.0%) and Washington (2.1%). Very small numbers were taken in the West Coast Vancouver Island and Oregon fisheries (0.2% and 0.1%, respectively). There were no obvious effects associated with size of juvenile; however, fish from later releases appear to contribute slightly more to the Georgia Strait catch.

For the combined fisheries (Table I-8) the largest number of fish were caught in Georgia Strait (36.3%), followed closely by Johnstone Strait (32.5%). These high proportions are attributable mainly to the large sport and net catches in each area, respectively. There were no obvious effects of size of juvenile on distribution; however, there were some pronounced effects of time of release - with later release the proportions taken in the Central Coast, Northwest Vancouver Island, and Johnstone Strait areas all show a gradual decline, associated with this is a marked increase in the proportion taken in Georgia Strait (from 18.1% to 50.8%).

PART II. THE 1983 RELEASE.

MATERIALS AND METHODS

EXPERIMENTAL DESIGN, SIZES AND NUMBERS OF JUVENILES RELEASED

This study consisted of a single release of three sizes of coded wire tagged 1981 brood juveniles, the objective being to further examine the effects of juvenile size on returns at maturity. A release date of May 30 was chosen, this being the date which had given highest returns for the 1980 and 1981 releases. The study was incorporated into a larger study being conducted by other investigators[1] to examine the effects of pond loading density on juvenile production and ocean survival. A description of the larger study and results up to and including release has been published (Fagerlund et al. 1984). The juveniles used for our study came from one of four ponds, of varying loading density, which made up the larger study. This pond was selected since its density approximated normal hatchery production density, as used in the 1980 and 1981 studies. As in the earlier studies, each size group was made up of three replicates, of approximately 4,000 juveniles each.

The procedures for grading to size and tagging were the same as for the 1980 and 1981 studies. Samples of tagged fish were collected 5 days before release to determine lengths, weights and sex. Samples for seawater adaptabilty tests were also taken. A health evaluation was conducted by the Diagnostics Services Unit of the Pacific Biological Station on the day of release. Additional samples were collected near the time of release for proximate analysis and to determine blood plasma cortisol levels and interrenal cell diameters, both of which are indicators of stress.

Estimates of sizes and numbers of juveniles released are given in Table II-1. Health, seawater adaptabilty, and sex ratios are discussed below; body composition, interrenal activity, and cortisol levels are reported by Fagerlund et al. (1984).

---

[1]U.H.M. Fagerlund and J.R. McBride,
Dept. of Fisheries and Oceans,
Biological Sciences Branch,
West Vancouver Laboratory,
4160 Marine Drive,
West Vancouver, B.C.
V7V 1N6

HEALTH, SEAWATER ADAPTABILITY, AND SEX RATIOS OF JUVENILES

Health

Furunculosis, which had caused two periods of high mortality (Fagerlund et al. 1984), was present at moderate to high incidence at the time of release (detected in 1 of the 50 randomly selected live fish sampled). It was still the major cause of ongoing mortality at the time of release (detected in 18 of the 20 moribund or freshly dead fish sampled). No other bacteria were detected, nor were any parasites or fungi found. Internal examination revealed no abnormalities. Externally, 19 of the 50 live fish sampled had clouding of the cornea of one or both eyes; this was not judged severe enough to be debilitating. Hematocrit values of the live fish were normal on average (35-45%) but there were a few exceptions on either side of this range. Values for the moribund fish were frequently below normal, characteristic of bacterial infection.

Seawater adaptability

Blood plasma sodium levels were determined in a sample of 24 fish on May 30, after 24 h exposure to seawater. Average sodium level in a freshwater control group was 157.8 meq/L (standard error 0.07); that of the exposed fish was 165.4 meq/L (standard error 1.6). These results indicate good seawater adaptability. There was no significant correlation between fork length or weight and ability to adapt to seawater.

Sex ratios

The numbers of males and females in the release samples are given in Table II-1. Differences in sex ratios between sizes were examined using the proportions of males in each replicate as a single observation in a one-way ANOVA, with pairwise comparisons between sizes.[1] The ratio for small fish was found to be significantly different from that for medium fish (male proportions of .43 and .52 respectively, $p<.05$). The ratio for large fish (male proportion of .46) was not significantly different from that for either small or medium fish.

A Heterogeneity G-test (Sokal and Rohlf 1981) was then conducted, using the pooled replicates for each size category. This was done to examine for differences from a 50:50 male to female ratio. This test also included a further test of differences in ratios among sizes. The ratio for the population as a whole (all samples pooled, male proportion of .47) was found to be significantly different from a 50:50 ratio ($p<.01$). Considering each size separately (proportions of males for each size are given in the

---

[1]This is a test for differences among sex ratios only, it is not a test of a 50:50 male to female ratio.

preceeding paragraph), small fish showed a significant predominance of females (p=.02); the ratios for medium and large fish were not significantly different from a 50:50 ratio. Sex ratios were not significantly different among sizes using this less sensitive test.

In summary, the above tests indicated there was a significantly higher proportion of females among small category juveniles.

RECOVERY OF JACKS (AGE 1.0) AND ADULTS (AGES 1.1 AND 1.2)

All jacks returning to Quinsam hatchery in the fall of 1983 were examined for adipose clips and CWT's; it was estimated that hatchery returns represented approximately 48.6% of the total, i.e. hatchery plus river, jack escapement (Quinsam hatchery records). All fish recovered were males. Sampling for hypural length and/or round weight was conducted throughout the run. In 1984, 80.1% of the adults returning to the hatchery were examined and sampled; it is estimated this sample constituted 67.1% of the total escapement. As in the previous studies, the escapement returns presented and discussed here are for the hatchery only and are therefore conservative. A similar hatchery recovery program conducted in 1985 did not detect any age 1.2 adults.

Estimates of the numbers taken in the 1983, 1984, and 1985 fisheries were obtained through the Mark Recovery Program, as described in Part I. There were no jacks caught (1983) and only one age 1.2 adult (1985).

DATA ANALYSIS AND RELIABILITY

Percentage returns (% returns) and biomass were calculated as in Part I of this report. Statistical methods are also described there; however, response surface analysis was not used, there being only one independent variable in this case.

RESULTS

Equations for significant regressions are given in Appendix Table 1.

RETURNS OF JACKS AND ADULTS (Table II-2)

Jack returns

Total return of jacks was 47, or 0.13% of the juveniles released. There were no recoveries in the fishery. There was a significant linear correlation ($p<.01$) between % return and juvenile weight (sexes combined), larger juveniles producing higher returns (Fig. II-1). Addition of a quadratic term did not significantly improve the fit.

Adult returns (sexes combined)[1]

Escapement

A total of 396 adults was recovered in the hatchery escapement. This represented 1.11% of the juveniles released. Although there was a suggestion of higher % returns from small category juveniles the correlation between % return and juvenile weight was not statistically significant.

Catch

Total contribution to the combined fisheries was estimated at 1,096 fish, or 3.08% of the juveniles released. There was no significant correlation between juvenile weight and % return although there was some suggestion of higher % returns from small category fish.

Catch plus escapement

An estimated total of 1,492 adults were recovered in the catch plus escapement, or 4.20% of the juveniles released (Fig. II-2). As with the catch and escapement returns individually, there was a suggestion of higher returns from small category juveniles. However, this correlation was not statistically significant and the quadratic curve shown is a line of best fit only ($r^2=.59$).

Jack plus adult returns

Escapement

A total of 443 jacks plus adults were recovered in the hatchery escapement, 1.25% of the juveniles released. There was no significant correlation between % return and juvenile weight.

Catch

No jacks were taken in the fishery and jack plus adult catch was therefore the same as that presented above for adults alone.

---

[1]Escapement returns are discussed separately for each sex in a later section.

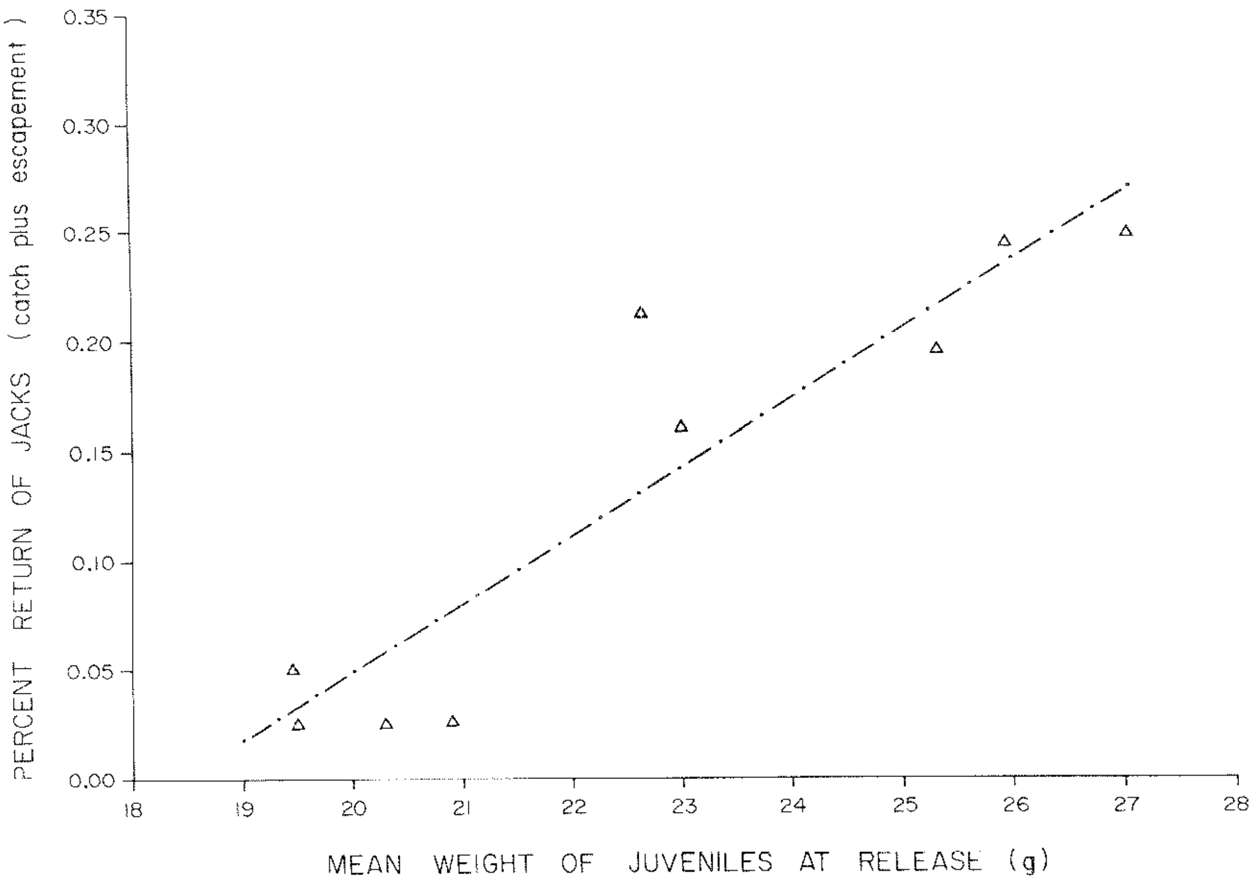

Fig. II-1. 1983 releases. Mean weights of juveniles (sexes combined) at time of release and total returns of jacks (catch plus escapement) as percentages of juveniles released.

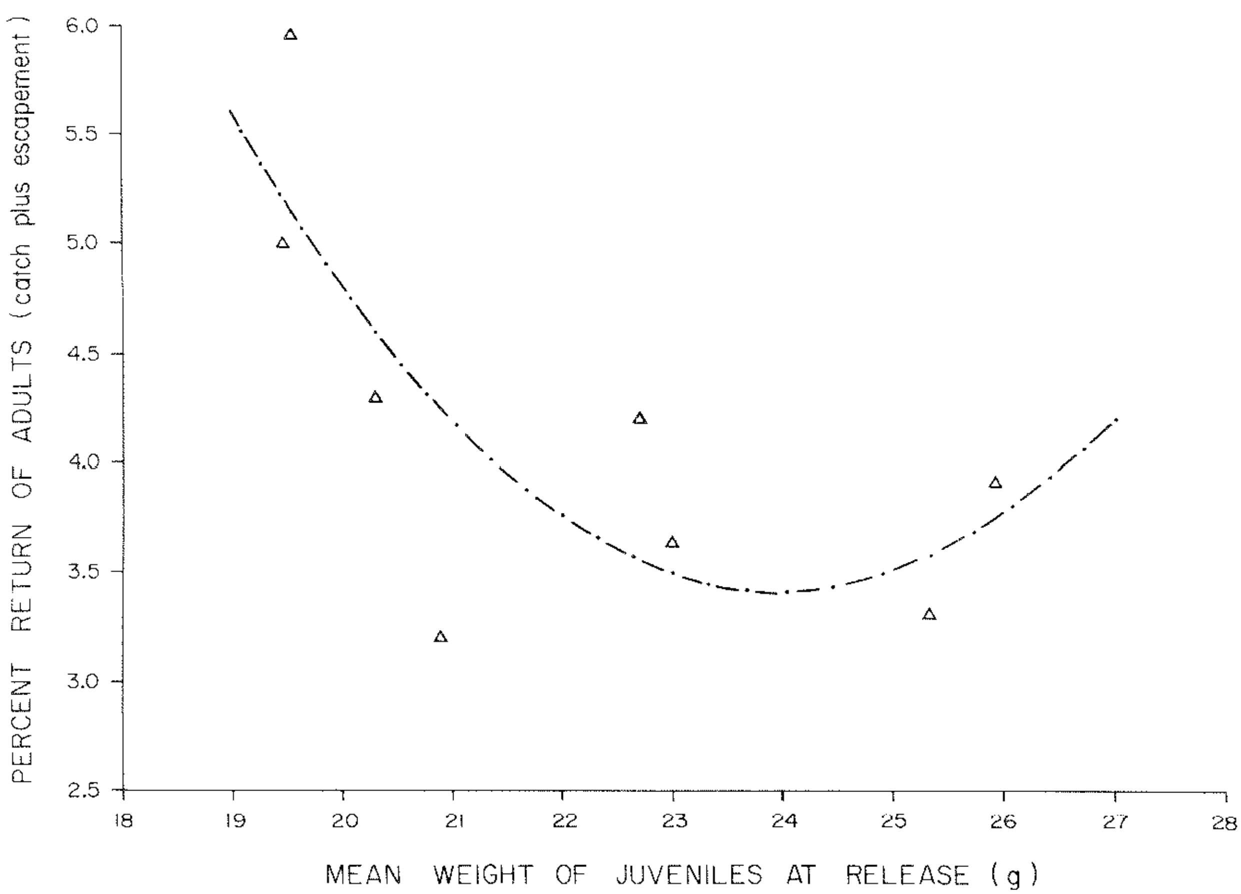

Fig. II-2. 1983 releases. Mean weights of juveniles (sexes combined) at time of release and total returns of adults (sexes combined, catch plus escapement) as percentages of juveniles released.

Catch plus escapement

An estimated total of 1,539 jacks plus adults were recovered, 4.33% of the juveniles released. There was no significant correlation between % return and juvenile weight, although, as with adults alone, there was a suggestion of higher returns from small category juveniles.

Incidence of jacks (jacks as a proportion of total returns)

Jacks as percentages of total returns (jack plus adult, catch plus escapement) were calculated for each group. Numbers of jacks and adults are given in Table II-2, the relationship between % jacks and juvenile weight (male plus female) is shown in Figure II-3. There was a highly significant linear correlation (r^2=.87, p<.01), with larger juveniles yielding higher proportions of jacks. Fit was not improved significantly by addition of a quadratic term.

BIOLOGICAL OBSERVATIONS ON ESCAPEMENT RETURNS (INCLUDES % RETURNS BY SEX)

Percentage returns of adult males and females

Returns by sex and juvenile weights by sex are given in Table II-2. There were no significant correlations between % return and juvenile weight for either sex; however, there was a suggestion of higher returns of females from small category juveniles. The male return of 235 adults represented 1.42% of the male juveniles released; the female return of 161 adults represented 0.85% of the female juveniles.

Sex ratios of adult escapement returns

The proportion of males in the adult hatchery returns was .59, much higher then the value of .47 observed in the juveniles at release. A Heterogeneity G-test was conducted comparing the adult sex ratios for medium and large fish with a juvenile estimate of .49 male, common to these two sizes. The sex ratio of small category adults was tested separately against the statistically distinct estimate of .43 for small category juveniles, using a G-statistic 2-way test of independence. The male proportions for medium and large category adults were .58 and .63, respectively. Both differed significantly from the juvenile proportion for these sizes (p=.033 and p=.001, respectively) but did not differ significantly from each other. The male proportion for small category adults was .57, also significantly higher than was observed in juveniles of the same size category (p<.001).

Sex ratios were also examined after adjustment for the additional adult males which might have resulted had the observed jacks matured as adults (see the corresponding section of Part I for details of method). The

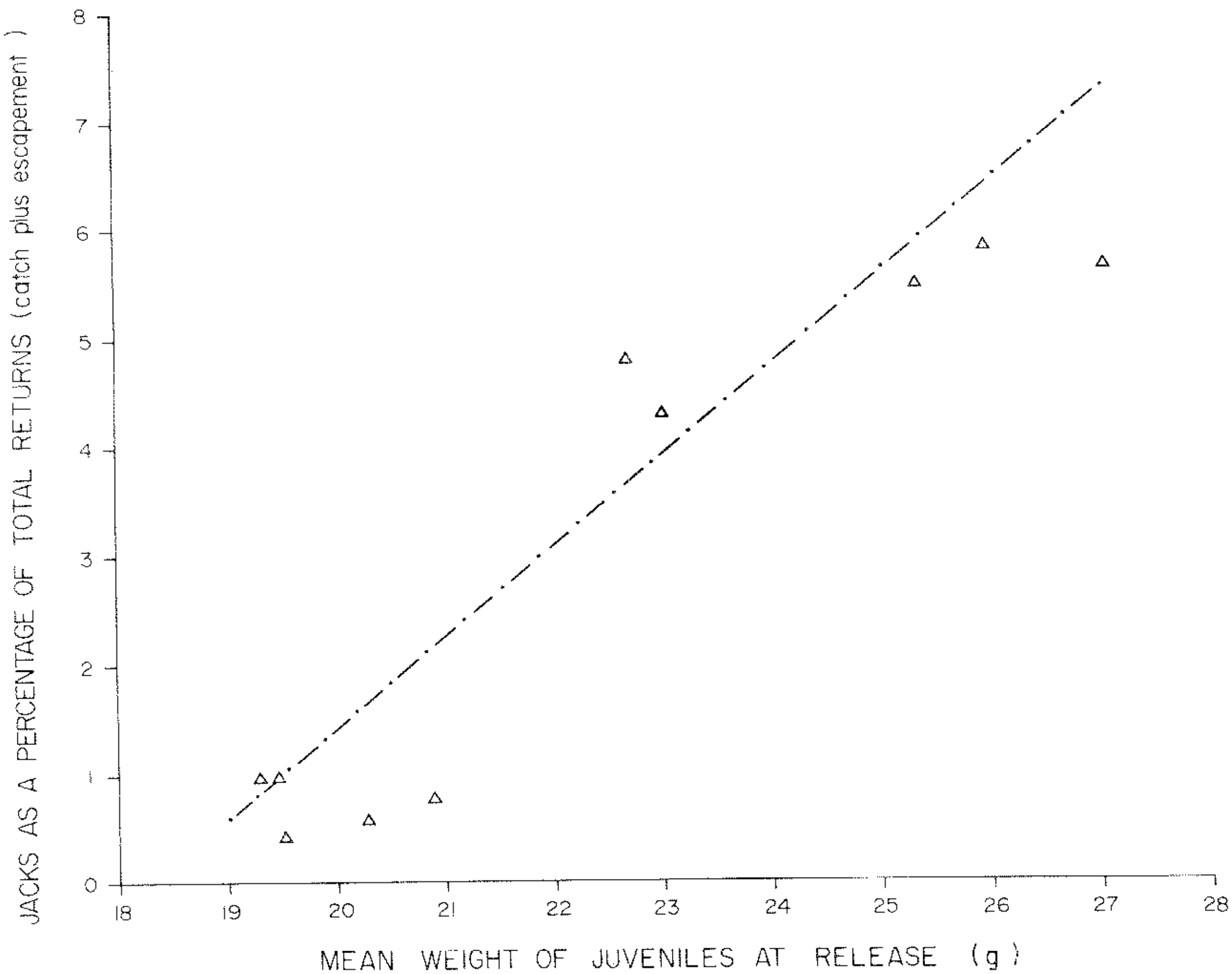

Fig. II-3. 1983 releases. Mean weights of juveniles (sexes combined) at time of release and jacks as a percentage of total returns (i.e. jacks plus adults of both sexes) to the catch plus escapement.

resulting adjusted adult male proportions were: small category, .58; medium category, .62; large category, .68; combined sizes, .62. Statistical tests were not done on the adjusted proportions.

Size of returning fish (Table II-3)

There was no significant correlation between weight of jacks in the escapement and male juvenile weights. ANOVA indicated differences in weight (among the seven replicates for which there were observations) were insignificant; the overall average jack weight was 0.299 Kg. For male adults, female adults, and for the combined sexes there were no significant correlations between adult weights and weights of juveniles of the same sex. Separate ANOVA's were done to test differences in adult weight among all replicates for each sex and for the combined sexes; all differences were statistically insignificant.

Female adults were considerably heavier than males. Average weight for males was 1.65 Kg., average weight for females was 2.22 Kg. This difference was highly significant (t-test, $p<.001$).

BIOMASS OF RETURNS (CATCH PLUS ESCAPEMENT)

Standardized biomass estimates (yield of flesh per 100,000 juveniles released) are given in Table II-4. For jacks there was a highly significant linear correlation between biomass and juvenile weight (male plus female), larger juveniles yielding greater biomass ($r^2=.86$, $p<.01$); fit was not improved by addition of a quadratic term. Neither adult biomass or jack plus adult biomass was significantly correlated with juvenile weight.

Total biomass estimates per 100,000 juveniles released (sizes pooled) were: jacks, 353.7 Kg; adults, 70,153 Kg.; jack plus adult, 70,506 Kg.

ANALYSIS OF CATCH[1]

Year of catch

An estimated 1,096 fish were taken in the combined fisheries (Table II-2). Of this total, 1,093 were caught as age 1.1 adults in 1984. Three age

---

[1]Catch figures are observed recoveries expanded for sampling rate and sportsman awareness; see MATERIALS AND METHODS in Part I.

1.2 adults (one observed recovery) were estimated to have been taken in the 1985 Alaska fishery. No fish were taken in the 1983 fishery (jacks).

Type of fishery (gear type)

Contribution of the various groups to the 1984 commercial troll, net, and sport fisheries are shown in Table II-5. Overall, the net fishery took 22.9% of the catch. The remainder was divided almost evenly between the commercial troll and sport. There were no apparent effects of size on distribution among gear types.

Harvest rates

Catch as a percentage of total returns for each group is given in Table II-2; results are summarized in the following table (replicates pooled).

Size category	Area of return			Catch as a percentage of total returns
	Catch	Escapement	Total	
Small	451	161	612	73.7
Medium	300	118	418	71.8
Large	345	117	462	74.7
Total	1096	396	1492	73.5

The frequencies in the above table were tested by Chi-square; area of return (and therefore harvest rate) was found to be independent of size category (χ^2=0.98, d.f.=2, p=.61).

Geographic distribution

The numbers of fish caught in various areas in 1984 for each type of fishery and for the combined fisheries are given in Table II-6.[1]

In the commercial troll the largest number of fish were taken in the Northwest Vancouver Island fishery (36.7%), followed closely by the Central Coast (30.9%). Other major areas of recovery were Southwest Vancouver Island (16.6%) and Georgia Strait (14.5%). None were taken in the North Coast, Alaska, or Oregon; two fish (0.5%) were taken in Washington. The large majority of net caught fish were taken in Johnstone Strait (92.0%). Low numbers were taken in the Central Coast, Juan de Fuca, and Washington (3.2%,

[1]The estimated three fish (1 observed) taken in Alaska were caught in 1985 and are not included here.

2.4%, and 2.4%, respectively). Almost all sport-caught fish were taken in Georgia Strait (96.1%); the remainder were taken in the Central coast.

Considering the combined fisheries, 41.8% of the fish were recovered in Georgia Strait, attributable mainly to the high sports catch. This was followed by Johnstone Strait (21.0%), attributable entirely to the net fishery. Equal numbers were taken in the Central Coast and Northwest Vancouver Island (14.5% for each). A substantial number were taken in Southwest Vancouver Island (6.6%). None were taken in the North Coast, Alaska, or Oregon. Small numbers were taken in Juan de Fuca and in Washington (0.5% and 0.7%, respectively).

Size had an effect on the geographic distribution of the catch. In all three fisheries the proportion of the catch taken in the Central Coast (the most northerly area of recovery, excluding the Alaska recovery in 1985) tended to increase with increasing size of juvenile. This relationship was found to be highly significant when tested in a 3 x 2 Chi-square using the total catch for each size category divided into Central Coast versus other areas combined (χ^2=22.5, d.f.=2, p<.001).

PART III. RESULTS AND DISCUSSION FOR THE COMBINED STUDIES

In this part, the results of the three studies are compared and consolidated for discussion; studies are referred to by the year in which the releases were made. Detailed results for the 1980 study are available in Bilton et al. (1984). Detailed results for the 1981 and 1983 studies are given in Parts I and II, respectively, of this report.

RETURNS OF JACKS AND ADULTS

In this section returns, unless otherwise indicated, refer to numbers of fish returning as percentages of juveniles released and are for the combined catch plus escapement.

Time of release had two major effects which were evident in both studies involving multiple releases (1980 and 1981): 1) survival was strongly affected, and 2) the incidence of jacks (i.e. the proportion of jacks in the total returns) decreased with later release.

The effects of size at release on adult returns were very minor compared to those of time of release. Juvenile size strongly affected production of jacks, however - in all studies both the returns of jacks and the incidence of jacks increased significantly with increasing juvenile size.

Response surface analyses of adult returns for the 1980 and 1981 studies predicted optimum release dates of June 4 and June 6 respectively; returns increased gradually until these dates and then decreased rapidly. In both years the contribution of size to the RSA models was statistically insignificant (marginally so in the 1980 study); however, both suggested slightly higher returns from smaller fish of earlier releases. The effect of size was statistically insignificant in the 1983 single release study also, but higher returns from smaller juveniles were again suggested. Although the relative differences in adult returns associated with time and size of release were similar within studies, total returns varied among the studies (i.e. among brood years). Total adult returns for the 1980 releases were 4.7%, compared to 5.4% for the 1981 releases. Total returns for the single May 30 release in 1983 were 4.2%, compared to an average of 10.1% for this release date in the 1980 and 1981 studies. Data from the 1980 and 1981 studies were standardized to remove the effects of these brood year differences and the standardized data was pooled to give a single predictive response surface model; data from the 1983 single release was not included since it provided information on only one independent variable. The standardization procedure is described below; the standardized returns are of a magnitude which could be expected based on results of the combined studies:

- highest return for a single group (average of 3 replicates for a time/size combination) in the 1980 study was 9.64% for medium category fish of the May 30 release.
- highest return in the 1981 study was 11.63% for large category fish of the May 30 release.
- the average of these two high returns was 10.6%. All data was adjusted using this value as a high standard (% returns for each replicate in the 1980 study were multiplied by 10.6/9.64; % returns in the 1981 study were multiplied by 10.6/11.63).

The RSA model obtained using the standardized data is shown in Figure III-1. Optimum release date is June 5 (Julian day 156) and is essentially the same for any size of juvenile (at least within the tested ranges). Adult returns increase gradually until this date and then drop sharply. In this model slightly higher returns from smaller juveniles of earlier releases are strongly indicated and the contribution of size is highly significant ($p<.0001$). There is very little apparent effect of size subsequent to the optimum date. For releases made on the optimum date returns of approximately 10.4% to 11.2% are predicted for juveniles weighing from 20 to 31 g (the range tested near this date), the higher returns resulting from smaller juveniles. Slightly higher returns are predicted from release of even smaller juveniles but it would be unwise to extrapolate too far beyond the tested range; predicted return at 14 g, the smallest weight tested in any of the releases, is 13.1%. The response surface suggests returns will begin to increase again at weights above 31 g, however, this region is completely beyond the tested weight range and again it would be dangerous to extrapolate. Returns from releases made prior to the optimum date will be lower but can be maximized by release of smaller juveniles.

As with the adult returns, the relative differences in jack returns associated with time and size were similar within each study but total returns differed among studies (brood years). While the incidence of jacks increased with earlier release and larger juvenile size, returns were also dependent on large differences in combined jack plus adult returns (i.e. overall survival) associated with time of release. Highest returns of jacks therefore resulted from large juveniles released at not the earliest, but at intermediate dates. Response surface analyses indicated conditions for maximum returns of jacks lay outside the tested ranges; within tested ranges highest returns were predicted from release of about 30 g juveniles in the approximate period May 8 (1980 study) to May 13 (1981 study). Earlier or later release or smaller juvenile size would decrease jack returns.

The effects of time of release on returns of jacks and adults combined were quite similar to those observed for adults alone; however, the effect of juvenile size on the incidence of jacks was reflected in higher combined returns (with a high jack component) from larger juveniles in some releases. Because jacks are less desirable than adults, the age composition of expected returns under various release conditions is important. To facilitate examination of expected age compositions the jack return data from the 1980 and 1981 studies was standardized to remove the effects of variabilty

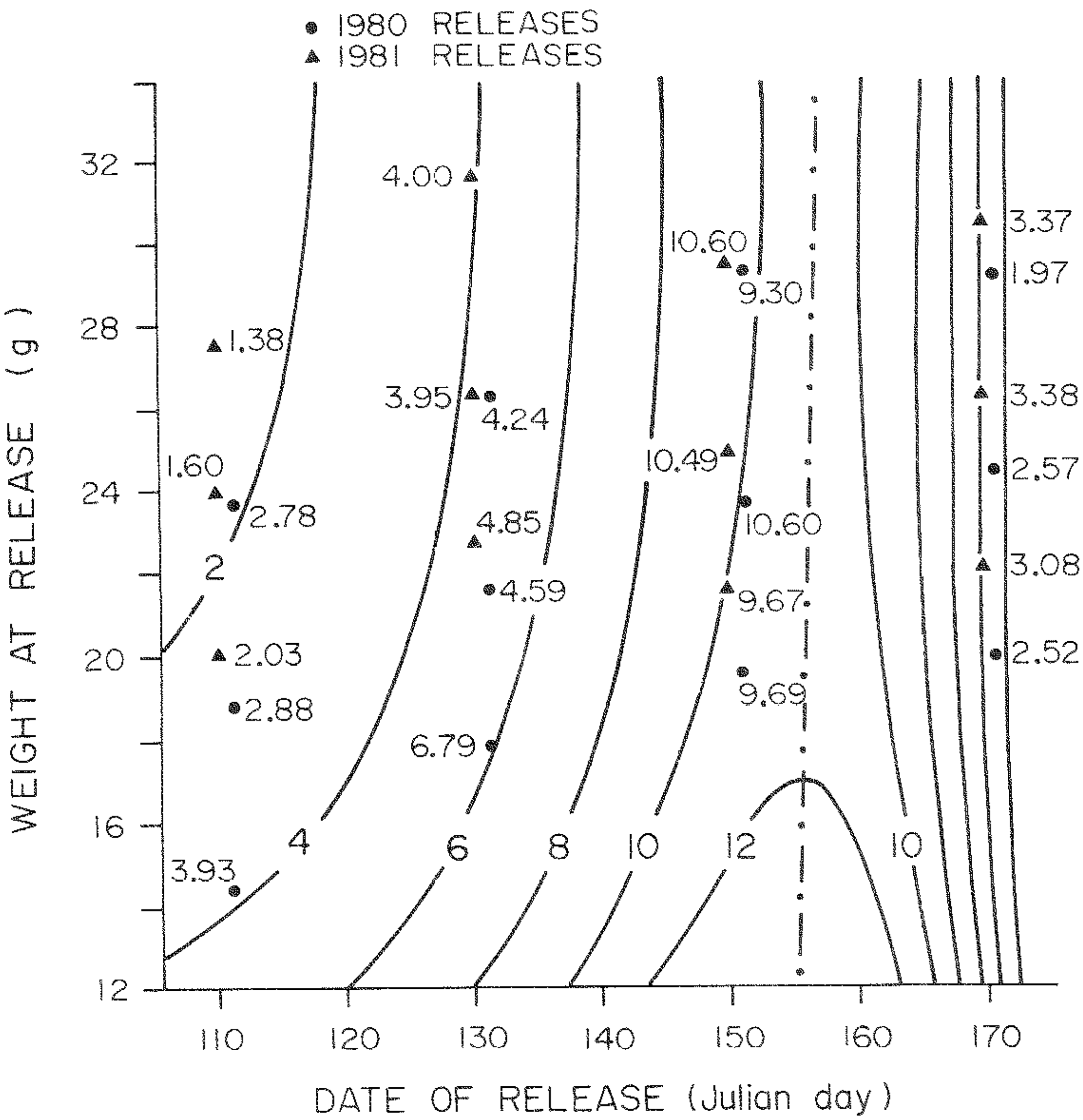

Fig. III-1. 1980 and 1981 releases combined. Response surface showing the relationship of returns of adults in the catch plus escapement (as percentages of juveniles released) to mean weight of juveniles at release and time of release. Data was adjusted to allow for differences in total returns between brood years, as described in the text. Contours represent estimated returns, individual points are the replicate means of the adjusted observations (values for individual replicates were used in the analysis but are not plotted due to lack of space).

in total returns among brood years in the same manner as was done for adult returns: highest jack return for a single group in the 1980 study was 1.96% (May 30 release, large); highest return for the 1981 study was 1.88% (May 10, large); data for both studies was adjusted using the average of these two values, 1.9%, as a high standard. The RSA model based on the standardized jack % return data is shown in Figure III-2, superimposed on the adult return response surface already presented in Figure III-1. Maximum return of jacks (1.8%) is predicted for release of 31.5 g juveniles on May 13 (day 133). Decreasing returns with juvenile sizes greater than this are indicated; however, this is beyond the tested weight range and is likely an artifact of the model. Using Figure III-2 it is possible to examine the % returns of both jacks and adults which could be expected from various time/size release conditions. Some representative values are tabulated below.

		Juvenile weight (g)				
Day		14	18	22	26	30
110 (April 20)	Adult	3.9	2.7	2.1	1.7	1.5
	Jack	0.1	0.2	0.4	0.7	1.0
	Total	4.0	2.9	2.5	2.4	2.5
120 (April 30)	Adult	5.1	3.8	3.1	2.6	2.4
	Jack	0.1	0.3	0.5	0.9	1.4
	Total	5.2	4.1	3.6	3.5	3.8
130 (May 10)	Adult	7.1	5.6	4.8	4.3	4.0
	Jack	0.1	0.3	0.6	1.1	1.7
	Total	7.2	5.9	5.4	5.4	5.7
140 (May 20)	Adult	9.9	8.3	7.4	6.9	6.6
	Jack	0.1	0.3	0.5	1.0	1.6
	Total	10.0	8.6	7.9	7.9	8.2
150 (May 30)	Adult	12.6	11.1	10.2	9.7	9.5
	Jack	0.0	0.2	0.4	0.7	1.1
	Total	12.6	11.3	10.6	10.4	10.6
160 (June 9)	Adult	12.4	11.1	10.4	10.0	10.0
	Jack	0.0	0.0	0.3	0.4	0.6
	Total	12.4	11.1	10.7	10.4	10.6
170 (June 19)	Adult	4.2	3.6	3.3	3.2	3.3
	Jack	0.0	0.0	0.0	0.1	0.3
	Total	4.2	3.6	3.3	3.3	3.6

The size effects noted in the adult returns are attributable at least in part to differences in the incidence of jacks - since the highest proportions of jacks occurred in groups of juveniles released large and early

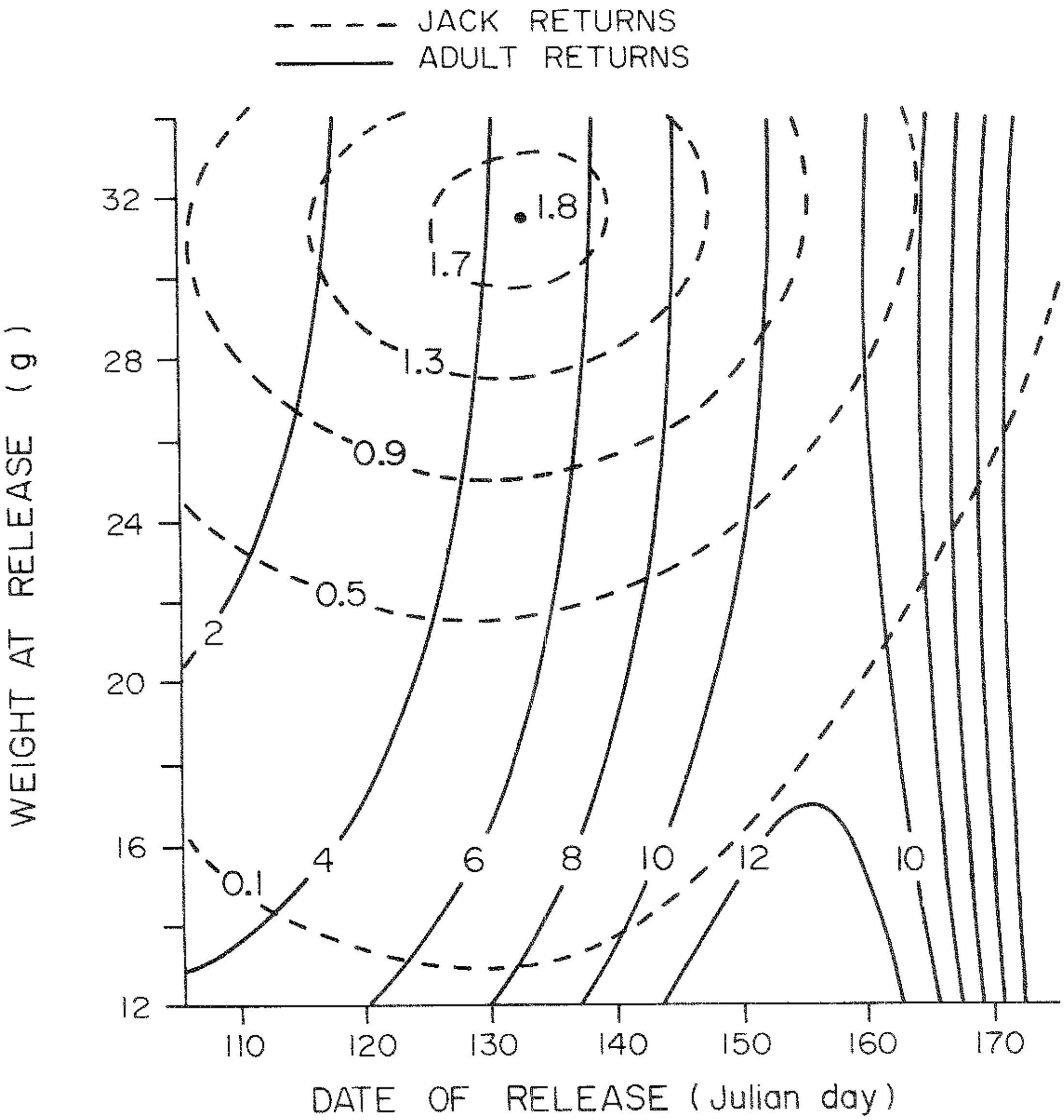

Fig. III-2. 1980 and 1981 releases combined. Response surface showing the relationship of estimated returns of jacks in the catch plus escapement (as percentages of juveniles released) to mean weight of juveniles at release and time of release, superimposed on that for adult returns (from Fig. III-1). Data for both surfaces was adjusted to allow for differences in total returns between brood years, as described in the text.

(jacks represented as much as 30% of the total returns in some groups), highe. adult returns might be expected from the smaller juveniles of earlier releases, as was the case. To examine this more closely the individual % returns observed for adults were adjusted by adding an estimate of the number of additional adults which might have resulted had the observed jacks matured the following year.[1] Response surface analyses were then repeated for both the 1980 and 1981 studies, using the adjusted adult returns. The effect in both studies was to further reduce the significance of size. In the 1980 study size was of marginal significance in the original model (p=.06) and effects were quite strongly indicated by the surface contours; these effects were much less evident in the adjusted model and the significance of size reduced considerably (p=.39). In the 1981 study size effects in the original model were of considerably less significance than in the 1980 study (p=.27), but were still weakly indicated by the surface contours; in the adjusted model there were virtually no indications of size effects in the contours and the significance of size was reduced to p=.34. For the single release in 1983 slightly higher adult returns from smaller juveniles were again suggested but were not statistically demonstrated; since returns of jacks were very low (3.1% of total returns) the adjustment for jacks had almost no effect. These results suggest juvenile size (at least within the tested ranges) may have had little direct effect on survival potential, with any size-associated differences in adult returns resulting from reduced adult production associated with high incidences of jacks.

The percentage returns discussed above are for the combined catch plus escapement. In the case of jacks very few fish were recovered in the fishery; however, some time and size effects were indicated and were consistent with those seen in the escapement. In the case of adult returns time effects were similar in both the catch and escapement for all studies; however, size effects differed between catch and escapement in some studies. In the 1980 study adult returns to the escapement were significantly higher from smaller juveniles of the first three releases; in the catch and catch plus escapement this was evident (to a lesser degree) for the second release only. In the 1981 and 1983 studies size effects were much less evident and differences between catch and escapement were very minor. The discrepancies seen in the 1980 study may have resulted from selection by the fishery for larger fish; this is discussed in more detail in a later section dealing with the fishery. The point to be noted here is that interpretations based on only fishery, or more importantly, only hatchery returns, could be quite misleading. Green and MacDonald (1987) reached a similar conclusion when they used log-linear models to analyse the effects of various release conditions on fishery and hatchery returns of chinook salmon; they also reanalysed Bilton's Rosewall Creek coho study data (Bilton et al. 1982) using the same technique.

---

[1]Estimates of additional adults were made by subtracting estimated mortalities for a further year of ocean residence from the numbers of jacks observed, using monthly instantaneous mortality rates derived from a Puget Sound study as described by Ricker (1976).

They found "the conditions which maximize returns to the hatchery will not necessarily be the the same conditions which maximize catches in the fishery".

In conclusion, if the objective is to maximize adult returns there is a narrow "time window" for release centered at about June 5 (Julian day 156); time of release becomes particularly critical beyond this date and returns decline rapidly. Although size at release is of much less importance, there is some advantage to releasing smaller juveniles (at least within the tested range of approximately 14 to 30 g), particularly in earlier releases. The operative mechanism for this size effect appears to be the increased incidence of jacking associated with larger juvenile size.

BIOMASS OF RETURNS

An alternative criterion for maximum production would be the amount of flesh produced, rather than percent returns alone. Analyses of standardized adult biomass estimates (Kg flesh/100,000 juveniles released) gave results which did not differ greatly from those observed for % returns, particularly with regard to juvenile size effects. Biomass data for the 1980 and 1981 studies were standardized and combined to give a single RSA model, as was done for jack and adult returns: greatest biomass for a single group in the 1980 study was 23,064 Kg (May 30 release, medium size category); greatest biomass for the 1981 study was 33,351 Kg (May 30 release, large category); data from both studies were adjusted using the average of these two values, 28,207 Kg, as a high standard. The RSA model based on the standardized data is shown in Figure III-3. As with the 1981 adult biomass model, it was necessary to fix certain parameters in order to achieve model stability (see Appendix Table 2). The surface is quite similar to that for adult returns (Fig. III-1). Within the tested weight range, maximum adult biomass of approximately 30,000 to 31,000 kg per 100,000 juveniles is predicted for releases in the period June 2 to June 4 (Julian days 151 to 153), the optimum date increasing slightly with increasing juvenile size. This date is about 3 to 5 days earlier than that for maximum adult returns, reflecting the larger size of adults from earlier releases. Size effects were highly significant ($p=.0004$) and very similar to those observed for adult % returns, with slightly greater biomass indicated for smaller juveniles, particularly for earlier releases. The observed tendency for larger juveniles to produce larger adults is apparently overridden by the higher returns associated with smaller juvenile size, as discussed above.

Since jacks contributed very little to total biomass results of analyses of jack plus adult biomass were almost identical to those for adult biomass alone, and are not discussed here.

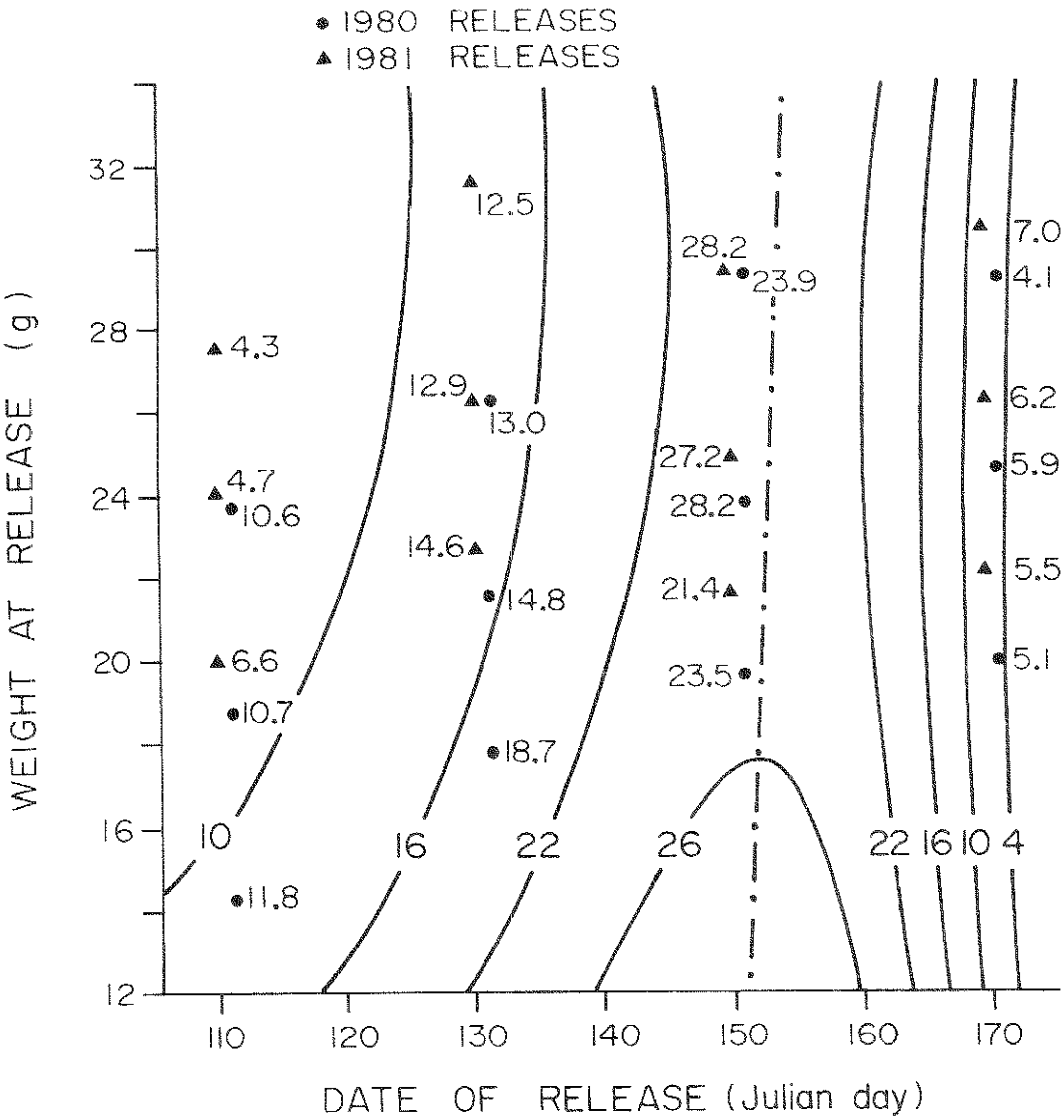

Fig. III-3. 1980 and 1981 releases combined. Response surface showing the relationship of adult biomass in the catch plus escapement (standardized to Kg per 100,000 juveniles released and shown in 1000's of Kg) to mean weight of juveniles at release and time of release. Data was adjusted to allow for differences in total biomass between brood years, as described in the text. Contours represent estimated returns, individual points are the replicate means of the adjusted observations (values for individual replicates were used in the analysis but are not plotted due to lack of space).

THE FISHERY

The geographic distribution of the catch was similar for all studies, with approximately 90% of the catch occurring in three major areas - Georgia Strait, Johnstone Strait, and Central Coast/Northwest Vancouver Island. The catch for each area was largely attributable to a different gear type; sport, net, and commercial troll, respectively. Time of release affected geographic distribution, with fish of later releases showing a less extended northward range. There were no apparent effects of juvenile size on geographic distribution in the 1981 study; however, the proportion taken in the more northern areas increased with increasing juvenile size in the 1980 study and the same effect was suggested in the 1983 study.

The harvest rate on adults was quite consistent between studies, with the catch making up 79.7%, 76.2%, and 73.5% of the total returns for the 1980, 1981, and 1983 releases, respectively. These rates overestimate slightly, since the escapement figures used do not include estimates of marked fish among river spawners or among the few fish not sampled at the hatchery. If such estimates are included the harvest rate estimates change to 74.6%, 71.0%, and 65%, respectively.[1]

Time of release had little effect on adult harvest rates; the only apparent effect was in the 1981 study, where the rate was significantly higher for fish of the last release. This may relate to the less extended northward range of fish of later releases (as discussed above) resulting in differential exposure to various fisheries; however, the same was not seen in the 1980 study, where fish of later releases also showed a less extended northward range.

In the 1980 study harvest rates were significantly higher for adults resulting from large category juveniles for the first three releases; this is consistent with the significantly higher escapement returns from smaller juveniles of these releases. In this study there was a pronounced tendency for larger juveniles to produce larger adults, thus, selection by the fishery for large adults is indicated. Selection for larger coho by commercial troll and gillnet gears has been previously demonstrated by Ricker and Wickett (1980). Similar juvenile size to adult size relationships were only weakly indicated in the 1981 study and none were apparent in the 1983 study; this could explain the lack of juvenile size associated effects on adult harvest rates in these studies.

The effects of time and size at release on distribution of the adult catch among gear types were not entirely consistent among studies, although

---

[1]Bilton et al. (1984) reported that the adult escapement figure used in analysis of the 1980 study represented approximately 59% of the total escapement. This has since been revised to 74.8%; the estimate of 78% reported for jacks has been revised to 76.2%.

there were some important similarities. While the net fishery portion of the total catch for each study ranged from 23% - 40%, the remainder was shared approximately equally between the commercial troll and sport fisheries in all studies. In the two studies involving multiple releases this was true for the catches attributable to the combined releases for each study but was not always true for catches attributable to individual releases. In both studies the sport share (with over 90% caught in Georgia Strait) increased markedly with later release, from approximately 15-20% of the total catch for the April 20 releases to slightly over 40% for the June 19 releases. The later is equivalent to the Georgia Strait sport fishery contribution observed by Schubert and Lister (1987) for both cultured and wild Salwein Creek coho, a more southerly British Columbia stock which could be expected to contribute more heavily than Quinsam to the Georgia Strait fishery because of its geographic location.

The only apparent influence of juvenile size on distribution of the adult catch among gear types was in the 1981 study, where the net share was significantly higher for adults resulting from small category juveniles. This was true for all releases in the study. The reason for this is not readily apparent. One possible explanation might be differences in susceptability to the various gear types related to adult size, since there was a significant positive correlation between adult size and juvenile weight in one release in the study and suggestions of this in two others. If this were true, it is strange that similar gear type distribution differences were not seen in the 1980 study, where adult size showed a much stronger positive correlation with juvenile weight. Another possiblity is that differences in geographical distribution related to juvenile size may have resulted in differential exposure to various gear types; however, such size related differences in geographical distribution, while at least indicated in the other studies, were not apparent in this study, as discussed earlier.

Very little information was available on gender of fish in the catch; however, sex ratios of the escapement returns suggest there may have been some sex selectivity by the fishery. This is discussed in a later section dealing with sex ratios.

The most obvious and consistent feature of the fishery returns was the effect of time of release on the distribution of the catch among gear types. This suggests the possibility of timing releases to benefit particular fisheries. For example, if the goal were to increase contribution to the sport fishery it might appear reasonable to make later releases. However, caution is advised - response surface analysis of sport caught adults for the 1980 study showed the optimum time and size at release for returns to that fishery were almost identical to those for maximum total returns. The gains achieved by optimizing for total returns so far outweighed the relative differences in contribution to the various fisheries that sport fishery returns were maximized as well; later release would in fact decrease sport fishery returns.

OTHER OBSERVATIONS

Sex ratios of adults

The sex ratios of adults in the escapement returns were usually different from those of the juveniles at the time of release. In the two multiple release studies the proportions of males in adult escapement returns were generally lower than in the juveniles, including the May 30 releases, the date used in the 1983 single release study. In the 1983 study the opposite was observed, with a higher proportion of males in the adult escapement returns than in the juveniles. The reduction in adult males in the 1980 and 1981 studies can be at least partially explained by the effect of jacking; since jacks are all males a high incidence of jacking would reduce the incidence of adult males. Hager and Noble (1976) also observed decreased proportions of males in adult coho returns in association with larger juvenile size and offer a similar explanation. Examination of theoretical escapement returns from the 1980 and 1981 studies, which included an adjustment for the effect of jacks, supported this explanation; however, other explanations are required for the high proportions of males in the adult escapement returns in the 1983 study. These could possibly include selection by the fishery for females. A small amount of information on gender of the tagged adults recovered in the fishery was available for the 1983 study and, although not conclusive, supports this possiblity (no information was available for the 1980 and 1981 studies). A total of 39 tagged adults from the study taken in the 1984 fishery were sampled for gender; all were net caught.[1] Twenty-four of these (62%) were females. Heterogeneity G-tests were conducted comparing this ratio to that of the juveniles at release (53% female) as well as to a 50:50 ratio. The ratio observed in the fishery did not differ significantly from either; however, failure to demonstrate statistical significance is not surprising with such a small sample. Healey (1986) found sex selectivity in the commercial troll fishery; he found coho females to be significantly more numerous than males in the 1981 - 1983 British Columbia catches, the overall average being 54.7% female. This proportion decreased from north to south but was greater than 50% in the areas where most Quinsam study fish were recovered. Healey's study thus suggests there may well have been selection for females by the commercial troll fishery, however, information on the gender of time and size study fish taken in this fishery was not available to confirm this. If selection by the fishery for females did occur in the 1983 study it is difficult to understand why it was not indicated in the other studies.

---

[1]Eighteen of the 39 were identified as siene caught, 3 as gillnet caught, and 18 were from mixed seine/gillnet catches; the majority of those of mixed origin were likely taken in the Johnstone Strait seine fishery.

The influence of seawater adaptability of juveniles

In the 1980 study, seawater challenge tests were conducted from late March until mid-June. Seawater adaptability changed little during the period of the releases but was slightly better in the tests performed on April 17 and May 8. Adaptability was not correlated with fork length or weight during the period of the releases. Response surface analysis of the plasma sodium data from all tests indicated that adaptability reached a maximum during the third week of April, near the time of the first release. Results were similar in the 1981 study. All groups in this study showed good adaptability during the period of the releases and again, there was no correlation between fork length or weight and ability to adapt to seawater during this time. Response surface analysis indicated adaptabilty reached a maximum during mid-April, just prior to the first release. The single test of the juveniles released on May 30, 1983 indicated adaptability was good at the time of release and was not correlated with fork length or weight.

The results of these studies indicate that differences in return rate among the four release dates did not result from changes in seawater adaptability of the smolts. Seawater adaptability peaked near the time of the first releases (April 20) and then declined slightly over the next two months. It is noteworthy that adaptabilty peaked about 7 weeks before the optimum release date. This is likely a result of rearing in spring-fed water, which is warmer than surface water during the winter. There was no significant correlation between smolt size and seawater adaptability during the release period, suggesting that all fish were large enough to undergo the parr-smolt transformation.

We suggest that use of surface water from Quinsam River for coho rearing will delay smolting and thereby bring it closer to the optimum release date. This should reduce the stress caused by prolonged holding of fish in the hatchery after smolting. Use of the cooler surface water would have the added benefit of controlling growth, resulting in smaller juveniles and, subsequently, slightly higher adult returns, as discussed earlier.

The influence of juvenile health

The most serious health problem encountered in the juveniles was furunculosis. In the 1980 study juveniles of the last release had a very high incidence of this disease and were in generally very poor condition at the time of release. Although lowest returns resulted from this release, the similarity of the returns in the 1981 study, when furunculosis was not a problem, suggests survival was not greatly affected. The second high incidence of furunculosis was in the single release in 1983, where a moderate to high incidence was observed in the juveniles. Returns for this release were abnormally low compared to releases on the same date in other studies but it is difficult to say whether this was disease related. The incidence of furunculosis in this study was not as high, nor the general health as poor, as in the 1980 study, suggesting other factors may have been involved.

GENERAL COMMENTS

A potentially complicating factor in these studies is the possibility of biases associated with grading of populations of juveniles to obtain different size groups. This is discussed in detail by Bilton et al. (1982a) in their report on the Rosewall Creek study, where grading was also used. They point out that there is accumulating evidence suggesting hereditary factors are at least partly involved in determining rate of growth and age at maturity (Ricker 1972). This suggests the possibility that the larger juveniles selected from a population are genetically predisposed toward rapid growth and early maturity; in studies where grading is used to achieve size differences this could result in inflated proportions of jacks in large category juveniles. While similar in design to the Quinsam studies, the Rosewall study involved multiple ponds for each of the four releases; the fish in each pond were graded into three sizes, each of which was tagged distinctively. Since mean weights for the ponds differed it was possible to compare the proportions of jacks in the returns from graded size groups in each release with those from ungraded pond populations having similar mean weights and released at the same time. In only one case was the proportion of jacks in the returns from a graded size group demonstrably different from that in returns from a pond having a similar mean weight and time of release; this was for large fish of the last release. Analysis of variance indicated that, with the exception of this group, information on size category (small, medium, large) did not add significantly to that provided by mean weight alone in explaining jack returns. A similar analysis of variance on adult returns gave the same result. It was concluded there was little evidence that grading to size influenced the returns. However, it was acknowledged that minor alterations in response surfaces for jack and adult returns might occur, and growth control was recommended as the preferable method for achieving size differences in future studies. In the Quinsam studies growing to size was not practical and because of the simplified experimental design it was not possible to examine the data for grading effects, as was done with the Rosewall data. It must therefore be assumed that if biases due to grading did occur they would have been minor, as was the case at Rosewall.

One obvious effect of grading was the differences in sex ratios of juveniles amongst the graded size groups taken from single populations. In the Rosewall Creek study there was a pronounced trend toward higher proportions of males with increasing size category (Bilton 1978). This was also observed in the 1981 and 1983 Quinsam studies, but was not observed in the 1980 study. Both the Rosewall Creek grading analyses discussed above and the similarity of results among the three Quinsam studies (in one of which juvenile sex ratio differences were not evident) indicate the influences of differences in juvenile sex ratios were minor.

In summary, these studies show that quite precise release timing is required to achieve maximum coho production at Quinsam Hatchery, with juvenile size being of much less importance. While there were differences in total survival among brood years, the relative differences in survival associated with time and size at release were quite similar for each year, indicating the results obtained should be applicable to future production strategy. However, Green and Macdonald (1987) caution against extrapolation of results between years. This is based on an analysis of several years of return data for Robertson Creek Hatchery chinook in which they found interaction between brood year and other release variables. They did not analyse multiple years of coho returns and it is possible brood year variabilty may be less for this species but further studies would be required to confirm this. The studies reported here found differences in survival associated with releasing juveniles at different times and sizes, however, they do not explain the underlying mechanisms determining these differences. The observed relationships between survival and time and size at release were probably the net results of complex interactions between many variables and it is possible changes in any of these would alter these relationships. Such variables might include culture practices (e.g. diet, rearing density, temperature regimes), genetic factors, meteorological and oceanographic events affecting food supply in the marine environment, and possibly many other unrecognized factors. In view of this it is recommended that similar, perhaps simpler, studies be conducted periodically to monitor for possible changes in the effects of time and size at release.

It is also important to note that the results obtained at Quinsam do not appear to be applicable to all sites. For example, in the Rosewall study maximum adult returns were predicted from release of 25.1 g juveniles on June 22 (day 173). This date is considerably later than the optimum date of June 5 (day 156) determined for Quinsam. No optimum juvenile size was determined for Quinsam but adult returns were predicted to increase slightly with decreasing size in earlier releases. Preliminary analysis of the first of the Capilano studies mentioned in the introduction indicates maximum returns from release of 19 g juveniles on day 154 (June 3); results of the second study differed, with an optimum date of approximately day 147 (May 27) and no optimum weight determined. Although weight effects were inconsistent, optimum time for release in both Capilano studies is earlier than for Quinsam or Rosewall. Site specificity thus appears to be a problem - if the optimum conditions found at Rosewall were applied to Quinsam, adult returns of less than 1% are predicted, in contrast to a possible maximum of about 12%. It is therefore recommended that studies be conducted at all sites.

ACKNOWLEDGEMENTS

The authors wish to thank the staff at Quinsam hatchery, especially R. Reinhart and M. Wolter, for their extensive help and co-operation in carrying out these studies. We would also like to thank the Diagnostic Services Unit of the Pacific Biological Station for their participation and advice. We are grateful to J. Irvine and J. Jensen for their helpful criticism of the manuscript and to S. Mckinnell and J. Jensen for their assistance with the response surface analyses. The special efforts of L. Lapi and M. Holmes in providing mark recovery data are much appreciated.

REFERENCES

Bilton, H. T. 1978. Returns of adult coho salmon in relation to mean size and time at release of juveniles. Fish. Mar. Serv. Tech. Rep. 832: 73 p.

1980. Returns of adult coho salmon in relation to mean size and time at release of juveniles to the catch and the escapement. Can. Tech. Rep. Fish. Aquat. Sci. 941: 41 p.

Bilton H. T. and A. S. Coburn. 1981. Time and size at release experiment: four releases of three size categories of juvenile coho salmon from Quinsam Hatchery in the spring of 1980. Can. Data Rep. Fish. Aquat. Sci. 252: 23 p.

Bilton H. T. and D. W. Jenkinson. 1976. Time and size at release experiment: three releases of three major size categories of juvenile coho salmon from Rosewall Creek in the spring of 1975. Fish. Mar. Serv. Data Rec. 7: 16 p.

Bilton H. T., D. F. Alderdice, and J. T. Schnute. 1982a. Influence of time and size at release of juvenile coho salmon (Oncorhynchus kisutch) on returns at maturity. Can. J. Fish. Aquat. Sci. 39: 426-447.

Bilton H. T., A. S, Coburn, and R. B. Morley. 1982b. Time and size at release experiment: four releases of three size groups of juvenile coho salmon from Quinsam Hatchery, spring of 1981. Can. Data Rep. Fish. Aquat. Sci. 329: 21 p.

Bilton H. T., R. B. Morley, A. S. Coburn, and J. Van Tine. 1984. The influence of time and size at release of juvenile coho salmon (Oncorhychus kisutch) on returns at maturity; results of releases from Quinsam Hatchery, B.C., in 1980. Can. Tech. Rep. Fish. Aquat. Sci. 1306: 98 p.

Bilton, H. T., R. B. Morley, and E. Stone. 1982c. Time and size at release experiment: four releases of three size categories of juvenile coho salmon from the Capilano Hatchery in the spring of 1981. Can. Data Rep. Fish. Aquat. Sci. 347: 18 p.

Bilton, H. T., R. B. Morley, E. Stone, and D. Brouwer. 1983. Time and size at release experiment: four releases of three size categories of juvenile coho salmon from the Capilano Hatchery in the spring of 1982. Can. Data Rep. Fish. Aquat. Sci. 383: 16 p.

Blackburn, J. and W. C. Clarke. 1987. Revised procedure for the 24 hour seawater challenge test to measure seawater adaptability of juvenile salmonids. Can. Tech. Rep. Fish. Aquat. Sci. 1515: 35 p.

BMDP Statistical Software. 1981. University of California Press, Berkeley, CAL.

DPA. 1982. The Georgia Strait sport fishery creel surveys (5 vols). DPA consultants for Dept. Fish. and Oceans.

Fagerlund, U. H. M., J. R. McBride, B. S. Dosanjh, H. T. Bilton, R. B. Morley, and J. Van Tine. 1984. Density effects on performance to release of three size groups within populations of pond reared juvenile coho salmon. Smolts released from Quinsam Hatchery in 1983. Can. Tech. Rep. Fish. Aquat. Sci. 1337: 19 p.

Green, P. E. J. and P. D. M. Macdonald. 1987. Analysis of mark-recapture data from hatchery-raised salmon using log-linear models. Can. J. Fish. Aquat. Sci. 44: 316-326.

Hager, R. C. and R. E. Noble. 1976. Relation of size at release of hatchery-reared coho salmon to age, size, and sex composition of returning adults. Prog. Fish. Cult. 38: 144-147.

Healey, M. C. 1986. Regional and seasonal attributes of catch in the British Columbia troll fishery. Can. Tech. Rep. Fish. Aquat. Sci. 1494: 65 p.

Koo, T. S. Y. 1962. Age designation in salmon, p. 37-38. In: T. S. Y. Koo [Ed.]. Studies of Alaska red salmon. Univ. Wash. Press, Seattle, WA.

Ricker, W. E. 1972. Hereditary and environmental factors affecting certain salmonid populations, p. 19-160. In: R. C. Simon and P. A. Larkin [Ed.]. The stock concept in Pacific salmon. H. R. MacMillan Lectures in Fisheries. Mitchell Press Ltd., Vancouver, B.C.

Ricker, W. E. 1976. A review of the rate of growth and mortality of Pacific salmon in salt water, and noncatch mortality caused by fishing. J. Fish. Res. Board Can. 33: 1483-1524.

Ricker, W. E. and W. P. Wickett. 1980. Causes of the decrease in size of coho salmon (*Oncorhynchus kisutch*). Can. Tech. Rep. Fish. Aquat. Sci. 971: 63 p.

Schnute, J. and S. McKinnell. 1984. A biologically meaningful approach to response surface analysis. Can. J. Fish. Aquat. Sci. 43: 936-953.

Schubert, N. D. and D. B. Lister. 1986. A comparision of the catch distribution, harvest rate and survival of wild and cultured Salwein Creek coho salmon. Can. Tech. Rep. Fish. Aquat. Sci. 1425: 37 p.

Sokal, R. R. and F. J. Rohlf. 1981. Biometry (2nd Ed.). W. H. Freeman Co., San Francisco, CAL.

Table I-1a. Estimated numbers of tagged coho smolts released at Quinsam Hatchery on April 20, 1981 (Julian day 110) and returns originating from this release. Also shown are returns as percentages of smolts released and adult catches as percentages of total adult returns.

		Smolts						Jacks/Immatures (1981 returns)				Adults (1982 and 1983 returns)[a]								Jacks & Adults (catch & escapement)	
		No. released			x̄ weight (g)			Escape-ment	Catch	Catch & escapement		Escapement				Catch	Catch & escapement		Catch as % of total return		
	Size											♂	♀	Total							
Tag code	category	♂	♀	♂+♀	♂	♀	♂+♀	No.	No.	No.	%	No.	No.	No.	%	No.	No.	%		No.	%
8-18-46	Sm	1693	1960	3653	20.18	19.48	19.81	12	1 (8)	13 (20)	0.36	13	12	26 (25)	0.71	63 (59)	89 (84)	2.44	70.8(70.2)	102(104)	2.79
8-18-49	Sm	1658	1996	3654	20.73	19.85	20.25	13	0	13	0.36	8	13	21	0.57	81	102	2.79	79.4	115	3.15
8-18-52	Sm	1708	1856	3564	19.40	20.28	19.86	12	0	12	0.34	11	8	19	0.53	33	52	1.46	63.5	64	1.80
8-18-47	Med	1784	1846	3630	25.43	22.74	24.06	25	0 (3)	25 (28)	0.69	7	20	27	0.74	40 (39)	67 (66)	1.85	59.7(59.1)	92 (94)	2.53
8-18-50	Med	1562	2083	3654	24.91	23.18	23.92	22	0	22	0.60	5	19	25	0.69	35	60	1.65	58.3	82	2.25
8-18-53	Med	1913	1650	3563	25.10	22.91	24.08	16	0 (3)	16 (19)	0.45	1	10	11	0.31	52 (50)	63 (61)	1.77	82.5(82.0)	79 (80)	2.22
8-18-48	Lg	1693	1960	3653	28.04	27.09	27.53	14	0 (3)	14 (17)	0.38	6	8	14	0.38	56 (55)	70 (69)	1.92	80.0(79.7)	84 (86)	2.30
8-18-51	Lg	2062	1591	3653	28.64	26.54	27.73	16	0	16	0.44	8	7	15	0.41	23	38	1.04	60.5	54	1.48
8-18-54	Lg	1788	1868	3656	29.10	26.18	27.61	23	2 (9)	25 (32)	0.68	4	5	10 (9)	0.25	48 (45)	58 (54)	1.59	82.8(83.3)	83 (86)	2.27
Total		15861	16810	32671	24.61	23.14	23.87	153	3(26)	156(179)	0.48	63	102	168(166)	0.51	431(420)	599(586)	1.83	72.0(71.7)	755(765)	2.31

[a]Adult returns are 1982 unless otherwise indicated.

Notes: Catch in 1982 was divided into jacks and immature adults and the returns adjusted accordingly (see MATERIALS AND METHODS); numbers in parentheses are unadjusted figures with all fish caught in 1982 classified as jacks.

Escapement numbers are actual counts of hatchery returns; catch numbers are observed recoveries expanded to reflect sampling effort and sportsman "awareness" as described in MATERIALS AND METHODS.

Table I-1b. Estimated numbers of tagged coho smolts released at Quinsam Hatchery on May 10, 1981 (Julian day 130) and returns originating from this release. Also shown are returns as percentages of smolts released and adult catches as percentages of total adult returns.

		Smolts						Jacks/Immatures (1981 returns)				Adults (1982 and 1983 returns)[a]								Jacks & Adults (catch & escapement)	
		No. released			$\bar{x}$ weight (g)			Escape-ment	Catch	Catch & escapement		Escapement				Catch	Catch & escapement		Catch as % of total return		
	Size											♂	♀	Total							
Tag code	category	♂	♀	♂+♀	♂	♀	♂+♀	No.	No.	No.	%	No.	No.	No.	%	No.	No.	%		No.	%
8-18-55	Sm	2087	1768	3855	24.57	22.37	23.56	32	0	32	0.83	18	37	55	1.43	147	202	5.24	72.8	234	6.07
8-18-59	Sm	1891	1966	3857	23.02	20.99	21.98	30	0	30	0.78	21	35	56	1.45	153[b]	209	5.42	73.2	239	6.20
8-18-62	Sm	1905	1953	3858	23.52	21.79	22.64	27	0	27	0.70	18	25	43	1.11	161	204	5.29	78.9	231	5.99
8-18-56	Med	1899	1959	3858	27.20	24.94	26.05	55	0	55	1.43	22	31	53	1.37	144	197	5.11	73.1	252	6.53
8-18-58	Med	1957	1919	3876	26.64	25.16	25.91	50	0	50	1.29	11	26	38	0.98	114	152	3.92	75.0	202	5.21
8-18-61	Med	2029	1830	3859	27.80	25.06	26.50	52	1 (8)	53 (60)	1.37	10	24	35 (34)	0.91	118 (115)	153 (149)	3.96	77.1(77.2)	206 (209)	5.34
8-18-57	Lg	1950	1918	3868	33.66	30.26	31.98	66	2(14)	68 (80)	1.76	17	26	45 (53)	1.16	146 (141)	191 (184)	4.94	76.4(76.6)	259 (264)	6.70
8-18-60	Lg	2250	1608	3858	31.92	29.53	30.92	82	1 (8)	83 (90)	2.15	10	24	35 (34)	0.91	119 (116)	154 (150)	3.99	77.3(77.3)	237 (240)	6.14
8-18-63	Lg	2106	1767	3873	33.92	29.99	32.13	66	0	66	1.70	9	23	33	0.85	131	164	4.23	79.9	230	5.94
		18074	16688	34762	28.03	25.57	26.77	460	4(30)	464(490)	1.33	136	251	393(389)	1.13	1233(1222)	1626(1611)	4.68	75.8(75.9)	2090(2101)	6.01

[a]Adult returns are 1982 unless otherwise indicated.
[b]Includes 2 recoveries in 1983 (expanded from 1 observed).

Notes: Catch in 1982 was divided into jacks and immature adults and the returns adjusted accordingly (see MATERIALS AND METHODS); numbers in parentheses are unadjusted figures with all fish caught in 1982 classified as jacks.

Escapement numbers are actual counts of hatchery returns; catch numbers are observed recoveries expanded to reflect sampling effort and sportsman "awareness" as described in MATERIALS AND METHODS.

Table I-1c. Estimated numbers of tagged coho smolts released at Quinsam Hatchery on May 30, 1981 (Julian day 150) and returns originating from this release. Also shown are returns as percentages of smolts released and adult catches as percentages of total adult returns.

		Smolts						Jacks/Immatures (1981 returns)				Adults (1982 and 1983 returns)[a]									Jacks & Adults (catch & escapement)	
		No. released			$\bar{x}$ weight (g)			Escapement	Catch	Catch & escapement		Escapement				Catch	Catch & escapement		Catch as % of total return			
												♂	♀	Total								
Tag code	Size category	♂	♀	♂+♀	♂	♀	♂+♀	No.	No.	No.	%	No.	No.	No.	%	No.	No.	%			No.	%
8-18-10	Sm	1818	1986	3804	21.77	21.14	21.44	11	0	11	0.29	57	61	118	3.10	298	416	10.94	71.6		427	11.23
8-18-43	Sm	1781	2172	3953	22.76	22.00	22.34	8	0	8	0.20	37	55	93	2.35	304	397	10.04	76.6		405	10.25
8-18-45	Sm	1144	1438	2582	22.44	20.54	21.38	7	0	7	0.27	23	41	64	2.48	216[b]	280	10.84	77.1		287	11.12
8-18-11	Med	1844	1975	3819	25.85	24.55	25.18	31	0	31	0.81	28	59	90	2.36	345	435	11.39	79.3		466	12.20
8-18-41	Med	1648	2157	3805	25.38	25.47	25.43	30	0	30	0.79	46	58	105	2.76	323	428	11.25	75.5		458	12.04
8-18-44	Med	1610	2205	3815	25.20	23.17	24.02	30	0	30	0.79	49	57	108	2.84	346	454	11.90	76.2		484	12.69
8-18-12	Lg	1849	2021	3870	30.70	28.08	29.33	43	0	43	1.11	49	58	107	2.76	342	449	11.60	76.2		492	12.71
8-18-13	Lg	2239	2084	4323	29.99	28.45	29.25	57	0	57	1.32	60	67	129	2.98	384	513	11.87	74.9		570	13.19
8-18-42	Lg	2096	1738	3834	31.48	28.20	29.99	53	1(16)	64 (79)	1.67	42	61	105(103)	2.74	333 (325)	438 (428)	11.42	76.0(75.9)		502 (507)	13.1
Total		16209	17776	33805	26.17	24.62	25.37	280	1(16)	281(296)	0.83	391	517	919(917)	2.72	2891(2883)	3810(3800)	11.27	75.9(75.9)		4091(4096)	12.10

[a]Adult returns are 1982 unless otherwise indicated.
[b]Includes 3 recoveries in 1983 (expanded from 1 observed).

Notes: Catch in 1982 was divided into jacks and immature adults and the returns adjusted accordingly (see MATERIALS AND METHODS); numbers in parentheses are unadjusted figures with all fish caught in 1982 classified as jacks.

Escapement numbers are actual counts of hatchery returns; catch numbers are observed recoveries expanded to reflect sampling effort and sportsman "awareness" as described in MATERIALS AND METHODS.

Table I-1d. Estimated numbers of tagged coho smolts released at Quinsam Hatchery on June 19, 1981 (Julian day 170) and returns originating from this release. Also shown are returns as percentages of smolts released and adult catches as percentages of total adult returns.

		Smolts						Jacks/Immatures (1981 returns)				Adults (1982 and 1983 returns)[a]									Jacks & Adults (catch & escapement)	
		No. released			x̄ weight (g)			Escapement	Catch	Catch & escapement		Escapement				Catch	Catch & escapement		Catch as % of total returns		
												♂	♀	Total							
Tag code	Size category	♂	♀	♂+♀	♂	♀	♂+♀	No.	No.	No.	%	No.	No.	No.	%	No.	No.	%		No.	%
8-18-01	Sm	1714	2414	4128	23.42	21.60	22.35	4	0	4	0.10	13	17	31	0.75	132	163	3.95	81.0	167	4.05
8-18-04	Sm	1486	2322	3808	22.08	21.86	21.95	1	0	1	0.03	15	5	22	0.58	105	127	3.34	82.7	128	3.36
8-18-07	Sm	1770	1983	3753	22.54	21.56	22.02	0	0	0	0.00	12	14	28	0.75	79	107	2.85	73.8	107	2.85
8-18-02	Med	1901	1868	3769	27.53	24.63	26.09	4	0	4	0.11	17	12	29	0.77	125	154	4.09	81.2	158	4.19
8-18-05	Med	1858	1926	3784	26.83	26.03	26.42	0	0	0	0.00	18	15	33	0.87	116	149	3.94	77.9	149	3.94
8-18-08	Med	1930	1890	3820	27.76	25.07	26.43	3	0	3	0.08	20	14	34	0.89	85	119	3.12	71.4	122	3.19
8-18-03	Lg	2121	1650	3771	30.05	28.34	29.30	9	0	9	0.24	14	11	25	0.66	112[b]	137	3.63	81.8	146	3.87
8-18-06	Lg	1907	1869	3776	32.47	29.45	30.97	9	0	9	0.24	12	10	22	0.58	92	114	3.02	80.7	123	3.26
8-18-09	Lg	2132	1655	3787	32.08	29.17	30.81	9	0	9	0.24	11	12	24	0.63	144	168	4.44	85.7	177	4.67
Total		16819	17577	34396	27.20	25.30	26.26	39	0	39	0.11	132	110	248	0.72	990	1238	3.60	80.00	1277	3.71

[a]Adult returns are 1982 unless otherwise indicated.
[b]Includes 4 recoveries in 1983 (expanded from 1).

Notes: Catch in 1982 was divided into jacks and immature adults and the returns adjusted accordingly (see MATERIALS AND METHODS); numbers in parentheses are unadjusted figures with all fish caught in 1982 classified as jacks.

Escapement numbers are actual counts of hatchery returns; catch numbers are observed recoveries expanded to reflect sampling effort and sportsman "awareness" as described in MATERIALS AND METHODS.

Table I-2a. Average lengths and weights of jacks and adults originating from the April 20, 1981 (Julian day 110) release of coho smolts from Quinsam Hatchery, as sampled in the 1981 and 1982 hatchery escapements.

		Jacks						Adults ♂						Adults ♀						Adults Sexes combined					
		Hypural length (mm)			Weight (kg)			Hypural length (mm)			Weight (kg)			Hypural length (mm)			Weight (kg)			Hypural length (mm)			Weight (kg)		
Tag code	Size category	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n
08-18-46	Sm	276.0	55.15	2	0.511	0.131	11	521.4	51.02	8	4.16	1.62	7	510.5	46.91	4	3.45	0.84	8	517.8	47.80	12	3.78	1.27	15
08-18-49	Sm	257.3	35.12	4	0.485	0.161	12	464.0	50.84	4	2.33	0.43	5	532.0	46.27	4	3.44	1.11	11	498.0	57.85	8	3.09	1.07	16
08-18-52	Sm	-	-	-	0.475	0.099	12	487.1	67.84	8	3.74	1.80	5	551.6	41.36	5	3.89	0.87	6	511.9	65.73	13	3.82	1.29	11
08-18-47	Med	282.5	20.51	2	0.462	0.101	25	528.0	31.1	2	2.90	1.38	5	559.6	40.41	9	3.22	1.20	13	553.8	39.57	11	3.14	1.22	18
08-18-50	Med	275.0	21.52	3	0.494	0.121	20	550.0	74.73	5	1.75	-	1	529.3	41.58	11	3.39	0.70	10	535.8	52.35	16	3.24	0.83	11
08-18-53	Med	275.3	24.45	4	0.484	0.154	16	-	-	-	4.59	-	1	524.0	29.68	4	2.88	0.46	7	524.0	29.68	4	3.09	0.74	8
08-18-48	Lg	257.0	-	1	0.562	0.127	14	563.7	29.37	3	4.49	0.97	3	533.0	51.03	3	3.33	0.47	4	548.3	40.85	6	3.83	0.90	7
08-18-51	Lg	279.0	-	1	0.536	0.112	16	547.2	36.83	5	3.13	1.71	4	559.0	15.72	3	3.60	0.67	3	551.6	29.72	8	3.33	1.29	7
08-18-54	Lg	331.0	-	1	0.530	0.141	22	452.5	153.44	2	2.57	2.58	3	585.8	42.67	4	3.34	-	1	541.3	102.65	6	2.76	2.14	4
Total		274.4	29.43	18	0.503	0.128	148	515.19	65.77	37	3.36	1.58	34	542.6	42.60	47	3.37	0.89	63	530.5	55.39	84	3.36	1.17	97

Table I-2b. Average lengths and weights of jacks and adults originating from the May 10, 1981 (Julian day 130) release of coho smolts from Quinsam Hatchery, as sampled in the 1981 and 1982 hatchery escapements.

		Jacks						Adults																	
								♂						♀						Sexes combined					
		Hypural length (mm)			Weight (kg)			Hypural length (mm)			Weight (kg)			Hypural length (mm)			Weight (kg)			Hypural length (mm)			Weight (kg)		
Tag code	Size category	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n
08-18-55	Sm	247.5	15.07	4	0.419	0.080	29	469.0	96.95	7	3.42	1.35	13	520.2	55.77	17	3.44	0.93	23	505.3	71.98	24	3.43	1.08	36
08-18-59	Sm	251.7	27.60	6	0.435	0.115	28	525.6	70.06	5	3.15	1.47	17	522.4	40.75	15	3.42	0.99	20	523.2	47.53	20	3.30	1.22	37
08-18-62	Sm	255.0	14.47	5	0.391	0.086	27	484.5	75.74	12	2.82	1.22	11	524.7	39.37	15	3.16	0.95	12	506.8	60.62	27	2.99	1.07	23
08-18-56	Med	272.2	19.92	5	0.443	0.106	51	498.2	74.03	12	3.55	1.67	16	518.7	51.48	13	3.23	1.02	18	508.8	62.8	25	3.38	1.35	34
08-18-58	Med	266.3	5.69	3	0.461	0.095	50	477.4	60.48	5	3.32	0.92	5	521.1	35.64	12	3.67	1.02	15	508.2	47.00	17	3.58	0.99	20
08-18-61	Med	258.4	24.04	8	0.459	0.106	51	505.3	94.68	4	3.59	1.87	7	535.3	36.65	15	3.74	0.83	12	529.0	51.94	19	3.68	1.27	19
08-18-57	Lg	273.3	21.06	8	0.474	0.133	66	495.9	56.96	7	3.00	1.31	10	526.0	37.68	13	3.33	1.20	15	515.5	46.25	20	3.20	1.23	25
08-18-60	Lg	263.2	22.43	5	0.454	0.107	80	451.5	14.84	2	2.98	1.61	8	503.3	69.05	10	3.55	1.06	19	494.7	65.78	12	3.38	1.24	27
08-18-63	Lg	262.1	15.06	12	0.452	0.090	65	479.8	60.87	4	3.44	1.48	8	544.2	39.58	10	3.63	0.82	15	525.8	53.41	14	3.56	1.06	23
Total		261.6	20.03	53	0.449	0.106	447	489.72	71.04	58	3.25	1.43	95	524.08	45.32	120	3.46	0.98	149	512.9	57.16	178	3.38	1.18	244

Table I-2c. Average lengths and weights of jacks and adults originating from the May 30, 1981 (Julian day 150) release of coho smolts from Quinsam Hatchery, as sampled in the 1981 and 1982 hatchery escapements.

		Jacks						Adults ♂						Adults ♀						Adults Sexes combined					
		Hypural length (mm)			Weight (kg)			Hypural length (mm)			Weight (kg)			Hypural length (mm)			Weight (kg)			Hypural length (mm)			Weight (kg)		
Tag code	Size category	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n
08-18-10	Sm	245.01	11.31	2	0.340	0.056	11	435.8	56.75	21	2.11	0.98	42	463.6	66.19	23	2.68	1.04	41	450.3	62.74	44	2.39	1.04	83
08-18-43	Sm	-	-	-	0.366	0.165	7	432.7	55.30	13	1.91	0.68	26	475.5	54.11	30	2.75	0.98	29	462.5	57.36	43	2.36	0.94	55
08-18-45	Sm	-	-	-	0.348	0.109	6	435.1	48.16	10	2.24	1.00	16	486.8	51.43	16	2.49	0.69	28	466.9	55.50	26	2.40	0.81	44
08-18-11	Med	239.0	14.14	2	0.351	0.064	31	471.4	70.44	11	2.78	1.04	21	516.1	34.25	16	2.79	0.80	46	497.9	55.57	27	2.78	0.87	67
08-18-41	Med	246.0	16.08	5	0.369	0.086	28	461.3	67.38	16	2.66	1.03	32	484.0	50.43	20	3.01	0.82	45	473.9	58.80	36	2.86	0.92	77
08-18-44	Med	235.7	6.43	3	0.343	0.052	28	466.9	68.73	23	2.63	1.16	33	492.8	49.77	20	2.83	0.93	44	478.9	61.36	43	2.74	1.03	77
08-18-12	Lg	259.2	12.22	6	0.353	0.067	38	457.8	56.41	22	2.34	0.99	38	495.8	55.09	25	2.80	0.89	42	478.0	58.35	47	2.58	0.96	80
08-18-13	Lg	245.1	23.93	8	0.367	0.056	55	464.8	71.27	32	2.85	1.34	37	513.6	41.04	28	3.05	0.99	44	487.5	63.58	60	2.96	1.16	81
08-18-42	Lg	242.8	14.33	11	0.358	0.068	60	480.3	60.94	18	2.91	1.38	27	495.4	53.19	25	3.17	0.92	39	489.1	56.36	43	3.06	1.13	66
Total		245.7	16.5	37	0.357	0.070	264	458.0	63.69	166	2.49	1.13	272	491.0	53.19	203	2.86	0.91	358	476.1	60.35	369	2.70	1.03	630

Table I-2d. Average lengths and weights of jacks and adults originating from the June 19, 1981 (Julian day 170) release of coho smolts from Quinsam Hatchery, as sampled in the 1981 and 1982 hatchery escapements.

		Jacks						Adults																	
								♂						♀						Sexes combined					
	Size	Hypural length (mm)			Weight (kg)			Hypural length (mm)			Weight (kg)			Hypural length (mm)			Weight (kg)			Hypural length (mm)			Weight (kg)		
Tag code	category	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n
08-18-01	S	238.0	-	1	0.295	0.034	4	378.7	33.50	7	1.88	0.78	7	454.6	50.30	7	2.38	0.70	14	416.6	56.88	14	2.21	0.75	21
08-18-04	S	-	-	-	-	-	-	411.8	28.85	8	1.69	0.49	9	435.3	34.93	4	1.76	0.44	2	419.6	31.57	12	1.70	0.46	11
08-18-07	S	-	-	-	-	-	-	399.4	16.41	5	1.59	0.43	9	487.6	51.22	7	2.14	0.82	8	450.8	59.92	12	1.85	0.68	17
08-18-02	M	249.0	-	1	0.313	0.049	3	406.2	55.02	5	1.86	0.94	14	468.0	-	1	2.30	0.68	11	416.5	55.30	6	2.06	0.85	25
08-18-05	M	-	-	-	-	-	-	406.2	51.82	12	1.61	0.63	13	479.8	25.61	5	2.32	0.79	11	427.8	56.62	17	1.94	0.78	24
08-18-08	M	-	-	-	0.303	0.035	3	410.3	45.13	10	1.54	0.58	12	432.6	30.36	5	2.19	0.66	12	417.7	41.12	15	1.86	0.70	24
08-18-03	L	204.0	22.63	3	0.258	0.037	8	430.7	31.14	6	2.25	0.91	10	458.0	78.9	3	2.38	1.10	10	439.8	48.48	9	2.31	0.98	20
08-18-06	L	217.0	12.72	2	0.299	0.041	7	415.0	-	1	1.67	0.69	10	473.3	51.4	3	2.25	0.50	8	458.8	51.10	4	1.93	0.66	18
08-18-09	L	239.0	-	1	0.303	0.062	8	448.0	86.70	4	2.33	1.10	9	449.6	51.14	5	2.61	0.66	8	448.9	64.24	9	2.46	0.90	17
Total		224.0	20.89	7	0.291	0.047	33	409.3	45.31	58	1.81	0.77	93	460.20	46.40	40	2.31	0.73	84	430.1	52.0	98	2.05	0.79	177

Table I-3. Standardized biomass estimates (kg per 100,000 smolts released) for returns of jack and adult coho from smolt releases at Quinsam hatchery in 1981.

		Smolts		Biomass (kg)		
Release date	Tag code	Size category	$\bar{x}$ weight (g)	Jacks	Adults	Jacks & Adults
April 20	08-18-46	Sm	19.81	181.9	9215	9397
	08-18-49	Sm	20.25	172.6	8633	8805
	08-18-52	Sm	19.86	159.9	5572	5732
	08-18-47	Med	24.06	318.2	5787	6105
	08-18-50	Med	23.92	298.2	5229	5528
	08-18-53	Med	24.08	217.4	5617	5834
	08-18-48	Lg	27.53	215.4	7338	7554
	08-18-51	Lg	27.73	234.8	3467	3702
	08-18-54	Lg	27.61	362.4	4382	4745
	Average			240.1	6138	6378
May 10	08-18-55	Sm	23.56	347.8	17984	18331
	08-18-59	Sm	21.98	338.3	17695	18033
	08-18-62	Sm	22.64	273.6	15832	16106
	08-18-56	Med	26.05	631.5	17248	17880
	08-18-58	Med	25.91	594.7	14049	14643
	08-18-61	Med	26.50	630.4	14599	15230
	08-18-57	Lg	31.98	833.3	15782	16615
	08-18-60	Lg	30.92	988.5	13497	14485
	08-18-63	Lg	32.13	770.3	15077	15848
	Average			600.9	15751	16352
May 30	08-18-10	Sm	21.44	98.3	26115	26213
	08-18-43	Sm	22.34	72.5	23671	23744
	08-18-45	Sm	21.38	97.1	25726	25823
	08-18-11	Med	25.18	284.9	31710	31995
	08-18-41	Med	25.43	290.9	32226	32516
	08-18-44	Med	24.02	269.7	32654	32923
	08-18-12	Lg	29.33	392.2	29933	30325
	08-18-13	Lg	29.25	483.9	35162	35646
	08-18-42	Lg	29.99	597.6	34957	35555
	Average			287.5	30239	30527

Table I-3 (cont'd)

		Smolts		Biomass (kg)		
Release date	Tag code	Size category	$\bar{x}$ weight (g)	Jacks	Adults	Jacks & Adults
June 19	08-18-01	Sm	22.35	28.6	8747	8776
	08-18-04	Sm	21.95	7.8	5666	5674
	08-18-07	Sm	22.02	0.0	5260	5260
	08-18-02	Med	26.09	32.7	8405	8438
	08-18-05	Med	26.42	0.0	7628	7628
	08-18-08	Med	26.43	24.2	5809	5834
	08-18-03	Lg	29.30	69.3	8154	8223
	08-18-06	Lg	30.97	68.2	6603	6671
	08-18-09	Lg	30.81	68.0	9702	9770
	Average			33.1	7330	7364

Table I-4. Estimated numbers[a] and percentages of the 1982 catch taken in the commercial troll, net, and sport fisheries, for each time and size category of smolts released from Quinsam hatchery in 1981 (replicates pooled).

Release date	Smolts: Size category	Smolts: $\bar{x}$ weight (g)		Type of fishery: Commercial troll	Net	Sport	Total
April 20	Sm	19.97	No	47	106	20	173
			%	27.2	61.3	11.6	
	Med	24.02	No	50	44	30	124
			%	40.3	35.5	24.2	
	Lg	27.62	No	64	44	15	123
			%	52.0	35.8	12.2	
	Pooled	23.87	No	161	194	65	420
			%	38.3	46.2	15.5	
May 10	Sm	22.74	No	155	196	108	459
			%	33.8	42.7	23.5	
	Med	26.15	No	164	121	88	373
			%	44.0	32.4	23.6	
	Lg	31.68	No	147	119	122	388
			%	37.9	30.7	31.4	
	Pooled	26.86	No	466	436	318	1220
			%	38.2	35.7	26.1	
May 30	Sm	21.72	No	249	335	231	815
			%	30.6	41.1	28.4	
	Med	24.88	No	337	341	336	1014
			%	33.2	33.6	33.1	
	Lg	29.52	No	367	364	320	1051
			%	34.9	34.6	30.4	
	Pooled	25.37	No	953	1040	887	2880
			%	33.1	36.1	30.8	
June 19	Sm	22.11	No	98	110	108	316
			%	31.0	34.8	34.2	
	Med	26.31	No	64	103	159	326
			%	19.6	31.6	48.8	
	Lg	30.36	No	95	103	146	344
			%	27.6	29.9	42.4	
	Pooled	26.26	No	257	316	413	986
			%	26.1	32.0	41.9	
Grand total			No	1837	1986	1683	5506
			%	33.4	36.1	30.6	

Table I-4 (cont'd)

Release date	Smolts: Size category	Smolts: $\bar{x}$ weight (g)		Type of fishery: Commercial troll	Type of fishery: Net	Type of fishery: Sport	Total
Totals by size category	Sm		No	549	747	467	1763
			%	31.1	42.4	26.5	
	Med		No	615	609	613	1837
			%	33.5	33.2	33.4	
	Lg		No	673	630	603	1906
			%	35.3	33.1	31.6	

Notes: [a]Observed recoveries expanded to reflect sampling effort and fisherman "awareness", see MATERIALS AND METHODS. Some numbers may differ slightly from those shown for the individual fisheries (Tables 5, 6, and 7) due to rounding differences.

Table I-5. Estimated numbers[a] and percentages of commercial troll caught coho taken in different fishing areas in 1982, for each time and size category of smolts released from Quinsam Hatchery in 1981 (replicates pooled).

Release date	Smolts: Size category	Smolts: $\bar{x}$ weight (g)		Fishing Area[b]: A	N	Central: NC	Central: SC	Central: NC/SC	West Coast: NWV	West Coast: SWV	West Coast: NWV/SWV	C/NWV	GS	Wa	Ore	Total
April 20	Sm	19.97	No	0	0	0	17	0	25	0	0	1	3	0	0	46
			%	0	0	0	37.0	0	54.3	0	0	2.2	6.5	0	0	
	Med	24.02	No	0	4	6	26	0	6	0	0	0	7	0	0	49
			%	0	8.2	12.2	53.1	0	12.2	0	0	0	14.3	0	0	
	Lg	27.62	No	0	0	0	12	1	16	26	1	0	9	0	0	65
			%	0	0	0	18.5	1.5	24.6	40.0	1.5	0	13.8	0	0	
	Pooled	23.87	No	0	4	6	55	1	47	26	1	1	19	0	0	160
			%	0	2.5	3.8	34.4	.6	29.4	16.3	.6	.6	11.9	0	0	
May 10	Sm	22.74	No	0	0	0	42	1	52	36	1	0	24	0	0	156
			%	0	0	0	26.9	.6	33.3	23.1	.6	0	15.4	0	0	
	Med	26.15	No	0	0	0	74	0	12	35	1	1	35	4	3	165
			%	0	0	0	44.8	0	7.3	21.2	.6	.6	21.2	2.4	1.8	
	Lg	31.68	No	3	15	0	54	0	32	28	2	1	11	0	0	146
			%	2.1	10.3	0	37.0	0	21.9	19.2	1.4	.7	7.5	0	0	
	Pooled	26.86	No	3	15	0	17.0	1	96	99	4	2	70	4	3	467
			%	.6	3.2	0	36.4	.2	20.6	21.2	.9	.4	15.0	.9	.6	
May 30	Sm	21.72	No	0	0	19	84	0	18	59	0	1	68	0	0	249
			%	0	0	7.6	33.7	0	7.2	23.7	0	.4	27.3	0	0	
	Med	24.88	No	0	0	18	124	0	59	51	5	1	76	3	0	337
			%	0	0	5.3	36.8	0	17.5	15.1	1.5	.3	22.6	.9	0	
	Lg	29.52	No	0	0	4	90	0	65	124	0	0	84	0	0	367
			%	0	0	1.1	24.5	0	17.7	33.8	0	0	22.9	0	0	
	Pooled	25.37	No	0	0	41	298	0	142	234	5	2	228	3	0	953
			%	0	0	4.3	31.3	0	14.9	24.6	.5	.2	23.9	.3	0	

Table I-5 (cont'd)

Release date	Smolts Size category	$\bar{x}$ weight (g)		Fishing Area[b] A	N	Central NC	SC	NC/SC	West Coast NWV	SWV	NWV/SWV	C/NWV	GS	Wa	Ore	Total
June 19	Sm	22.11	No	0	0	3	22	0	26	23	0	0	24	0	0	98
			%	0	0	3.1	22.4	0	26.5	23.5	0	0	24.5	0	0	
	Med	26.31	No	0	0	0	6	0	13	7	0	0	36	2	0	64
			%	0	0	0	9.4	0	20.3	10.9	0	0	56.3	3.1	0	
	Lg	30.36	No	0	0	0	27	0	11	17	0	0	39	0	0	94
			%	0	0	0	28.7	0	11.7	18.1	0	0	41.5	0	0	
	Pooled	26.26	No	0	0	3	55	0	50	47	0	0	99	2	0	256
			%	0	0	1.2	21.5	0	19.5	18.4	0	0	38.7	.8	0	
Grand total			No	3	19	50	578	2	335	406	10	5	416	9	3	1836
			%	.2	1.0	2.7	31.5	.1	18.2	22.1	.5	.3	22.7	.5	.2	
Totals by size category	Sm		No	0	0	22	165	1	121	118	1	2	119	0	0	549
			%	0	0	4.0	30.1	.2	22.0	21.5	.2	.4	21.7	0	0	
	Med		No	0	4	24	230	0	90	93	6	2	154	9	3	615
			%	0	.7	3.9	37.4	0	14.6	15.1	1.0	.3	25.0	1.5	.5	
	Lg		No	3	15	4	183	1	124	195	3	1	143	0	0	672
			%	.4	2.2	.6	27.2	.1	18.5	29.0	.4	.1	21.3	0	0	

Footnotes to Table I-5.

[a]Observed recoveries expanded to reflect sampling effort, see MATERIALS AND METHODS.

[b]Fishing area		Statistical area
A	Alaska	-
N	Northern Coast	1-5
SC	South Central Coast	10-12
NC	North Central Coast	6-9, 30
NC/SC	Central Coast (North/South Combination)	6-12, 30
NWV	North West Vancouver Island	25-27
SWV	South West Vancouver Island	21, 23, 24
NWV/SWV	Northwest/Southwest Vancouver Island	21, 23-27
C/NWV	Central Coast/Northwest Vancouver Island	6-12, 30, 25-27
GS	Georgia Strait	13-18, 29, A, B, C
Wa	Washington	-
Ore	Oregon	-

Table I-6. Estimated numbers[a] and percentages of net caught coho taken in different fishing areas in 1982 for each time and size category of smolts released from Quinsam Hatchery in 1981 (replicates pooled).

	Smolts			Fishing Area[b]										
							West Coast							
Release date	Size category	$\bar{x}$ weight (g)		A	N	C	NWV	SWV	JF	F	JS	GS	Wa	Total
April 20	Sm	19.97	No	6	0	4	0	0	0	0	91	0	5	106
			%	5.7	0	3.8	0	0	0	0	85.8	0	4.7	
	Med	24.02	No	0	0	4	0	0	0	0	40	0	0	44
			%	0	0	9.1	0	0	0	0	90.9	0	0	
	Lg	27.62	No	0	0	0	0	0	0	0	44	0	0	44
			%	0	0	0	0	0	0	0	100.0	0	0	
	Pooled	23.87	No	6	0	8	0	0	0	0	175	0	5	194
			%	3.1	0	4.3	0	0	0	0	90.2	0	2.6	
May 10	Sm	22.74	No	0	0	0	0	0	12	0	179	0	6	197
			%	0	0	0	0	0	6.1	0	90.9	0	3.0	
	Med	26.15	No	0	0	6	0	0	0	0	113	0	2	121
			%	0	0	5.0	0	0	0	0	93.4	0	1.7	
	Lg	31.68	No	0	0	0	0	0	5	0	114	0	0	119
			%	0	0	0	0	0	4.2	0	95.8	0	0	
	Pooled	26.86	No	0	0	6	0	0	17	0	406	0	8	437
			%	0	0	1.4	0	0	3.9	0	92.9	0	1.8	
May 30	Sm	21.72	No	0	0	0	0	0	19	0	294	0	23	336
			%	0	0	0	0	0	5.7	0	87.5	0	6.8	
	Med	24.88	No	0	0	3	2	0	22	0	298	0	15	340
			%	0	0	.9	.6	0	6.5	0	87.6	0	4.4	
	Lg	29.52	No	0	0	3	0	0	0	8	331	1	21	364
			%	0	0	.8	0	0	0	2.2	90.9	.3	5.8	
	Pooled	25.37	No	0	0	6	2	0	41	8	923	1	59	1040
			%	0	0	.6	.2	0	3.9	.8	88.8	.1	5.7	

Table I-6 (cont'd)

Release date	Smolts: Size category	Smolts: $\bar{x}$ weight (g)		Fishing Area[b]: A	N	C	West Coast: NWV	West Coast: SWV	JF	F	JS	GS	Wa	Total
June 19	Sm	22.11	No	0	0	0	0	0	5	0	100	5	0	110
			%	0	0	0	0	0	4.5	0	90.9	4.5	0	
	Med	26.31	No	0	0	3	0	0	0	0	97	3	0	103
			%	0	0	2.9	0	0	0	0	94.2	2.9	0	
	Lg	30.36	No	0	0	0	0	4	5	0	90	0	4	103
			%	0	0	0	0	3.9	4.9	0	87.4	0	3.9	
	Pooled	26.26	No	0	0	3	0	4	10	0	287	8	4	316
			%	0	0	.9	0	1.3	3.2	0	90.8	2.5	1.3	
Grand total			No	6	0	23	2	4	68	8	1791	9	76	1987
			%	.3	0	1.2	.1	.2	3.4	.4	90.1	.5	3.8	
Totals by size category	Sm		No	6	0	4	0	0	36	0	664	5	34	749
			%	.8	0	.5	0	0	4.8	0	88.7	.7	4.5	
	Med		No	0	0	16	2	0	22	0	548	3	17	608
			%	0	0	2.6	.3	0	3.6	0	90.1	.5	2.8	
	Lg		No	0	0	3	0	4	10	8	579	1	25	630
			%	0	0	.5	0	.6	1.6	1.3	91.9	.2	4.0	

Footnotes to Table I-6.

[a]Observed recoveries expanded to reflect sampling effort; see MATERIALS AND METHODS.

[b]Fishing Area		Statistical Area
A	Alaska	-
N	Northern Coast	1-5
C	Central Coast	6-11
NWV	Northwest Vancouver Island	25-27
SWV	Southwest Vancouver Island	21-24
JF	Juan de Fuca	20
F	Fraser River	29 A, B, C, D, E
JS	Johnstone Strait	12, 13
GS	Georgia Strait	14, 18
Wa	Washington	-

Table I-7. Estimated numbers[a] and percentages of sport fishery caught coho taken in different fishing areas in 1982, for each time and size category of smolts released from Quinsam Hatchery in 1981 (replicates pooled).

	Smolts			Fishing Area[b]					
Release date	Size category	$\bar{x}$ weight (g)		W	C	GS	Wa	Ore	Total
April 20	Sm	19.97	No	0	4	16	0	0	20
			%	0	20.0	80.0	0	0	
	Med	24.02	No	0	0	30	0	0	30
			%	0	0	100.0	0	0	
	Lg	27.62	No	0	4	11	0	0	15
			%	0	26.7	73.3	0	0	
	Pooled	23.87	No	0	8	57	0	0	65
			%	0	12.3	87.7	0	0	
May 10	Sm	22.74	No	0	8	100	0	0	108
			%	0	7.4	92.6	0	0	
	Med	26.15	No	0	8	71	9	0	88
			%	0	1.1	80.7	10.2	0	
	Lg	31.68	No	0	4	114	4	0	122
			%	0	3.3	93.4	3.3	0	
	Pooled	26.86	No	0	20	285	13	0	318
			%	0	6.3	89.6	4.1	0	
May 30	Sm	21.72	No	0	4	220	7	0	231
			%	0	1.7	95.2	3.0	0	
	Med	24.88	No	0	16	315	5	0	336
			%	0	4.8	93.8	1.5	0	
	Lg	29.52	No	0	4	304	10	2	320
			%	0	1.3	95.0	3.1	.6	
	Pooled	25.37	No	0	24	839	22	2	887
			%	0	2.7	94.6	2.5	.2	
June 19	Sm	22.11	No	0	12	96	0	0	108
			%	0	11.1	88.9	0	0	
	Med	26.31	No	4	0	155	0	0	159
			%	2.5	0	97.5	0	0	
	Lg	30.36	No	0	4	142	0	0	146
			%	0	2.7	97.3	0	0	
	Pooled	26.26	No	4	16	393	0	0	413
			%	1.0	3.9	95.2	0	0	
Grand total			No	4	68	1574	35	2	1683
			%	.2	4.0	93.5	2.1	.1	

Table I-7 (cont'd)

Release date	Smolts: Size category	Smolts: $\bar{x}$ weight (g)		Fishing Area[b]: W	C	GS	Wa	Ore	Total
Totals by size category	Sm		No	0	28	432	7	0	467
			%	0	6.0	92.5	1.5	0	
	Med		No	4	24	571	14	0	613
			%	.7	3.9	93.1	2.3	0	
	Lg		No	0	16	571	14	2	603
			%	0	2.7	94.7	2.3	.3	

[a]Observed recoveries expanded to reflect fisherman "awareness". See MATERIALS AND METHODS.

[b]Fishing area	Statistical area
W = West coast Vancouver Island	21-27
C = Central	6-12, 30
GS = Georgia Strait	13-20, 28, 29
Wa = Washington	-
Ore = Oregon	-

Table I-8. Estimated numbers[a] and percentages of the total catch taken in different fishing areas in 1982 for combined gear types (commercial troll, net, and sport); for each time and size category of coho smolts released from Quinsam Hatchery in 1981 (replicates pooled).

	Smolts			Fishing Area[b]													
							West Coast										
Release date	Size category	$\bar{x}$ weight (g)		A	N	C	NWV	SWV	NWV/SWV	C/NWV	JF	F	JS	GS	Wa	Ore	Total
April 20	Sm	19.97	No	6	0	25	25	0	0	1	0	0	91	19	5	0	172
			%	3.5	0	14.5	14.5	0	0	.6	0	0	52.9	11.0	2.9	0	
	Med	24.02	No	0	4	36	6	0	0	0	0	0	40	37	0	0	123
			%	0	3.3	29.3	4.9	0	0	0	0	0	32.5	30.1	0	0	
	Lg	27.62	No	0	0	17	16	26	1	0	0	0	44	20	0	0	124
			%	0	0	13.7	12.9	21.0	.8	0	0	0	35.5	16.1	0	0	
	Pooled	23.87	No	6	4	78	47	26	1	1	0	0	175	76	5	0	419
			%	1.4	1.0	18.6	11.2	6.2	.2	.2	0	0	41.8	18.1	1.2	0	
May 10	Sm	22.74	No	0	0	51	52	36	1	0	12	0	179	124	6	0	461
			%	0	0	11.1	11.3	7.8	.2	0	2.6	0	38.8	26.9	1.3	0	
	Med	26.15	No	0	0	88	12	35	1	1	0	0	113	106	15	3	374
			%	0	0	23.5	3.2	9.4	.3	.3	0	0	30.2	28.3	4.0	.8	
	Lg	31.68	No	3	15	58	32	28	2	1	5	0	114	125	4	0	387
			%	.8	3.9	15.0	8.3	7.2	.5	.3	1.3	0	29.5	32.3	1.0	0	
	Pooled	26.86	No	3	15	197	96	99	4	2	17	0	406	355	25	3	1222
			%	.2	1.2	16.1	7.9	8.1	.3	.2	1.4	0	33.2	29.1	2.0	.2	
May 30	Sm	21.72	No	0	0	107	18	59	0	1	19	0	294	288	30	0	816
			%	0	0	13.1	2.2	7.2	0	.1	2.3	0	36.0	35.3	3.7	0	
	Med	24.88	No	0	0	161	61	51	5	1	22	0	298	391	23	0	1013
			%	0	0	15.9	6.0	5.0	.5	.1	2.2	0	29.4	38.6	2.3	0	
	Lg	29.52	No	0	0	101	65	124	0	0	0	8	331	389	31	2	1051
			%	0	0	9.6	6.2	11.8	0	0	0	.8	31.5	37.0	2.9	.2	
	Pooled	25.37	No	0	0	369	144	234	5	2	41	8	923	1068	84	2	2880
			%	0	0	12.8	5.0	8.1	.2	.1	1.4	.3	32.0	37.1	2.9	.1	

Table I-8 (cont'd)

	Smolts			Fishing Area[b]														
							West Coast											
Release date	Size category	$\bar{x}$ weight (g)		A	N	C	NWV	SWV	NWV/SWV	C/NWV	JF	F	JS	GS	Wa	Ore	Total
June 19	Sm	22.11	No	0	0	37	26	23	0	0	5	0	100	125	0	0	316
			%	0	0	11.7	8.2	7.3	0	0	1.6	0	31.6	39.6	0	0	
	Med	26.31	No	0	0	9	13	7	4	0	0	0	97	194	2	0	326
			%	0	0	2.8	4.0	2.1	1.2	0	0	0	29.8	59.5	.6	0	
	Lg	30.36	No	0	0	31	11	21	0	0	5	0	90	181	4	0	343
			%	0	0	9.0	3.2	6.1	0	0	1.5	0	26.2	52.8	1.2	0	
	Pooled	26.26	No	0	0	77	50	51	4	0	10	0	287	500	6	0	985
			%	0	0	7.8	5.1	5.2	.4	0	1.0	0	29.1	50.8	.6	0	
Grand total			No	9	19	721	337	410	14	5	68	8	1791	1999	120	5	5506
			%	.2	.3	13.1	6.1	7.4	.3	.1	1.2	.1	32.5	36.3	2.2	.1	
Totals by size category	Sm		No	6	0	220	121	118	1	2	36	0	664	556	41	0	1765
			%	.3	0	12.5	6.9	6.7	.1	.1	2.0	0	37.6	31.5	2.3	0	
	Med		No	0	4	294	92	93	10	2	22	0	548	728	40	3	1836
			%	0	.2	16.0	5.0	5.1	.5	.1	1.2	0	29.8	39.7	2.2	.2	
	Lg		No	3	15	207	124	199	3	1	10	8	579	715	39	2	1905
			%	.2	.8	10.9	6.5	10.4	.2	.1	.5	.4	30.4	37.5	2.0	.1	

Footnotes to Table I-8.

[a]Observed recoveries expanded to reflect sampling effort and sportsman "awareness", see MATERIALS AND METHODS.

[b]Fishing area		Statistical area
A	Alaska	-
N	North Coast	1-5
C	Central Coast	6-12, 30
NWV	Northwest Vancouver Island	25-27
SWV	Southwest Vancouver Island	21-24
NWV/SWV	Northwest/Southwest Vancouver Island	21-27
C/NWV	Central Coast/Northwest Vancouver Island	6-12, 30, 25-27
JF	Juan de Fuca	20
F*	Fraser River	29, A, B, C, D, E
JS*	Johnstone Strait	12, 13
GS*	Georgia Strait	13-20, 28, 29
Wa	Washington	-
Ore	Oregon	-

*Net fishery only under this area classification; these areas are included in Georgia Strait or Central Coast for other types of fisheries (see individual fishery tables).

Table II-1. Numbers of tagged coho juveniles released from Quinsam hatchery on May 30, 1983 (Julian day 150) and estimated lengths and weights for each group from samples taken at time of release.

Tag code	No. of tagged fish released[a]	Size category	Male $\bar{x}$	Male S.D.	Male n	Female $\bar{x}$	Female S.D.	Female n	Male and Female $\bar{x}$	Male and Female S.D.	Male and Female n	Male and Female Coefficient of variation (%)	Male and Female Median	Male and Female Skewness[b]
						a) Length (mm)								
8-21-16	4002	Sm.	126.14	7.04	51	125.24	6.07	63	125.64	6.51	114	5.2	125.50	+
8-21-17	4000	Sm.	126.89	7.28	53	125.94	6.50	67	126.36	6.84	120	5.4	125.50	-
8-21-18	4018	Sm.	125.13	6.80	32	123.90	6.70	49	124.38	6.72	81	5.4	125.00	+
8-21-55	3890	Med	128.65	5.96	51	128.30	5.67	46	128.48	5.80	97	4.5	129.00	-
8-21-56	3707	Med.	133.55	8.38	44	130.74	4.56	47	132.10	6.79	91	5.1	131.00	+*
8-21-57	3750	Med.	132.63	7.50	48	131.34	5.69	41	132.03	6.72	89	5.1	132.00	+
8-21-58	4073	Lg.	137.48	6.56	58	135.74	6.60	66	136.56	6.61	124	4.8	137.00	+
8-21-59	4106	Lg.	137.98	7.21	41	138.64	7.54	56	138.36	7.37	97	5.3	139.00	+
8-21-60	4010	Lg.	142.18	8.58	51	137.51	6.69	55	139.75	7.97	106	5.7	139.00	+
Total	35556				429			490			919			
						b) Weight (g)								
8-21-16	4002	Sm.	19.62	3.36	51	19.43	2.89	63	19.51	3.10	114	15.9	19.58	+
8-21-17	4000	Sm.	20.47	3.57	53	20.14	3.49	67	20.29	3.51	120	17.3	19.70	+
8-21-18	4018	Sm.	19.41	3.11	32	19.44	3.32	49	19.45	3.22	81	16.6	19.26	+*
8-21-55	3890	Med.	20.86	2.70	51	20.93	2.89	46	20.89	2.78	97	13.3	20.78	+
8-21-56	3707	Med.	23.93	4.47	44	22.13	3.00	47	23.00	3.87	91	16.8	22.93	+
8-21-57	3750	Med.	23.14	3.49	48	22.14	3.07	41	22.68	3.32	89	14.7	23.07	+
8-21-58	4073	Lg.	25.70	4.43	58	25.00	3.92	66	25.33	4.16	124	16.4	25.09	+**
8-21-59	4106	Lg.	25.28	4.20	41	26.43	4.47	56	25.94	4.37	97	16.8	26.02	+
8-21-60	4010	Lg.	28.34	5.19	51	25.87	4.49	55	27.06	4.98	106	18.4	26.52	+*
Total	35556				429			490			919			

[a]Estimated tag loss of 5.3% applied.

[b]+ indicates skewed right; - indicates skewed left.

* and ** indicate significance at α=.05 and .01, respectively.

Table II-2. Estimated numbers of tagged coho smolts released at Quinsam hatchery on May 30, 1983 (Julian day 150) and returns originating from this release. Also shown are returns as percentages of smolts released and adult catches as percentages of total returns.

		Smolts						Jacks (1983 returns)				Adults (1984 and 1985 returns)[a]								Jacks & adults (catch & escapement)	
		No. released			x̄ weight (g)			Escape-ment	Catch	Catch & escapement		Escapement ♂	Escapement ♀	Escapement Total		Catch	Catch & escapement		Catch as % of total return		
Tag code	Size group	♂	♀	♂+♀	♂	♀	♂+♀	No.	No.	No.	%	No.	No.	No.	%	No.	No.	%		No.	%
08-21-16	Sm.	1,790	2,212	4,002	19.62	19.43	19.51	1	0	1	.025	31	23	54	1.35	185	239	5.97	77.4	240	6.00
08-21-17	Sm.	1,767	2,233	4,000	20.47	20.14	20.29	1	0	1	.025	24	23	47	1.18	125	172	4.30	72.7	173	4.33
08-21-18	Sm.	1,587	2,431	4,018	19.41	19.44	19.45	2	0	2	.050	37	23	60	1.49	141	201	5.00	70.2	203	5.05
	Total	5,144	6,876	12,020				4	0	4	.033	92	69	161	1.34	451	612	5.092	73.7	616	5.12
08-21-55	Med.	2,045	1,845	3,890	20.86	20.93	20.89	1	0	1	.026	20	17	37	0.95	88	125	3.21	70.4	126	3.24
08-21-56	Med.	1,792	1,915	3,707	23.93	22.13	23.00	6	0	6	.162	23	21	44	1.19	91	135	3.64	67.4	141	3.80
08-21-57	Med.	2,022	1,728	3,750	23.14	22.14	22.68	8	0	8	.213	26	11	37	0.99	121	158	4.21	76.6	166	4.43
	Total	5,859	5,488	11,347				15	0	15	.132	69	49	118	1.04	300	418	3.68	71.8	433	3.82
08-21-58	Lg.	1,905	2,168	4,073	25.70	25.00	25.33	8	0	8	.196	24	08	32	0.79	103	135	3.32	76.3	143	3.51
08-21-59	Lg.	1,736	2,370	4,106	25.28	26.43	25.94	10	0	10	.244	23	13	36	0.88	125[b]	161	3.92	77.6	171	4.17
08-21-60	Lg.	1,929	2,081	4,010	28.34	25.87	27.06	10	0	10	.249	27	22	49	1.22	117	166	4.14	70.5	176	4.39
	Total	5,570	6,619	12,189				28	0	28	.230	74	43	117	0.96	345	462	3.79	74.7	490	4.02
Grand Total		16,573	18,983	35,556				47	0	47	.132	235	161	396	1.11	1,096	1,492	4.20	73.5	1,539	4.33

[a] Adult returns are 1984 unless otherwise indicated.

[b] Includes 3 fish (estimated from 1 recovery) from Alaska in 1985.

Notes: Escapement numbers are actual counts of hatchery returns; catch numbers are observed recoveries expanded to reflect sampling effort and sportsman "awareness" as described in MATERIALS AND METHODS.

Table II-3. Average lengths and weights of jacks and adults originating from the May 30, 1983 (Julian day 150) release of coho smolts from Quinsam hatchery, as sampled in the 1983 and 1984 hatchery escapements.

		Jacks						Adults																	
								♂						♀						Sexes combined					
		Hypural length (mm)			Weight (kg)			Hypural length (mm)			Weight (kg)			Hypural length (mm)			Weight (kg)			Hypural length (mm)			Weight (kg)		
Tag code	Size category	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n
08-21-16	Sm.	196.0	-	1	-	-	0	413.8	49.40	22	1.81	0.67	10	456.9	45.89	15	2.31	0.31	4	431.3	52.00	37	1.95	0.63	14
08-21-17	Sm.	244.0	-	1	-	-	0	408.7	51.53	15	1.54	0.38	6	459.6	43.04	21	2.10	0.60	13	438.4	52.60	36	1.92	0.59	19
08-21-18	Sm.	237.0	9.90	2	0.280	-	1	406.3	46.92	31	1.33	0.42	16	451.0	47.23	21	2.25	0.70	8	424.3	51.58	52	1.64	0.68	24
08-21-55	Med.	250.0	-	1	0.230	-	1	434.3	72.26	18	1.75	0.66	10	441.3	45.28	15	2.12	0.88	7	437.5	60.69	33	1.91	0.75	17
08-21-56	Med.	234.8	12.34	6	0.266	0.051	5	418.6	56.52	18	1.17	0.18	3	472.9	53.34	20	2.47	1.14	10	447.2	60.70	38	2.17	1.14	13
08-21-57	Med.	243.9	18.55	8	0.316	0.071	8	419.0	45.04	25	1.76	0.70	12	457.4	37.44	8	2.05	-	1	428.3	45.91	33	1.79	0.68	13
08-21-58	Lg.	234.9	14.29	8	0.284	0.071	8	409.8	56.86	19	1.59	0.87	5	469.0	21.26	7	1.84	0.14	2	425.8	56.15	26	1.66	0.72	7
08-21-59	Lg.	241.3	16.24	10	0.315	0.054	10	404.4	46.98	19	1.53	0.76	7	457.6	45.24	13	1.53	0.04	2	426.0	52.71	32	1.53	0.66	9
08-21-60	Lg.	243.0	17.57	10	0.307	0.064	9	441.3	62.24	22	2.03	1.13	12	478.3	51.11	18	2.62	1.20	4	458.0	59.76	40	2.18	1.14	16
Total		239.3	16.48	47	0.299	0.062	42	417.11	54.23	189	1.65	0.73	81	460.5	46.21	138	2.22	0.79	51	435.4	55.26	327	1.87	0.80	132

Table II-4. Standardized biomass estimates (kg per 100,000 smolts released) for returns of coho from smolts released at Quinsam hatchery in 1983.

Tag code	Smolts		Biomass (kg)		
	Size category	$\bar{x}$ weight (g)	Jacks	Adults	Jacks & Adults
08-21-16	Sm.	19.51	7.0	11,639	11,646
08-21-17	Sm.	20.29	7.0	8,265	8,272
08-21-18	Sm.	19.45	14.0	8,193	8,207
08-21-55	Med.	20.89	7.6	6,121	6,128
08-21-56	Med.	23.00	47.3	7,910	7,958
08-21-57	Med.	22.68	62.2	7,520	7,582
08-21-58	Lg.	25.33	58.0	5,261	5,319
08-21-59	Lg.	25.94	76.9	6,223	6,299
08-21-60	Lg.	27.06	73.7	9,021	9.095
Total			353.7	70,153	70,506

Table II-5. Estimated numbers[a] and percentages of the 1984 catch taken in the commercial troll, net, and sport fisheries; for coho smolts released from Quinsam hatchery on May 30, 1983.

	Smolts			Type of fishery			
Tag code	Size category	$\bar{x}$ weight (g)		Commercial troll	Net	Sport	Total
08-21-16	Sm.	19.51	No.	66	31	88	185
			%	35.7	16.8	47.6	
08-21-17	Sm.	20.29	No.	59	28	38	125
			%	47.2	22.4	30.4	
08-21-18	Sm.	19.45	No.	63	44	34	141
			%	44.7	31.2	24.1	
	Total		No.	188	103	160	451
			%	41.7	22.8	35.5	
08-21-55	Med.	20.89	No.	33	23	32	88
			%	37.5	26.1	36.4	
	Med.	23.00	No.	43	14	34	91
			%	47.3	15.4	37.4	
	Med.	22.68	No.	39	36	46	121
			%	32.2	29.8	38.0	
	Total		No.	115	73	112	300
			%	38.3	24.3	37.3	
08-21-58	Lg.	25.33	No.	37	37	29	103
			%	35.9	35.9	28.2	
08-21-59	Lg.	25.94	No.	54	20	48	122
			%	44.3	16.4	39.3	
08-21-60	Lg.	27.06	No.	39	17	61	117
			%	33.3	14.5	52.1	
	Total		No.	130	74	138	342
			%	38.0	21.6	40.4	
Grand Total				433	250	410	1093
				39.6	22.9	37.5	

[a]Observed recoveries expanded to reflect sampling effort and fisherman "awareness", see MATERIALS AND METHODS. Numbers may differ slightly from those shown in Tables II-2 and II-6 due to rounding differences.

Table II-6. Estimated numbers[a] and percentages of the 1984 catch taken in various areas for each type of fishery (gear type). For coho smolts released from Quinsam hatchery on May 30, 1983 (replicates pooled). Strokes indicate area classification is not applicable to that gear type, see footnotes.

Type of fishery (gear type)	Smolts: Size category	Smolts: $\bar{x}$ weight (g)		Fishing Area[b]: A[c]	N	C (West Coast)	NWV (West Coast)	SWV (West Coast)	NWV/SWV	C/NWV	JF	F	JS	GS	Wa	Ore	Total
Commercial troll	Sm.	19.75	No	0	0	33	82	51	0	1	–	–	–	18	2	0	187
			%			17.6	43.9	27.3		0.5				9.6	1.1		
	Med.	22.17	No	0	0	41	38	9	1	1	–	–	–	26	0	0	116
			%			35.3	32.8	7.8	0.9	0.9				22.4			
	Lg.	26.10	No	0	0	60	39	12	0	0	–	–	–	19	0	0	130
			%			46.2	30.0	9.2						14.6			
	Total		No	0	0	134	159	72	1	2	–	–	–	63	2	0	433
			%			30.9	36.7	16.6	0.2	0.5				14.5	0.5		
Net	Sm.	19.75	No	0	0	4	0	0	0	0	4	0	93	0	2	0	103
			%			3.9					3.9		90.3		1.9		
	Med.	22.17	No	0	0	0	0	0	0	0	0	0	73	0	0	0	73
			%										100.0				
	Lg.	26.10	No	0	0	4	0	0	0	0	2	0	64	0	4	0	74
			%			5.4					2.7		86.5		5.4		
	Total		No	0	0	8	0	0	0	0	6	0	230	0	6	0	250
			%			3.2					2.4		92.0		2.4		

Table II-6 (cont'd)

Type of fishery (gear type)	Smolts			Fishing Area[b]													
							West Coast										
	Size category	$\bar{x}$ weight (g)		A[c]	N	C	NWV	SWV	NWV/SWV	C/NWV	JF	F	JS	GS	Wa	Ore	Total
Sport	Sm.	19.75	No	0	0	4	0	0	0	0	-	-	-	156	0	0	160
			%			2.5								97.5			
	Med.	22.17	No	0	0	4	0	0	0	0	-	-	-	108	0	0	112
			%			3.6								96.4			
	Lg.	26.10	No	0	0	8	0	0	0	0	-	-	-	130	0	0	138
			%			5.8								94.2			
	Total		No	0	0	16	0	0	0	0	-	-	-	394	0	0	410
			%			3.9								96.1			
Combined	Sm.	19.75	No.	0	0	41	82	51	0	1	4	0	93	174	4	0	450
			%			9.1	18.2	11.3		0.2	0.9		20.7	38.7	0.9		
	Med.	22.17	No	0	0	45	38	9	1	1	0	0	73	134	0	0	301
			%			15.0	12.6	3.0	0.3	0.3			24.3	44.5			
	Lg.	26.10	No.	0	0	72	39	12	0	0	2	0	64	149	4	0	342
			%			21.1	11.4	3.5			0.6		18.7	43.6	1.2		
	Total		No	0	0	158	159	72	1	2	6	0	230	457	8	0	1093
			%			14.5	14.5	6.6	0.1	0.2	0.5		21.0	41.8	0.7		

Footnotes to Table II-6.

[a]Observed recoveries expanded to reflect sampling effort and fisherman "awareness"; see MATERIALS AND METHODS. Numbers may differ slightly from those in Tables II-2 and II-5 due to rounding differences.

[b]Fishing Area		Statistical Area
A	Alaska	-
N	North Coast	1-5
C	Central Coast	6-12, 30
NWV	Northwest Vancouver Island	25-27
SWV	Southwest Vancouver Island	21-24
NWV/SWV	Northwest/Southwest Vancouver Island	21-27
C/NWV	Central Coast/Northwest Vancouver Island	6-12, 30, 25-27
JF	Juan de Fuca	20
F*	Fraser River	29 A, B, C, D, E
JS*	Johnstone Strait	12, 13
GS*	Georgia Strait	13-20, 28, 29
Wa	Washington	-
Ore	Oregon	-

*Net fishery only under this area classification; these areas are included in Georgia Strait or Central Coast for other gear types.

[c]There was one observed Alaska recovery in 1985 (expanded estimate 3); type of fishery unknown.

Appendix table 1. Linear or quadratic equations and coefficients of determination (r^2) for various correlations examined in the text. Only statistically significant correlations are described.

Year of study[a]	Relationship[b]	Release date	r^2	n	Probability (p)	Equation
1981	% return of jacks vs. (♂+♀) juvenile weight	May 10	.847	9	<.01	$-1.7962 + 0.1167x$
1981	% return of jacks vs. (♂+♀) juvenile weight	May 30	.914	9	<.01	$-2.7412 + 0.1398x$
1981	% return of jacks vs. (♂+♀) juvenile weight	June 19	.697	9	<.01	$-0.5007 + 0.2340x$
1981	% return of adults (♂ + ♀) vs. juvenile weight (♂ + ♀), E only	June 19	.719	9	.009	$-5.8704 + 0.5173x - 0.0100x^2$
1981	% return of adults (♂ + ♀) vs. juvenile weight (♂ + ♀), C only	May 10	.614	9	.048	$24.3297 - 1.4968x + 0.0264x^2$
1981	% return of jacks & adults vs. juvenile weight (♂ + ♀), E only	May 10	.589	9	<.05	$0.4227 + 0.0756x$
1981	% return of jacks & adults vs. juvenile weight (♂ + ♀), E only	May 30	.741	9	<.01	$-0.4834 + 0.1574x$
1981	% return of jacks & adults vs. juvenile weight (♂ + ♀), E only	June 19	.654	9	.047	$-0.4157 + 0.3696x - 0.0067x^2$
1981	% return of jacks & adults vs. juvenile weight (♂ + ♀), C + E	May 30	.719	9	<.01	$5.7720 + 0.2477x$
1981	Incidence of jacks vs. juvenile weight (♂ + ♀)	April 20	.467	9	<.05	$-13.8902 + 1.4824x$
1981	Incidence of jacks vs. juvenile weight (♂ + ♀)	May 10	.768	9	<.01	$-26.0469 + 1.7995x$
1981	Incidence of jacks vs. juvenile weight (♂ + ♀)	May 30	.916	9	<.01	$-19.6276 + 1.0270x$
1981	Incidence of jacks vs. juvenile weight (♂ + ♀)	June 19	.684	9	<.01	$-13.0793 + 0.6112x$
1981	% returns of male adults vs. ♂ juvenile weight, E only	April 20	.486	9	<.05	$1.3832 - 0.0398x$
1981	Adult weight (♂) vs. juvenile weight (♂)	May 10	.701	7	.038	$-12.0327 + 1.0975x - 0.0193x^2$
1981	Adult weight (♂) vs. juvenile weight (♂)	May 30	.466	9	<.05	$0.7828 + 0.0653x$
1981	Adult weight (♀) vs. juvenile weight (♀)	May 30	.668	9	<.01	$1.5103 + 0.0540x$
1981	Adult weight (♂+♀) vs. juvenile weight (♂+♀)	May 30	.603	9	<.05	$1.1746 + 0.0594x$
1981	Jack weight vs. juvenile weight (♂)	May 10	.499	9	<.05	$0.3245 + 0.0042x$
1981	Jack biomass vs. juvenile weight (♂ + ♀)	May 10	.857	9	<.01	$-933.5 + 57.14x$
1981	Jack biomass vs. juvenile weight (♂ + ♀)	May 30	.918	9	<.01	$-998.5 + 50.68x$

Appendix table 1 (cont'd)

Year of study[a]	Relationship[b]	Release date	r^2	n	Probability (p)	Equation
1981	Jack biomass vs. juvenile weight (♂+♀)	June 19	.694	9	<.01	-141.4 + 6.642x
1981	Adult biomass (♂+♀) vs. juvenile weight (♂+♀)	May 30	.617	9	<.05	6297.9 + 944.78x
1981	Jack plus adult biomass vs. juvenile weight (♂+♀)	May 30	.635	9	<.05	5298.6 + 995.49x
1983	% return of jacks vs. juvenile weight (♂+♀)	May 30	.850	9	<.01	-0.5880 + 0.0318x
1983	Incidence of jacks vs. juvenile weight (♂+♀)	May 30	.874	9	<.01	-14.8136 + 0.7950x
1983	Jack biomass vs. juvenile weight (♂+♀)	May 30	.859	9	<.01	180.70 + 9.6986x

[a] i.e. year of release

[b] C = catch

E = escapement

Appendix table 2. Parameter estimates for response surface analysis models discussed in the text. The model is expressed as:

$$\hat{\eta} = P + q_1\xi_1 + r_{11}\xi_1^2 + r_{12}\xi_1\xi_2 + q_2\xi_2 + r_{22}\xi_2^2$$

Parameters are defined below, see Schnute and McKinnell (1984) for a full discussion of the technique.

	Response (to time and size at release) examined						
Parameter	Jack returns[a] 1981 study	Adult returns 1981 study	Jack plus adult returns, 1981 study	Adult biomass 1981 study	Jack returns[a] 1980 + 1981 studies	Adult returns 1980 + 1981 studies	Adult biomass 1980 + 1981 studies
γ	-1.4189	0.7967	0.6304	0.3738	-1.7618	0.6026	0.5211
α_1	0.2587	7.7693	6.2697	4.9193	1.9797	6.8966	5.8127
α_2	0.6435	1.0[b]	1.0[b]	1.0[b]	2.4883	0.3082	1.0[b]
p	0.6294	1.0927	0.9122	0.8037	0.4880	0.8169	0.6424
q_1	-0.4112	0.2013	0.1543	0.8933 x 10-1	-0.5326	0.1703 x 10-1	-0.1224
r_{11}	-0.9009	-1.7376	-1.5579	-1.4469	-0.6555	-1.4601	-1.3415
r_{12}	0.1911	0.8410 x 10-1	0.6332 x 10-1	0.1746	0.8448 x 10-1	0.1177	0.1631
q_2	0.4111	-0.5813 x 10-3	0.6579 x 10-1	0.3408 x 10-1	0.7878	-0.1916	-0.1372
r_{22}	-0.1068	0.1042 x 10-1	0.3711 x 10-1	0.2291 x 10-1	-0.4292	0.1126	0.1272
U_1	170	170	170	170	171	171	171
u_1	110	110	110	110	110	110	110
U_2	32.13	32.13	32.13	32.13	32.13	32.13	32.13
u_2	19.81	19.81	19.81	19.81	13.52	13.52	13.52
V	3.1773	11.900	13.185	35162	3.2007	12.430	33085
v	1.0000	1.040	1.478	3467	1.0000	0.948	2932

Definitions: $\hat{\eta}$ = estimated value of transformed response variable.

η = transformed response variable (y) observation.

$= (2y^{\gamma} - V^{\gamma} - v^{\gamma})/(V^{\gamma} - v^{\gamma})$

where V and v = largest and smallest observations, respectively, for y.

$$\text{note:} \quad y = \left[\frac{V^{\gamma} + v^{\gamma} + (v^{\gamma} - v^{\gamma})\,\eta}{2} \right]^{1/\gamma}$$

ξ_i = transformed independent variable (x_1 = time, x_2 = size) observations.

$= (2(x_i)^{\alpha i} - U_i^{\alpha i} - u_1^{\alpha i})/(U^{\alpha i} - u_1^{\alpha i})$

where U_i and u_i = largest and smallest values, respectively, for x_i.

[a]In some cases there were no jack returns. To avoid zeros the observed % returns were increased by 1% for analysis. Predicted values will therefore be 1% high but otherwise valid.

[b]This parameter fixed at 1.0 to achieve model stability.