Canadian Technical Report of

Fisheries and Aquatic Sciences No. 1306

August 1984

THE INFLUENCE OF TIME AND SIZE AT RELEASE OF JUVENILE COHO SALMON (*Oncorhynchus kisutch*) ON RETURNS AT MATURITY; RESULTS OF RELEASES FROM QUINSAM RIVER HATCHERY, B.C., IN 1980

by

H. T. Bilton, R. B. Morley, A. S. Coburn, and J. Van Tynel

Department of Fisheries and Oceans

Fisheries Research Branch

Pacific Biological Station

Nanaimo, British Columbia V9R 5K6

[1]Salmon Enhancement Program
Operations
Quinsam Hatchery
Campbell River, B.C.

Cat. No. Fs 97-6/1306E ISSN 0706-6457

Correct citation for this publication:

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

TABLE OF CONTENTS

ABSTRACT

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

Releases of juvenile coho salmon (Oncorhynchus kisutch) were made from Quinsam River production hatchery, Vancouver Island, British Columbia, on April 20, May 10, May 30, and June 19, 1980. These fish had been graded into small, medium, and large size groups, nose-tagged, and marked by removal of the adipose fin. Each time-size combination was replicated three times giving a total of 36 groups. Returns of jacks (precocious males, age 1.0) and adults (age 1.1) to the hatchery and various fisheries were analyzed using both simple regression techniques and response surface analysis. Maximum adult returns (catch plus escapement) of 11.2% are predicted for release of 15.7 g juveniles on June 4 (Julian day 156). Since this weight is below the actual weight range tested for this date, a release weight of approximately 20 g is recommended until the lower weight can be tested. Returns of approximately 10.2% are predicted for fish of this size. The effects of size at release were minor compared to those of time of release, with very little change in the optimum release weight over the season. As in an earlier study, production of jacks was favored by early release of large juveniles; within the tested ranges jack returns were predicted to be highest (≈2.5%) for release of 30 g juveniles on about May 8. For both jacks and adults, fish from earlier releases were larger on return. There was also a pronounced tendency for larger juveniles to produce larger jacks; a similar but less pronounced correlation was observed for adults. Taking these weight differences amongst mature fish into account, response surface analysis indicates maximum biomass of returns from a release of 16.6 g juveniles on June 3 (day 155), a combination only slightly different from that predicted to maximize percent return of adults. Almost all fish taken by the fishery were caught as adults. Most (41%) were taken in the net fishery, the remainder was divided approximately equally between commercial troll and sport, the sport proportion increasing with later release. Fish from earlier releases had an more extended northward range and there was strong evidence of selection by the fishery for larger fish and for males. Comparison of Quinsam returns with a previous study at an experimental hatchery on E. Vancouver Island and with other production hatcheries suggests the possibility of site specific factors limiting production at Quinsam. Nevertheless, the results indicate that production could be approximately doubled by the release of juveniles about 2 weeks later and approximately 5 g smaller than is currently practiced.

Key words: coho salmon, release time, release size, ocean survival, jack coho, hatchery production, salmon fisheries

RÉSUMÉ

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

Des lâchers de saumons cohos (Oncorhynchus kisutch) juvéniles ont été effectués à la pisciculture de la rivière Quinsam, les 20 avril, 10 mai, 30 mai, et 19 juin 1980. Étiquetés d'un fil métallique inséré dans la narine et marqués par l'ablation de la nageoire adipeuse, ces poissons ont été triés en groupes de tailles (petit, moyen, gros). Chaque combinaison date-taille a été triplée, générant ainsi 36 groupes. Les retours à la pisciculture et les captures dans diverses pêcheries de jeunes saumons mâles précoces (1 an) et d'adultes (1,1 an) ont été étudiés à l'aide d'analyses de régression simple et de surface dr réaction. Selon l'extrapolation, le lâcher, le 4 juin (156^{e} jour julien), de juvéniles de 15,7 g devrait générer un retour maximum (prises + échappées) d'adultes s'élevant à 11,2%. Comme ce poids est inférieur à la gamme de poids analysés à cette date, on recommande un poids au lâcher d'environ 20 g, jusqu'à ce qu'on poisse vérifier le premier. On prédit un retour d'environ 10,2% des poissons de cette taille. L'incidence de la taille au lâcher était faible quand on la compare à celle du moment du lâcher; le poids optimum au moment de la mise en liberté a peu varié pendant la saison. Comme cela a été le cas dans une étude antérieure, la production de jeunes mâles a bénéficié d'une mise en liberté hâtive de gros juvéniles; dans la gamme des poids étudiés, on a prédit un retour maximum de jeunes mâles (2.5%) au lâcher, vers le 8 mai, de juvéniles de 30 g. Chez le jeune mâle et l'adulte, les poissons relâchés plus tôt étaient plus gros au retour. En outre, les gros juvéniles avaient fortement tendance à produire des mâles plus gros; une corrélation semblable mais moins marquée a été observée chez les adultes. L'analyse de la surface de réaction, qui tient compte des différences de poids entre les poissons matures, révèle une biomasse maximum à la remonte à partir du lâcher, le 3 juin (155^{e} jour), de juvéniles de 16,6; cette combinaison est légèrement différente de celle extrapolée pour maximiser le retour procentuel d'adultes. Presque toutes les prises de l'industrie étaient des saumons adultes. La plupart des captures (41%) s'est faite à l'aide de filets tandis que le reste s'est réparti presque également entre la pêche aux lignes traînantes et la pêche sportive, la proportion reliée à cette dernière augmentant en fonction des lâchers tardifs. Les poissons relâchés plus tôt avaient une répartition septentrionale et les données semblent indiquer une pêche sélective de plus grôs poissons et de mâles. Une comparaison des retours de la Quinsam avec les résultats d'une étude antérieure menée à une pisciculture expérimentale de l'est de l'île Vancouver et avec les données recueillies à d'autres établissements porte à croire à la possibilité de facteurs particuliers au site limitant la production à la pisciculture de Quinsam. Malgré tout, les résultats indiquent que la production pourrait être presque doublée si les juvéniles étaient mis en liberté environ deux semaines plus tard et quand ils pèsent environ 5 g de moins que dans la pratique courante.

Mots-clés: saumon coho, moment du lâcher, taille au lâcher, survie marine, jeune mâle précoce, production piscicole, pêche du saumon

INTRODUCTION

A study at Rosewall Creek experimental hatchery, Vancouver Island, B.C., demonstrated that both the size and time of release of juvenile coho salmon influenced their subsequent survival, growth and age at maturity. By releasing under optimal conditions for these factors, substantial increases in production, i.e. returns of mature fish, could be expected (Bilton 1980, Bilton et al. 1982).

As part of a Federal-Provincial Salmonid Enhancement Program, similar studies were undertaken at two production hatcheries to determine the optimal time and size for release at these locations. Such studies were deemed necessary because of the possibility of site-specific differences. It was also decided to repeat the studies in two successive years at each location to examine for annual variation.

This report presents results from the first year's releases of coho from Quinsam River hatchery, Vancouver Island, in 1980. A complete record of the study up to and including release has been published previously (Bilton and Coburn 1981) and the reader is referred to that source for detailed information.

MATERIALS AND METHODS

DONOR STOCK AND REARING

A part of the production stock of 1978 brood Quinsam hatchery coho was used for the experiment. These fish were treated as production fish and reared at production densities in four Burrow's ponds, using normal hatchery water. They were fed Oregon moist pellets (OMP) according to routine hatchery feeding schedules.

EXPERIMENTAL DESIGN

Three size groups of juveniles were released at each of 4 different times. A different pond of fish was used 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 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 presented schematically below.

Size Category	Release date and approximate number of fish			
	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
Total	12,000	12,000	12,000	12,000
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
Total	12,000	12,000	12,000	12,000
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
Total	12,000	12,000	12,000	12,000
Grand Total	36,000	36,000	36,000	36,000

MARKING, TAGGING AND RELEASE

Fish for all releases were marked and tagged during November, 1979. Just prior to tagging the fish from each pond, a sample of 1,000 fish were removed and anesthetized; these fish were measured for fork length and returned to the pond. Length-frequency distributions derived from these data were used to determine size categories. This was done by rejecting 5% from each tail of the distribution (to remove extreme values) and dividing the remainder into three 30% portions classified as small, medium, or large.

Once size categories were established, marking and tagging were begun. Fish were first anesthetized and the adipose fin removed. They were then graded to size category and the appropriate nose tag was applied. Tagged fish were 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 at the same time as the marked fish. All marked mortalities between time of marking and release were examined for nose tags, and release figures adjusted accordingly.

Releases were made at approximately 1800 h on Julian days 111 (April 20), 131 (May 10), 151 (May 30), and 171 (June 19), 1980. A sample of 1,000 marked fish was removed from each pond on the day of its release. These were killed and frozen; at a later time the coded wire tags were removed and read and the fork length, weight, and sex of each fish determined. Tag retention was estimated from the proportion of marked fish in the sample having no nose tag and the estimates of numbers of tagged fish released adjusted accordingly. In addition, other samples were collected for health evaluation, histopathological studies, proximate analysis, and sea-water adaptability tests. Estimates of size, sex composition, and numbers released for each of the 36 groups are given in Tables 1a-4a. Analysis of sex ratios and results of health evaluation and sea-water adaptability tests are summarized below.

SEX RATIO, HEALTH, AND SEA-WATER ADAPTABILITY OF JUVENILES

Sex ratios

A two-way analysis of variance (ANOVA) was conducted on the proportions of males observed in the samples from each of the 36 groups. There were no significant differences in proportions associated with release date, size, or interaction (at the 5% significance level). However, a Chi-square analysis using the numbers of males and females observed in the combined samples (all 36 groups) showed the observed overall proportion of 52% males to be significantly different from a 50:50 male to female ratio ($p<0.01$)

Sex ratios were also examined for equality and deviations from 50:50 using a heterogeneity G-test (Sokal and Rohlf 1981). This test was done twice, once to test ratios within and between releases (using the total male and female counts for each release) and once to test ratios within and between size categories (using total male and female counts for each size). The conclusions drawn were identical to those arrived at using ANOVA and Chi-square.

Thus, although there was a significantly higher proportion of males than females amongst the fish released, no significant differences in this proportion were detected between size categories or between releases.

Health

This information was provided by the Diagnostic Services section (G. Hoskins) of the Pacific Biological Station and summarizes the results of health evaluation of juveniles sampled just prior to their release. Furunculosis was the only infectious disease encountered which might have had a significant influence on survivals. This was present in samples from all releases but increased in severity over time. The most significant finding was a general deterioration in health for fish of the last two releases. These showed acute signs of stress and infection when sampled. Fish of the June 19 release were in particularly poor condition. At release approximately 90% of these had external swellings, abrasions, and/or other disease symptoms. Incidence of furunculosis was 31%. This high incidence and the generally poor condition of these fish suggested their survival following release might not be as high as for the earlier releases (see Bilton and Coburn 1981 for further details).

Sea water adaptability

Information in this section was provided by C. Clarke of the Pacific Biological Station. It summarizes results of sea water adaptability tests performed on samples of fish collected just prior to release. In these tests, blood sodium levels after 24 h exposure to sea water were used as a measure of ability to osmoregulate. The data indicated that ability to adapt was similar for all releases. At the time of the releases there was little relationship between size and adaptability. Some early tests however, conducted on March 28 showed performance at this time was related to size, larger fish showing greater adaptability (see Bilton and Coburn 1981 for detail). This relationship is often observed in coho near time of smolting.

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

Escapement

a) Jacks

All jacks returning to the Quinsam River hatchery in the fall of 1980 were examined. A total of 612 tagged fish originating from the releases that spring was recovered[2]. Estimates of river spawners (not recovered) suggest that this total represents approximately 78% of the total jack escapement (i.e. hatchery plus river) resulting from the release (personal communication, Quinsam hatchery). Hatchery returns indicated no obvious differences in timing among the various groups. It is therefore assumed that all groups were sampled with equal intensity even though the proportion of river spawners varied throughout the season; i.e., the hatchery escapement is taken to be an unbiased subsample of the total escapement. Estimates of river spawners are not included in this analysis and escapement figures given are therefore conservative.

Fork length and round weight were either observed or estimated for all but 2 fish. Fork length was measured and recorded either directly in millimeters (258 fish) or in 20 mm interval length categories (352 fish). The later method was used in an attempt to speed the sampling procedure. Fish with lengths recorded by category only were later assigned a fork length corresponding to the midpoint of the length category.

---

[1]The European system of age designation (Koo 1962) is used in this report. The first digit indicates the number of annuli formed in fresh water and the second digit the number of annuli formed while fish were in the ocean.

[2]These fish were all precocious males; no "jills" (precocious females) were observed.

Although weight was of primary interest, only 189 fish were actually weighed (round weight in decagrams[1]). To speed sampling, weights of all others were estimated on the basis of fork length (either direct measure or category midpoint) and from length-weight regressions derived from direct measurements taken on 570 fish[2]. Three separate regressions were used corresponding to early, middle, and late segments of the escapement. This was done because of statistically confirmed differences in the length-weight relationship over time, later fish being of a lesser weight for a given fork length.

Snouts of all marked fish were removed and retained for subsequent examination of the coded wire tag.

b) Adults

In the fall of 1981 all adult coho returning to Quinsam hatchery were examined. Estimates of river spawners (unsampled) suggested that the recoveries at the hatchery represented approximately 59% of the total adult escapement (hatchery plus river) resulting from the releases (personal communications, Quinsam hatchery). As with the jacks the previous year, no obvious differences in time of return to the hatchery were apparent among groups, and the hatchery escapement was considered an unbiased subsample of the total escapement. Estimates of river spawners were again omitted from this analysis and escapement figures given here are therefore conservative.

Direct measurements of hypural length (posterior margin of eye orbit to hypural plate, in millimeters) and round weight (decagrams) were made on all marked fish; no estimation was involved as was done for the jacks. Sex of each fish was recorded and the snout removed for subsequent examination of the coded wire tag.

Catch

Estimates of the numbers of tagged coho taken in the 1980 and 1981 Canadian commercial and sport fisheries were obtained through the coast-wide mark recovery program. Commercial catches (net and troll) were sampled at a target intensity of 20%; the numbers of tags recovered were then expanded by adjusting for actual sampling intensity on each catch. Estimates of numbers taken in the sport fishery were made on the basis of voluntary returns of heads from marked coho (missing adipose fin) by sports fishermen. Returns were expanded by an "awareness factor" of .252, i.e. it was assumed that 25.2% of all marked fish caught in the sport fishery were recognized and reported. This value was calculated from a 1980-81 Georgia Strait Sport Fishing Creel Survey report (DPA 1982) and is an average awareness factor weighted for catch by region.

---

[1]i.e. to a precision of 1/100 of a kilogram.

[2]188 of these were tagged fish recovered from this experiment. The remainder were either untagged or tagged fish from other experiments.

Estimates of the numbers recovered in United States fisheries were provided by American agencies participating in the mark recovery program, using similar estimation procedures.

DATA COMPILATION AND RELIABILITY

Fishery recoveries in the year of release

Of major interest in the experiment were the proportions of jacks and adults that would result from releases of juveniles at different times and sizes. Therefore, it was desirable to classify fish recovered in the 1980 fisheries as either maturing jacks or potential adults. Although the total number taken in the fishery in 1980 was only 100 fish (expanded figure), this classification was important in the interpretation of the returns of a few groups.

Information on the sex and stage of maturity of the fish caught in 1980, which might have been used in classifying them as jacks or adults, was not available. For a few fish the area and time of recovery ruled out the possibility of them being jacks, but for the majority of the catches the numbers of jacks and potential adults had to be estimated.

The procedure used to make these estimates was based on two known figures, the 1980 jack escapement and the 1981 adult returns (expanded catch plus escapement). Any fish in the population during the 1980 fishery, if not caught in 1980, would eventually experience natural mortality or contribute to one of these returns, depending on whether it was a jack or a potential adult. If the 1980 catch is assumed to be an un-biased sample it would have the same jack : potential adult ratio as the total population, and survivors of the fishery would also have the same ratio. Therefore, if the 1981 adult returns are expanded to include an estimate of the natural mortalities of potential adults during their additional year of ocean residence, the known jack and adult returns can be used to provide an estimate of the jack: potential adult composition of the population at the time of the fishery in 1980. This ratio can then be used to divide the catch.

Estimates of natural mortality were calculated using monthly instantaneous rates derived from a Puget Sound coho study, as described by Ricker (1976). After division of the catch those designated as jacks were added to the 1980 jack recovery figure; those designated as potential adults were added to the 1981 adult recoveries after subtraction of estimated natural mortalities in the final year, again using the instantaneous mortality rates described by Ricker (1976).

Although this method requires a number of assumptions and estimates, the results appear reasonable and affect interpretation of the returns less drastically than designation of all 1980 fishery recoveries as either jack or adult. For example, for the April 20 release large fish (3 replicates combined) the designation of all 50 recoveries as either jack or adult gives estimates of jack returns of 0.97% or 0.53% respectively, and adult estimates of either 2.3% or 2.8%. Using the method described above gave intermediate results of 0.58% for jacks and 2.5% for adults. This example represents an extreme case, since one-half of the 100 (expanded) fishery recoveries in 1980 occurred here; effects on other groups are of much lesser magnitude.

Percent returns

Total returns from each of the 36 groups released were determined from the number of returning jacks and adults counted in the escapement to the hatchery and the number estimated to have been caught in the commercial and sport fisheries. Percent returns were calculated as total returns in relation to numbers of juveniles released. The numbers of jacks and adults in the escapement are considered conservative (since they do not include river spawners) but quite reliable. Estimates of numbers caught by the commercial fishery arise from a consistent sampling effort in most commercial fishing areas over the fishing season and are considered reasonable but less reliable than the escapement counts. Estimates of numbers taken by the sport fishery are considered lower in reliability since there is evidence that the awareness factor is to some extent site-specific (e.g. it is suspected that the value of .252 that was used provides overly conservative estimates for northern areas).

Biomass of returns

Standardized estimates of biomass of returning fish for each of the 36 groups were calculated as kilograms per 100,000 juveniles released. These estimates are based on (1) percent returns of jacks and adults for each group; (2) proportionally, the numbers that would have returned if 100,000 juveniles had been released in each group; and (3) the average weights of jacks and adults from each group as sampled at the hatchery. Final weights as observed at the hatchery were used since little biological information was available for fish recovered in the fisheries. Biomass is therefore probably overestimated since fish taken early in the fishery would not have reached their final weight.

ANALYTICAL METHODS

All statistical tests were based on Sokal and Rohlf (1981), unless otherwise indicated.

Results were examined using two approaches -- simple regression analysis and response surface analysis. For the regression analyses various dependent variables such as per cent return were plotted against the independent variable release weight for each release. Lines of best fit (as determined by the value of r^2, the coefficient of determination) to either linear or quadratic models were calculated and plotted to demonstrate trends in the data. For linear relationships the significance of r, the correlation coefficient, was determined, a significant r indicating significant slope to the line.

Response surface analysis was used to allow examination of the relationships between dependent (response) variables and both independent variables (time and weight at release) simultaneously. This approach enables one to examine or predict responses for any combination of time and weight (Schnute and McKinnell 1984). The significance of the contribution of each variable to the response surface model was tested by repeating the analysis using only single variables (omitting the variable being examined). Minimum function values obtained from these analyses were used to calculate approximate F statistic as described by Schnute and McKinnell, p. 946. A significant value of this statistic indicates that inclusion of the variable being examined significantly improves the fit of the model.

RESULTS

A. PERCENT RETURNS OF JACKS AND ADULTS, AND PROPORTIONS OF JACKS

Jack returns

Total return of jacks was 625. Of this total, 612 were recovered in the escapement to the hatchery and 13 are estimated to have been taken in the catch (Tables 1a-4a). Most of the fish taken in the catch (7 out of 13) resulted from the large category fish of the April 20 release; there was none resulting from the June 19 release.

Considering total returns (catch plus escapement), jack return for a common release date (9 groups combined) was highest for the May 30 release - 293 fish or 0.90%. Lowest return was from the June 19 release - 20 fish or 0.06%. Returns for the April 20 and May 10 releases were 118 fish or 0.35% and 195 fish or 0.57% respectively (Tables 1a-4a).

Within each release, total return of jacks was positively correlated with release weight, larger juveniles producing more jacks (Fig. 1; Table 5). The linear correlations for the April 20 and June 19 releases were both statistically significant ($p<0.05$) with r^2 values of 0.762 and 0.550 respectively. This increase in percent return of jacks with increasing juvenile weight was even more pronounced for the May 10 and May 30 releases. The respective r^2 values of 0.963 and 0.981 indicate almost all the observed variability can be accounted for by the slightly curvilinear lines that best describe the data.

Response surface analysis of total jack returns is shown in Fig. 2. Both time and size at release contributed significantly to the model ($F \approx 37.0$ and 26.3 respectively, $dF=4,25$, $p<.001$ for both). The percent return contours ascend toward the top center of the figure suggesting a theoretical maximum somewhere in this region but beyond the tested range. For all releases, higher returns of jacks are indicated for larger juveniles. Up

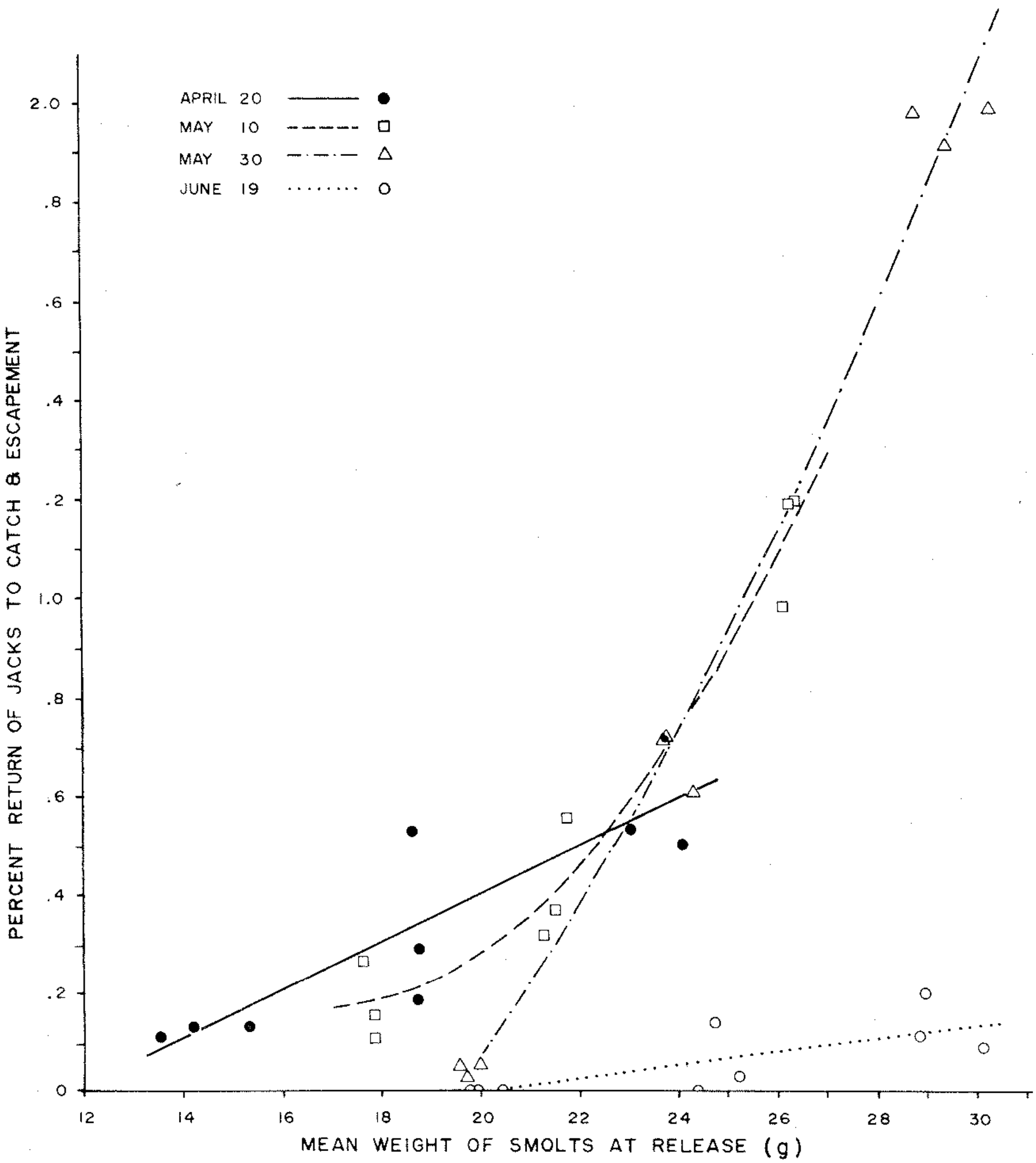

Fig. 1. Mean weights of juveniles (sexes combined) in release samples and total jack (catch plus escapement) as a percentage of juveniles released for each group.

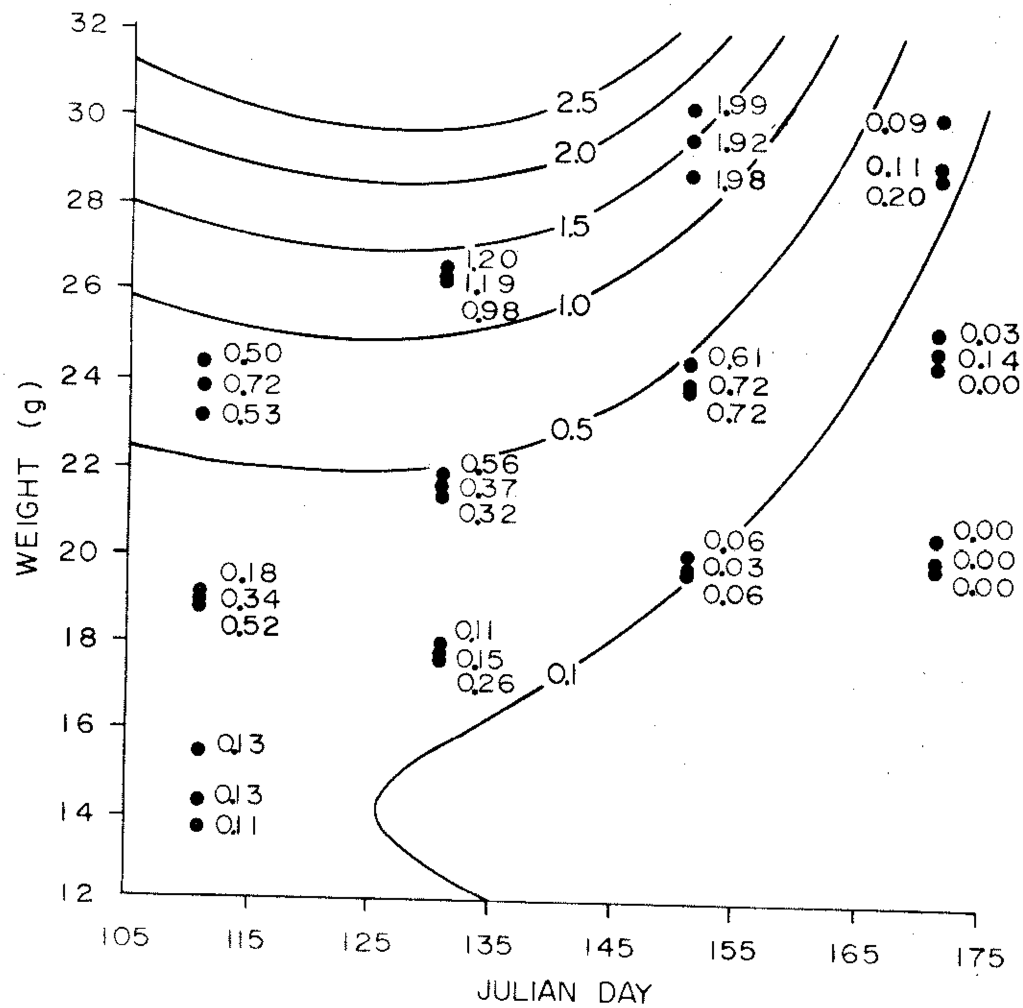

Fig. 2. Response surface showing influence of time at release (Julian days) and mean size at release (g) of juvenile coho on returns of jacks (catch plus escapement) as a percentage of juveniles released. Contours indicate the percent return of jacks from release of juveniles for various size-time combinations. The solid points indicate actual percent returns of jacks from experimental groups released.

until about day 141 returns for fish of the same size are fairly consistent; however, beyond this point increasingly larger juveniles are required to produce equivalent returns. Also, at about the same point, release date begins to assume greater importance, and returns for fish of given weight begin to decrease rapidly over time. Within the tested ranges, maximum jack returns (≈2.5%) can be expected from juveniles of about 30 grams released around May 8 (day 129); however, time is not critical within the approximate range April 20 to May 20 (day 111 to 141).

Adult returns (male plus female)[1]

a) Escapement

A total of 1,256 adults were recovered in the escapement to the hatchery (Tables 1a to 4a). Combined returns (9 groups) for a common release date were highest for the May 30 release - 594 fish or 1.82%. This was 2.1 times the next highest return, that from the May 10 release - 296 fish or 0.87%. Returns for the April 20 and June 19 releases were 219 fish or 0.65% and 147 fish or 0.47%, respectively.

For the first 3 releases there was a pronounced effect of size, smaller juveniles producing higher adult returns (Fig. 3, Table 5). The linear correlations between percent return and juvenile size for the April 20 and May 10 releases were both statistically significant ($p<0.05$) with r^2 values of 0.739 and 0.670, respectively. A quite strong negative curvilinear correlation ($r^2=0.658$) was observed for the May 30 release. For the June 19 release there was no apparent correlation between size and percent returns (curvilinear fit, $r^2=0.270$).

b) Catch

Adult contribution to the combined fisheries (sport plus commercial) was estimated at 4,944 fish[2] (Tables 1a-4a). This represents 79.7% of the total returns of 6,200 adults to the catch plus escapement. Juveniles released on April 20 and June 19 contributed least to the catch - 530 fish or 1.68% of the juveniles released and 765 fish or 2.26%, respectively. The contribution from the May 10 release was 1,311 fish or 3.86%. Highest catch was realized from the May 30 release - 2,338 fish or 7.15% of the juveniles released.

For the April 20 release there was a weak negative curvilinear relationship ($r^2=0.198$) between juvenile size and percent returns to the combined fisheries (Fig. 4, Table 5). For the May 10 release there was a strong tendency for small juveniles to produce higher returns than fish of larger categories ($r^2=0.679$). Results for the May 30 release are best

---

[1]Returns discussed here are for combined male and female returns. Returns to the escapement by sex are presented in Section B. Sex observations on catch were insufficient to allow male-female breakdown.

[2]This includes 39 fish assigned as adults from catches of 2-yr olds made in 1980, the year of release. All others were adults caught as 3-yr olds in 1981.

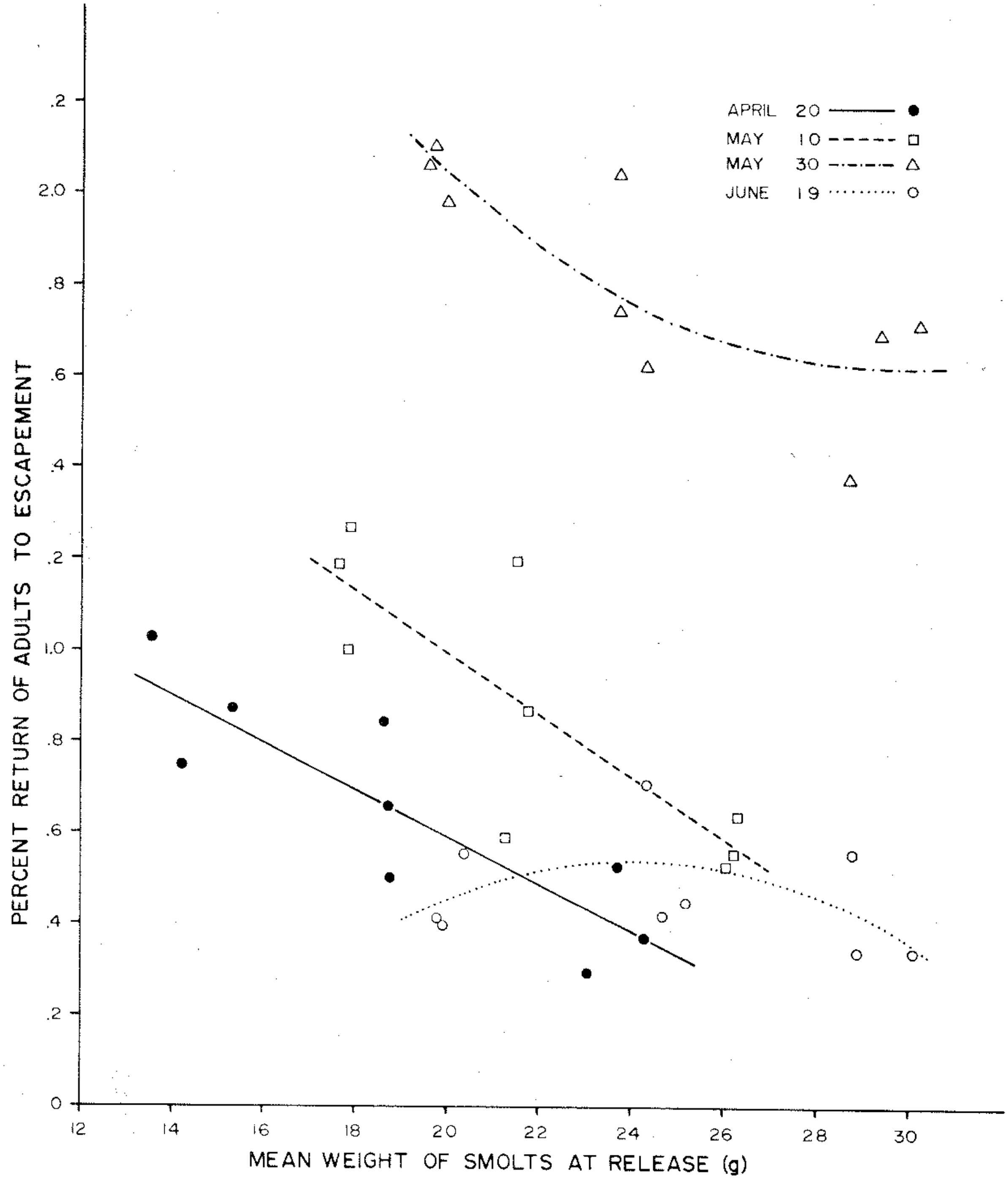

Fig. 3. Mean weights of juveniles (sexes combined) in release samples and adult returns (sexes combined) to escapement as a percentage of juveniles released for each group.

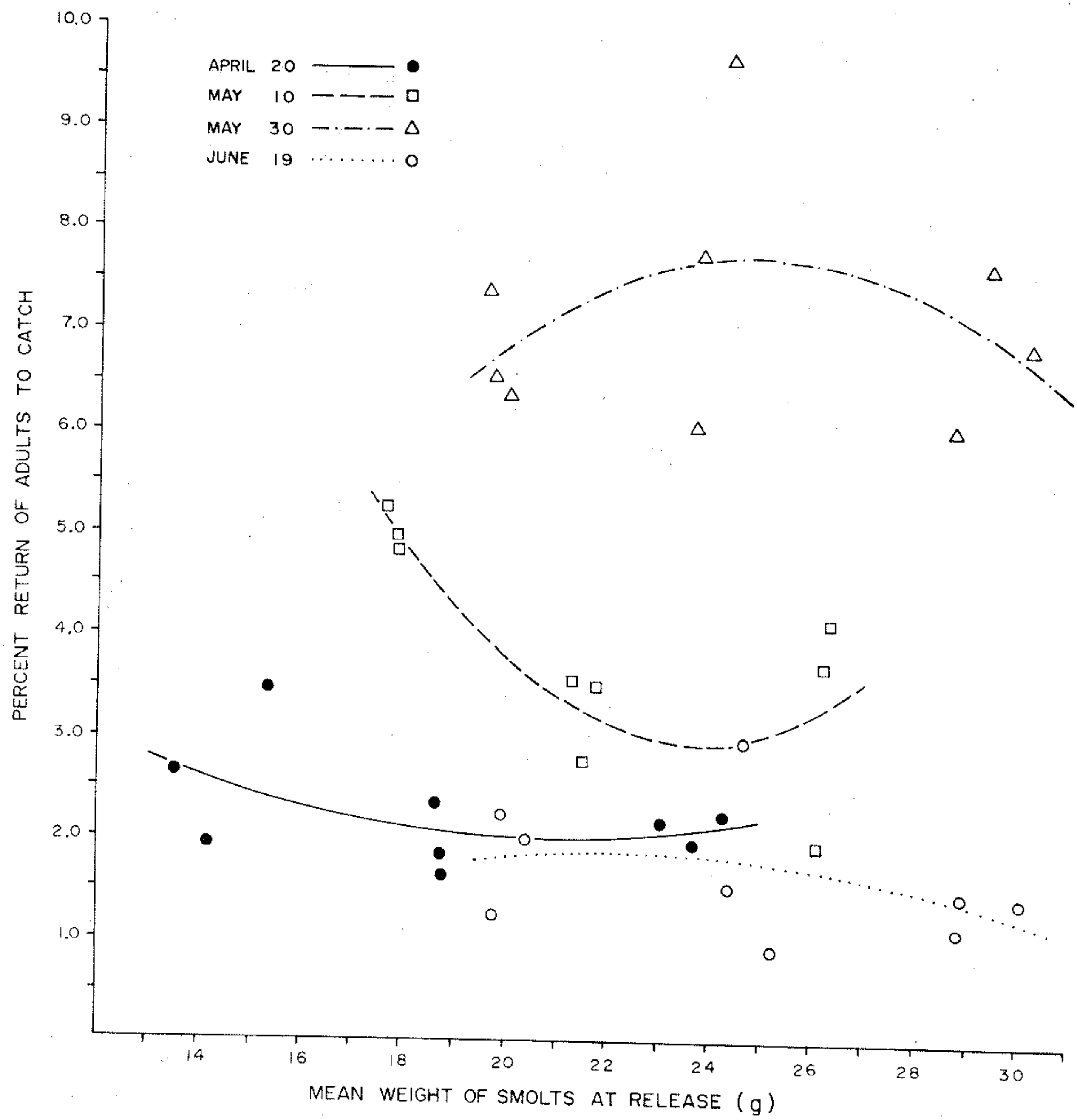

Fig. 4. Mean weights of juveniles (sexes combined) in release samples and adult returns (sexes combined) to catch as a percentage of juveniles released for each group.

described by a curvilinear line which suggests highest returns from medium sized juveniles; however, the 3 replicates for this size category show poor agreement and the fit of the line is consequently poor (r^2=0.148). For the June 19 release, there is little indication of any effect of juvenile size on adult returns (r^2=0.127).

For the April 20 and May 30 releases in particular, the shapes of the curves best describing the relationships between juvenile size and percent return of adults differ considerably from those based on escapement counts (Fig. 3, previous section). In the escapement, markedly higher returns were observed from small category juveniles (relative to the other size categories), while in the catch, adults from medium and large category juveniles are represented almost as heavily or even more heavily than adults from small category juveniles. One way these differences could arise would be through size selection in the fishery. To examine this possibility the following tables were prepared. They summarize the numbers of adults recovered in the catch and escapement by time and size categories (excluding the few assigned from catches the previous year) and also show catches expressed as percentages of total returns.

a) By release

Release	Size	Returns			Catch as a percentage of total return
		Catch	Escape	Total	
April 20	Small	300	99	399	75.2
	Medium	221	75	296	74.7
	Large	221	41	262	84.4
	Total	742	215	957	77.5
May 10	Small	569	131	700	81.3
	Medium	366	99	465	78.7
	Large	364	64	428	85.0
	Total	1299	294	1593	81.5
May 30	Small	739	224	963	76.7
	Medium	850	196	1046	81.3
	Large	745	173	918	81.2
	Total	2334	593	2927	79.7
June 19	Small	191	47	238	80.3
	Medium	193	56	249	77.5
	Large	146	44	190	76.8
	Total	530	147	677	78.3
Combined		4905	1249	6154	79.7

b) Releases pooled

Release	Size	Returns			Catch as a percentage of total return
		Catch	Escape	Total	
	small	1799	501	2300	78.2
	medium	1630	426	2056	79.3
	large	1476	322	1798	82.1
Combined		4905	1249	6154	79.7

The data of the above tables were subjected to a 3-way (time of release X juvenile size X place of recovery[1]) contingency table analysis and Pearson Chi-square analyses to test for differences in the catch : escapement ratios between the various groups. A significance level of .05 was used in all tests.

The three-way analysis indicated that while there were significant differences in the ratios, these differences were not consistently associated with either juvenile size or time of release. Subsequent Chi-square analysis showed that within each of the first three releases there were significant ratio differences associated with juvenile size (p=.008, .050, and .018, respectively). For the first two releases these differences appear to be attributable to higher catches of adults from large category juveniles; for the third release catches of adults from both large and medium juveniles are higher in comparison with those from small juveniles. Catch : escapement ratios for the three sizes in the fourth release were not significantly different (p=.650). Within the small size category there was a barely significant difference in recovery ratios between releases (p=.050). Within the medium and large categories the ratios did not differ significantly between releases (p=.075 and .056, respectively).

Overall, there was a highly significant difference (p=.008) in the catch : escapement ratios associated with juvenile size (releases combined), with higher catches of adults indicated for larger juveniles. The catch: escapement ratios between releases (sizes combined) were not significantly different (p=.073).

It is concluded that there were significant differences in the proportions of returning adults recovered in the fishery, with selection for fish resulting from larger juveniles of the first three releases. These differences are consistent with the differences in the relative contributions of the juvenile size categories to adult returns as observed in either the catch or escapement; adults originating from smaller juveniles were apparently less susceptible to the fishery and are thus represented more heavily in the escapement.

---

[1]i.e. catch or escapement.

c) Catch plus escapement

An estimated total of 6,200 adults was recovered in the catch plus escapement (Tables 1a-4a). Combined returns (9 groups) for a common release date were highest for the May 30 release - 8.97%. This was 1.9 times the next highest return, that from the May 10 release - 4.74%. Returns for the April 20 and June 19 releases were 2.91% and 2.14% respectively.

For the April 20 release there was a slight negative curvilinear trend between juvenile size and percent return (Fig. 5, Table 5). This correlation was quite weak with an r^2 value of 0.384. For the May 10 release there was a strong tendency for small juveniles to produce higher returns than fish of larger size categories. The r^2 value of 0.766 indicates a relatively close fit to the curvilinear line best describing the data. For the May 30 and June 19 releases there was very little effect of juvenile size on adult returns (r^2 values of 0.136 and 0.191 respectively).

As discussed previously under fishery recoveries, there was apparent selection by the fishery for adults originating from larger juveniles. This resulted in different estimates of the effect of juvenile size depending on whether escapement figures or catch figures were used. Since approximately 80% of the adults were recovered in the fishery, the relationship between juvenile size and adult returns using combined returns (escapement plus catch) is much closer to that observed using catch figures than to that based on escapement returns.

Response surface analysis

Response surface analysis of the total (catch + escapement) adult returns is shown in Fig. 6. The predicted maximum return at the center of the surface is 11.2% for release of 15.7 g juveniles on June 4 (day 156). However, it must be pointed out that although the analysis predicts a small (and apparently reasonable) optimum release weight, this weight falls outside the actual data range for fish released at about this time and should therefore be regarded with some caution ("maxima outside the tested range have no valid interpretation except as indicators of trend"; from Bilton et al. 1982). Of particular interest on the surface is the tendency for the % return contours to parallel the weight axis. This means that the effects of size at release are in general quite minor, since in ascending (or descending) the weight axis on any date, the returns tend to remain on the same % contour. The roughly horizontal dotted line passing through the surface center is the line of optimum release weight, i.e. for any given date (x axis intercept) the corresponding weight (y axis intercept as determined by this line) is the juvenile weight for which maximum adult returns are predicted. It can be seen that the optimum release weight changes very little with time. Note that except for the first release this line falls below the tested weight range and therefore is predictive only.

The surface also indicates a strong effect of time of release on returns. Up until the optimum release date (June 4), the % return contours are quite widely separated, showing a slow gradual increase in returns with advancing date. Beyond the optimum date returns begin to decrease and after about June 11 (day 163) drop extremely rapidly as indicated by the very close

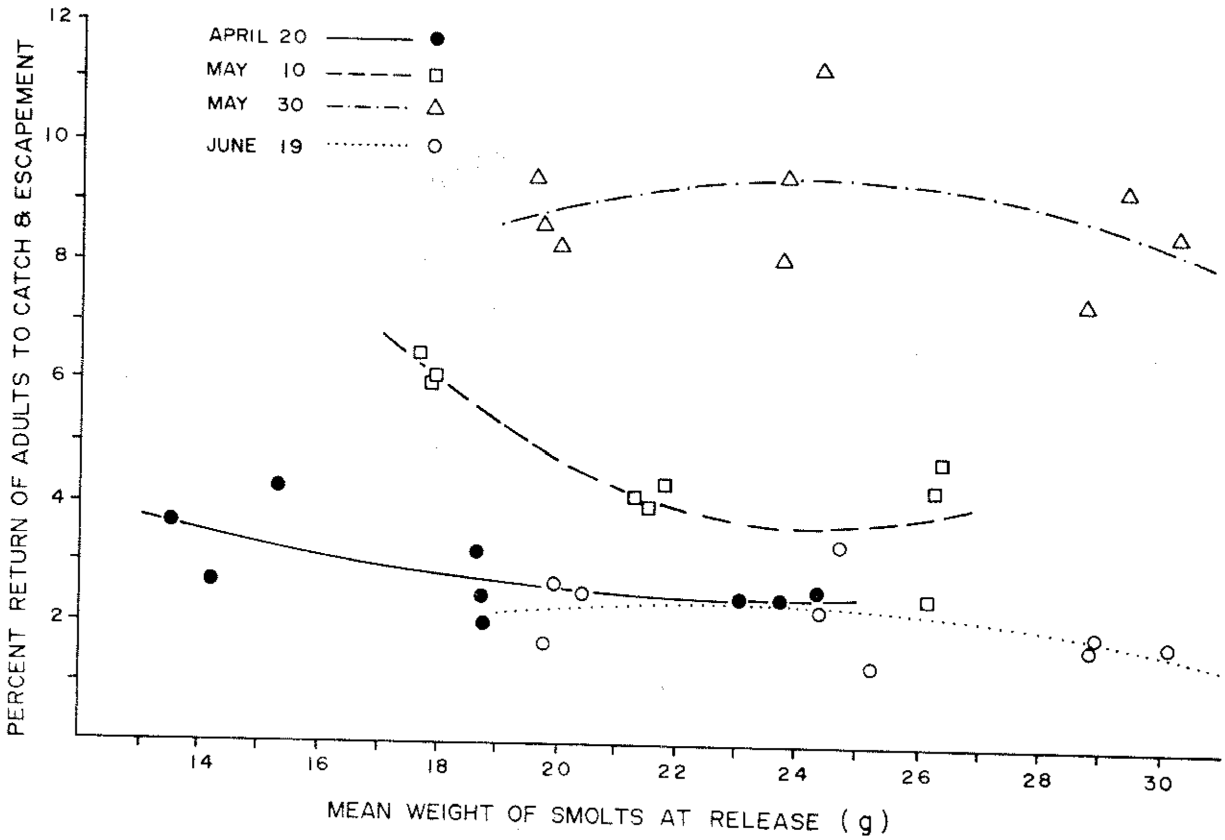

Fig. 5. Mean weights of juveniles (sexes combined) in release samples and total adult returns (sexes combined, catch plus escapement) as a percentage of juveniles released for each group.

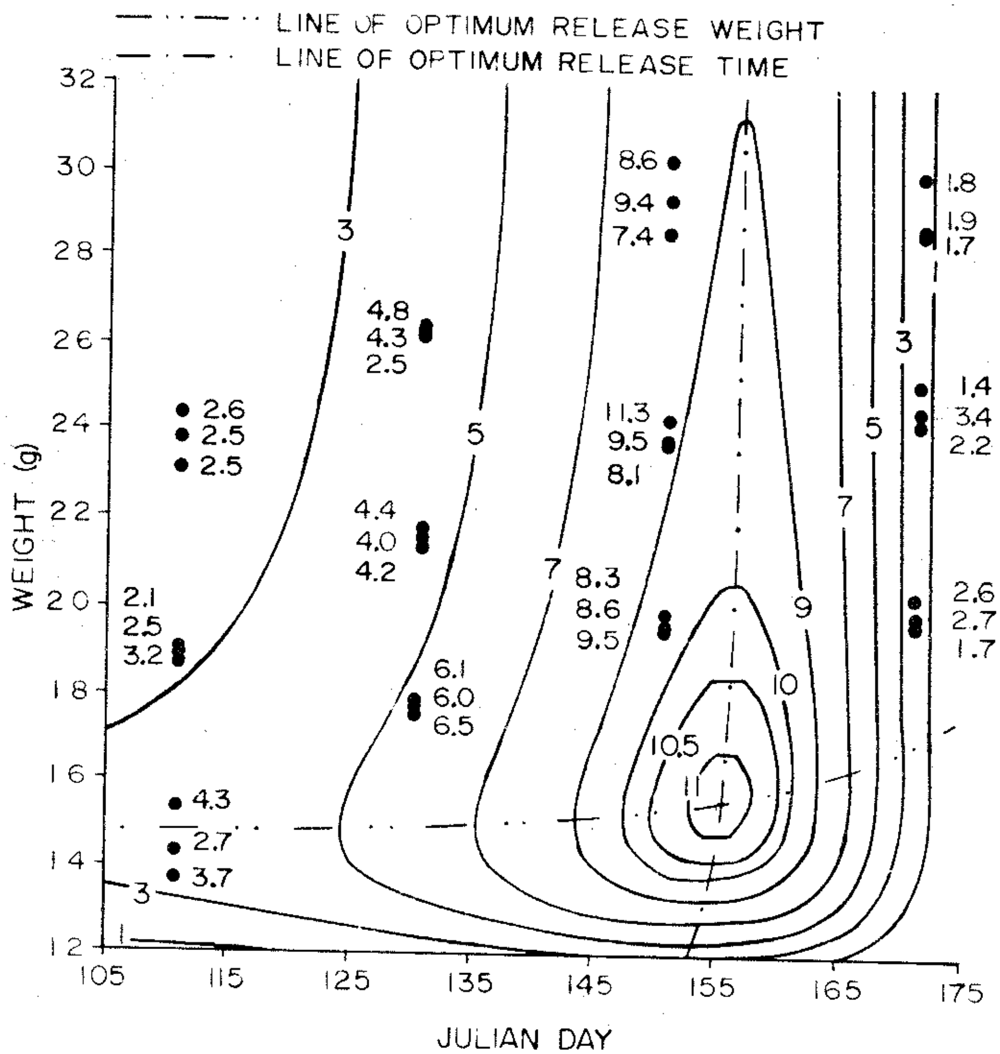

Fig. 6. Response surface showing influence of time at release (Julian days) and mean size at release (g) of juvenile coho on returns of adults (catch plust escapement) as a percentage of juveniles released. Contours indicate the percent return of adults from release of juveniles for various size-time combinations. Predicted maximum return is indicated where the ridges of optimum release weight and release time intersect e.g. Julian day 155.5, mean weight 15.66 g. The solid points indicate actual percent returns of adults from experimental groups released.

contours. The roughly vertical dotted line through the surface center is analogous to the line of optimum release weight. However, it it in this case represents the line of optimum release date, i.e. for juveniles of a given weight, maximum returns are predicted from release on the date determined by this line. This line indicates that the optimum date is essentially the same regardless of weight.

Tests of significance of the contribution of each factor to the response surface model support the preceding interpretations. The contribution of time was found to be highly significant ($F \approx 62.6$, $dF=4,25$, $p<.009$). The contribution of size was marginally non-significant ($F \approx 2.58$, $dF=4.25$, $p \approx .06$).

Jack plus adult returns

a) Escapement

A total of 1,868 jacks plus adults was recovered in the escapement to the hatchery (Tables 1a-4a). Combined returns (9 groups) for a common release date were highest for the May 30 release - 822 fish or 2.70%. Second highest returns were from the May 10 release - 489 fish or 1.44%. Returns for the April 20 and June 19 releases were 330 fish or 0.97% and 167 fish or 0.53%, respectively.

The relationships between release weight and jack plus adult escapement returns for the May 10 and May 30 releases (Fig. 7; Table 5) are similar to the relationships observed for jack returns alone, i.e. returns increase substantially with increasing size. These similarities are due to the high jack production from medium and large category juveniles of these releases, and the subsequent heavy contribution of jacks to the jack plus adult escapement totals. The relationships between release weight and jack plus adult returns for both the April 20 and June 19 releases ate best described as intermediate between those based on jack or adult returns alone, with very little effect of size.

b) Catch

Since only 13 jacks were estimated to have been recovered in the fishery, jack plus adult catch was negligibly different from that already described for adults alone.

c) Catch + escapement

A total of 6,825 jacks plus adults was recovered in the catch plus escapement (Tables 1a-4a). Combined returns (9 groups) for a common date were highest for the May 30 release - 3,225 fish or 9.86%. Second highest returns were from the May 10 release - 1,801 fish or 5.30%. Returns for the April 20 and June 19 releases were 1,102 fish or 3.25% and and 697 fish or 2.21%, respectively.

The relationships between release weight and jack plus adult returns (Fig. 8; Table 5) for the April 20 and June 19 releases are very similar to those based on adults alone (Fig. 5), with little effect of size except for

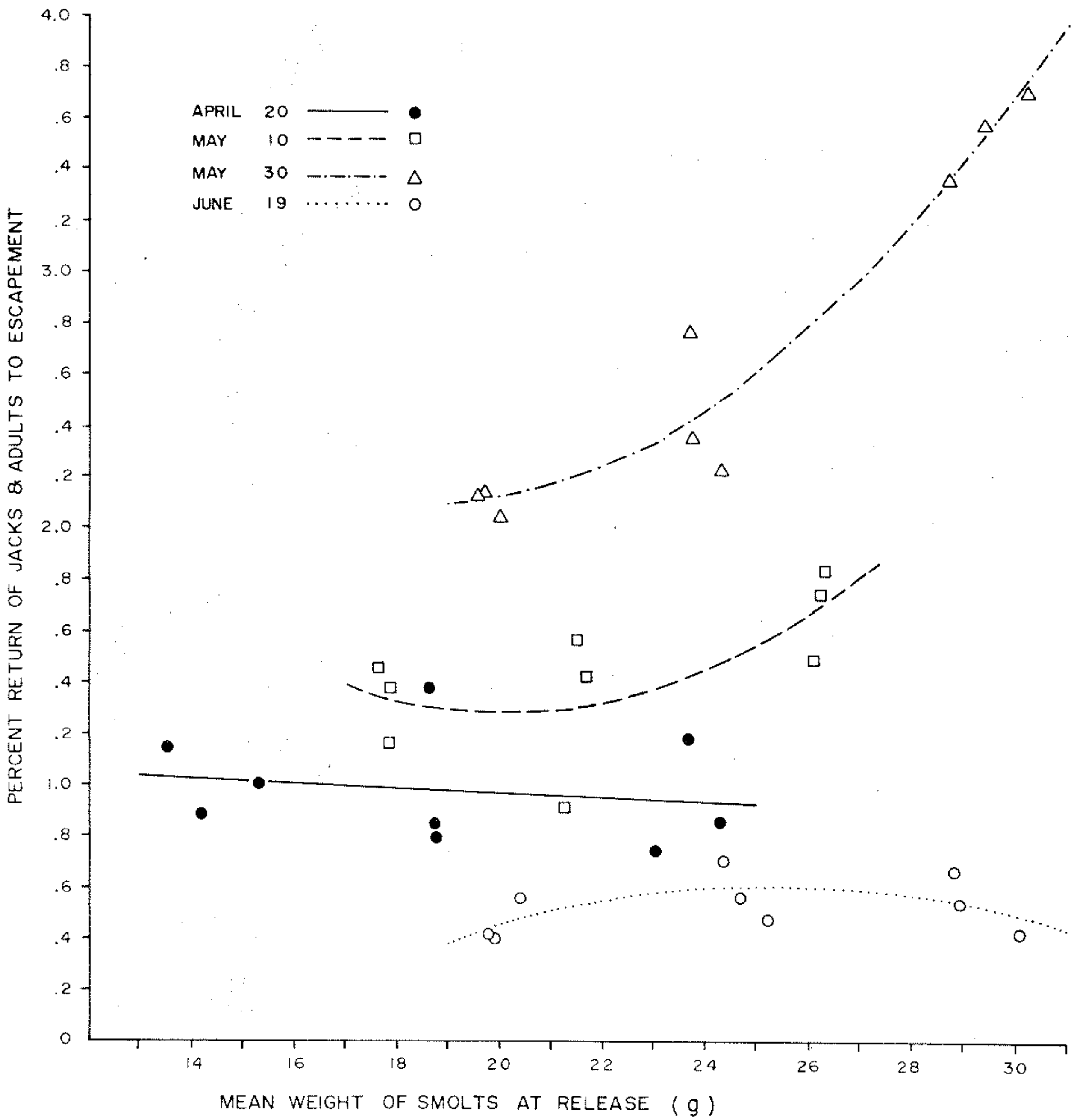

Fig. 7. Mean weights of juveniles (sexes combined) in release samples and returns to escapement only of jacks plus adults (sexes combined) as a percentage of juveniles released for each group.

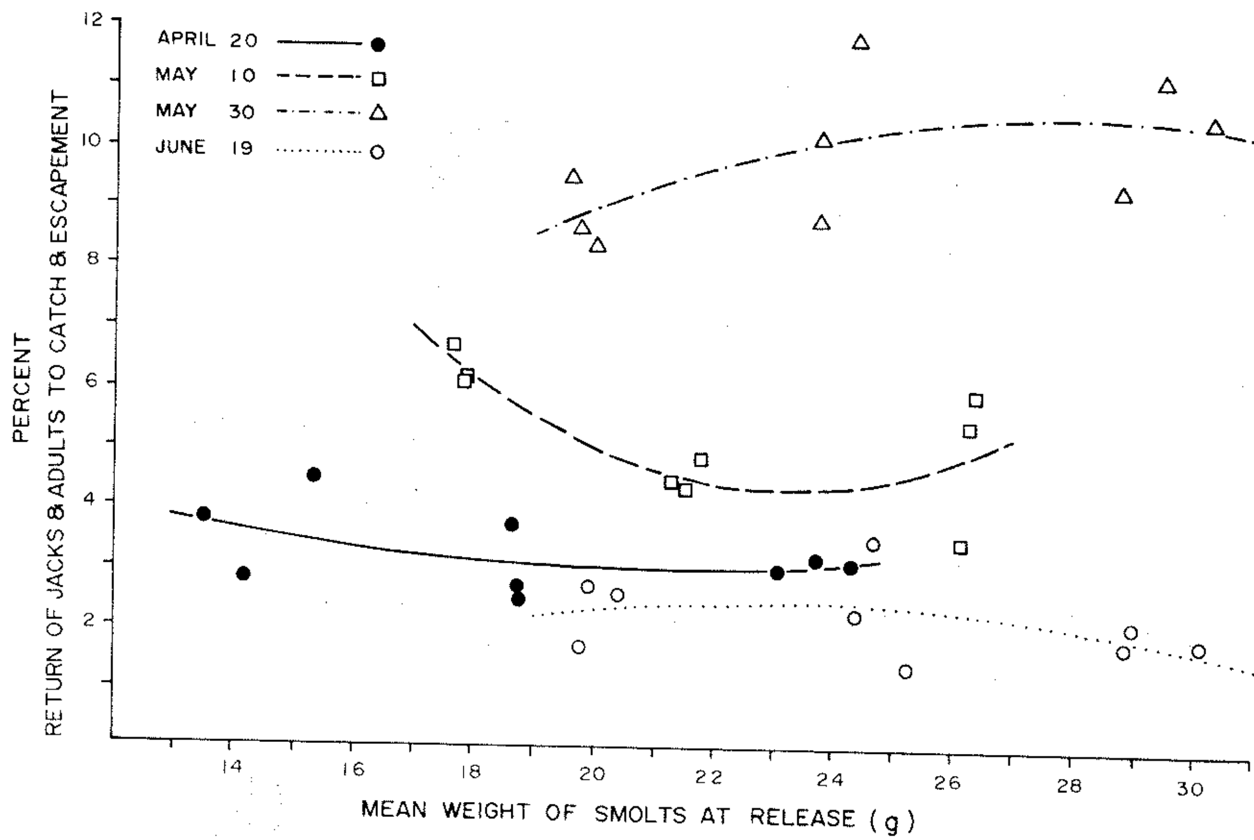

Fig. 8. Mean weights of juveniles (sexes combined) in release samples and total returns (catch plus escapement) of jacks plus adults (sexes combined) as a percentage of juveniles released for each group.

a slight indication of higher returns from small juveniles (r^2 = 0.168 and 0.135, respectively). For the May 10 and May 30 releases the very high jack production from larger juveniles of these releases is reflected in the jack plus adult totals, altering the size effects observed based on adult returns alone. Thus, for the May 30 release jack plus adult returns were highest for medium or large category fish (r^2 = .389) while adult returns alone indicated little size effect. For the May 10 release jack plus adult returns are highest for small category fish, as was observed for adults alone, however returns of large fish relative to medium fish were higher (r^2 = .600).

d) Response surface analysis

Response surface analysis of the total (fishery plus escapement) returns of jacks plus adults is shown in Figure 9. The center of this surface (at the intersection of the broken lines) has a different significance here than in the surface for adult returns alone (Fig. 6). In the adult surface the response center represents an optimum combination of time and size, with the % return contours increasing in magnitude as they converge on the center from any direction (the surface can be thought of as a conical mountain, with the center representing the highest elevation). This is not so for the jack plus adult surface where the response center represents a "saddle" point. Here the % return contours again increase in magnitude as they approach the center from either direction along the time axis; however, they decrease in magnitude as they approach the center from either direction along the weight axis. The center can thus be thought of as a low point (for weight) at the approximate center of a high ridge (for time). In the adult surface there is a "ridge" of optimum release weight; here the analogous line can be thought of as representing a "valley". For any given release date minimum returns are predicted from juveniles of the weight indicated by this line. The line of optimum release time has the same significance here as it did for adults only, again indicating a "ridge" of optimum time for release, with juveniles of a given weight producing highest returns when released on the date indicated by the line.

The effects of time of release are quite similar to those observed for adults alone, with the % return contours initially quite widely separated but showing a slow but steady increase in magnitude with advancing date. After passing the optimum date (about June 4 or day 156) returns begin to decline and drop very rapidly from about June 11 (day 163). The manner in which the % contours tend to parallel the weight axis (except in the immediate area of optimum time of release) indicates that, as for adult only returns, the effects of release weight are generally minor. When tested, the contribution of size to the response surface model was found to be statistically insignificant ($F \approx 0.54$, $dF=4,25$, $p=.71$).

Although no optimum time-size combination is defined on the surface, the line of optimum time of release indicates that the optimum release date is essentially June 4 for juveniles of any release weight. On this date, minimum returns of 10% are predicted for 24.4 g juveniles. The possibility of slightly higher returns with increasing or decreasing weight on either side of this point is suggested. At the approximate limits of the data range returns of about 10.5% are indicated for release of either 20 g or 30 g fish.

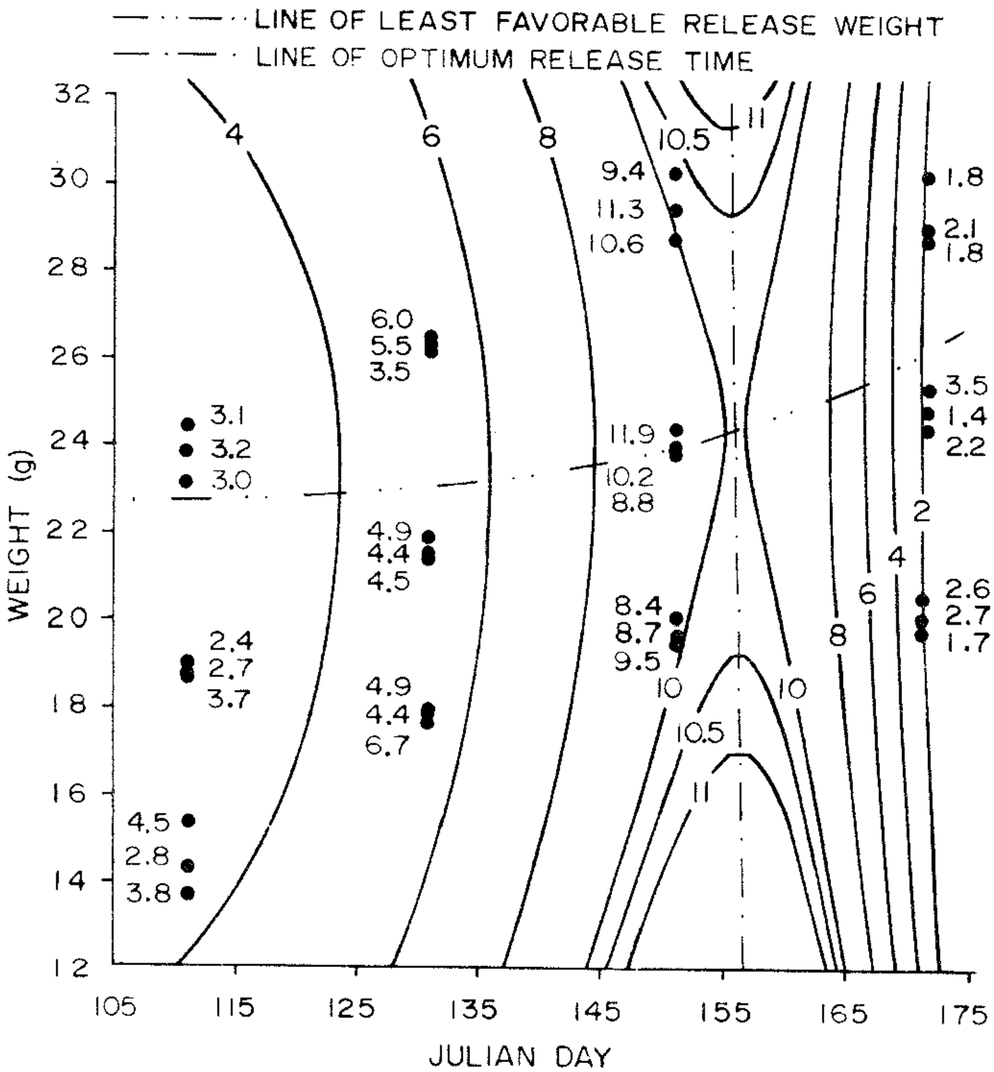

Fig. 9. Response surface showing influence of time at release (Julian days) and mean size at release (a) of juvenile coho on returns of jacks plus adults (catch plus escapement) as a percentage of juveniles released. Contours indicate the percent return of jacks plus adults from release of juveniles for various time-size combinations. The solid points indicate actual percent returns of jacks plus adults from experimental groups released.

Jacks as a proportion of total returns

To aid in examining the factors influencing life history types (i.e., jack or adult at maturity) the proportions that jacks represented in the total returns for each group (jacks plus adult, catch plus escapement) were calculated. Numbers of each type are given in Tables 1a-4a.

Both size and time of release were found to have a marked effect on the proportion returning as jacks (Fig. 10, Table 5). Within each release there was a strong positive relationship between juvenile weight and the proportion of jacks. The r^2 values for the slightly curvilinear relationships of the May 10, May 30, and June 19 releases were 0.927, 0.942, and 0.720, respectively. The linear relationship for the April 20 release was significant at $p<0.001$. The relative heights of the regression lines for each release show that for juveniles of a given size, the proportion returning as jacks decreases as releases are made progressively later in the season. For example, the predicted proportion of jacks in the returns from 22 g fish released on each of the four dates are: April 20 - 17%; May 10 - 10%; May 30 - 4%; and June 19 - 1%. In summary, the data indicate higher proportions of jacks result from early release of large juveniles.

B. BIOLOGICAL OBSERVATIONS OF ESCAPEMENT RETURNS (INCLUDING PERCENT RETURNS BY SEX)

Percent returns of males and females

The relationships between juvenile weights and returns to the escapement were analysed separately for each sex (Figs. 11-12: Table 5). These relationships were very similar to each other and also to that already presented for the combined sexes (see Percent returns, Fig. 3). For both males and females, returns were highest from the May 30 release, followed in decreasing order by the May 10, April 20, and June 19 releases. For the June 19 release there is very little effect of size indicated for either sex. For the April 20 and May 30 releases higher returns from smaller juveniles are indicated for both sexes. This same size effect is also evident for males of the May 10 release. However, the relationship for females of this release is confused by the high variability in returns from medium sized juveniles.

Sex ratios of adult escapement returns

The sex ratio of adult escapement returns (replicates combined) are shown in the following table. Values in parentheses have been adjusted for jacks. This was done to allow more valid comparison of the adult sex ratios with the sex ratio of the juveniles at release - since jacks are all males, adult returns without this adjustment are biased toward a higher proportion of females. The adjusted values were obtained by first estimating the number of adult males that would have resulted had the observed jacks not matured in their first year at sea. This was done by subtracting mortality estimates for

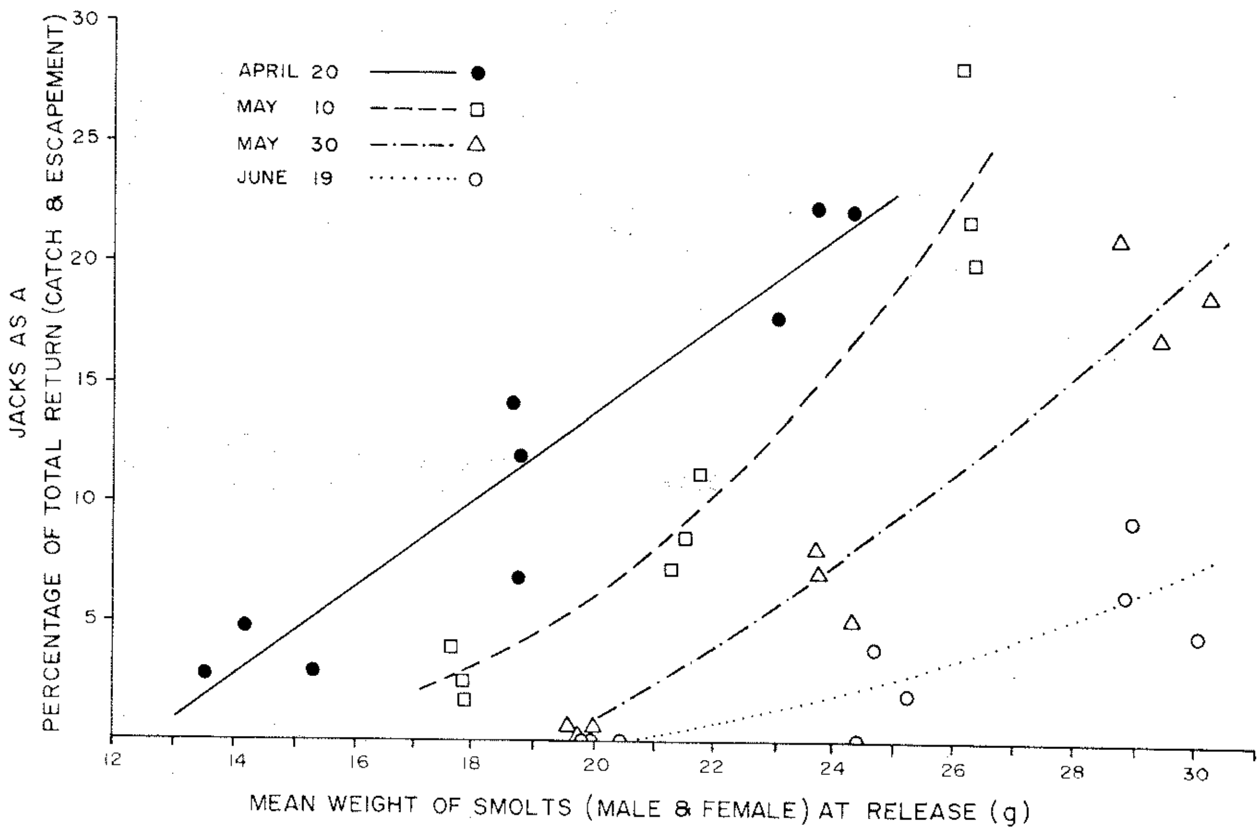

Fig. 10. Mean weights of juveniles (sexes combined) in release samples and jack returns as a percentage of total return (sexes combined, catch plus escapement) for each group.

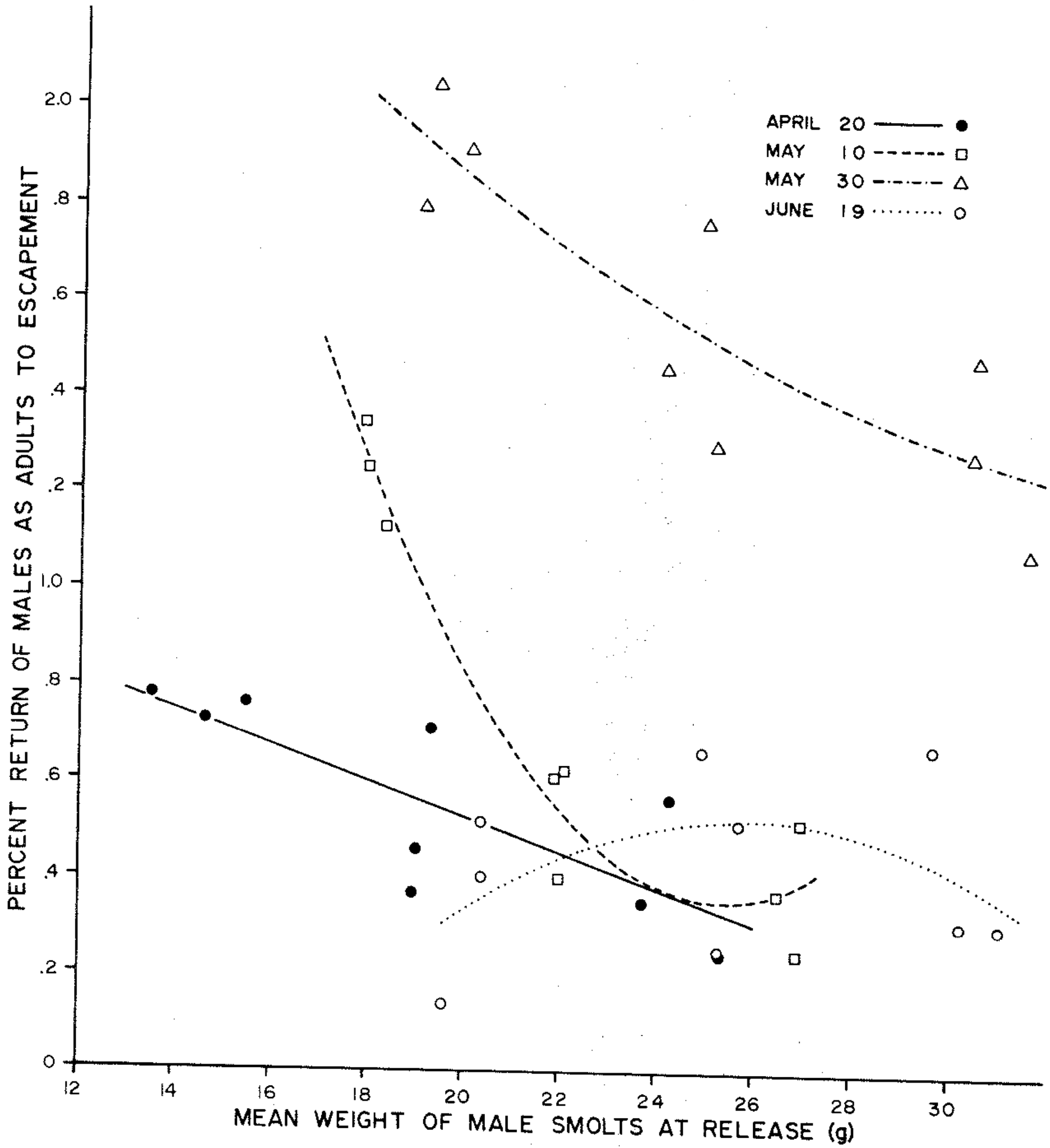

Fig. 11. Mean weights of female juveniles in release samples and returns of adult males as a percentage of male juveniles released for each group; escapement returns only.

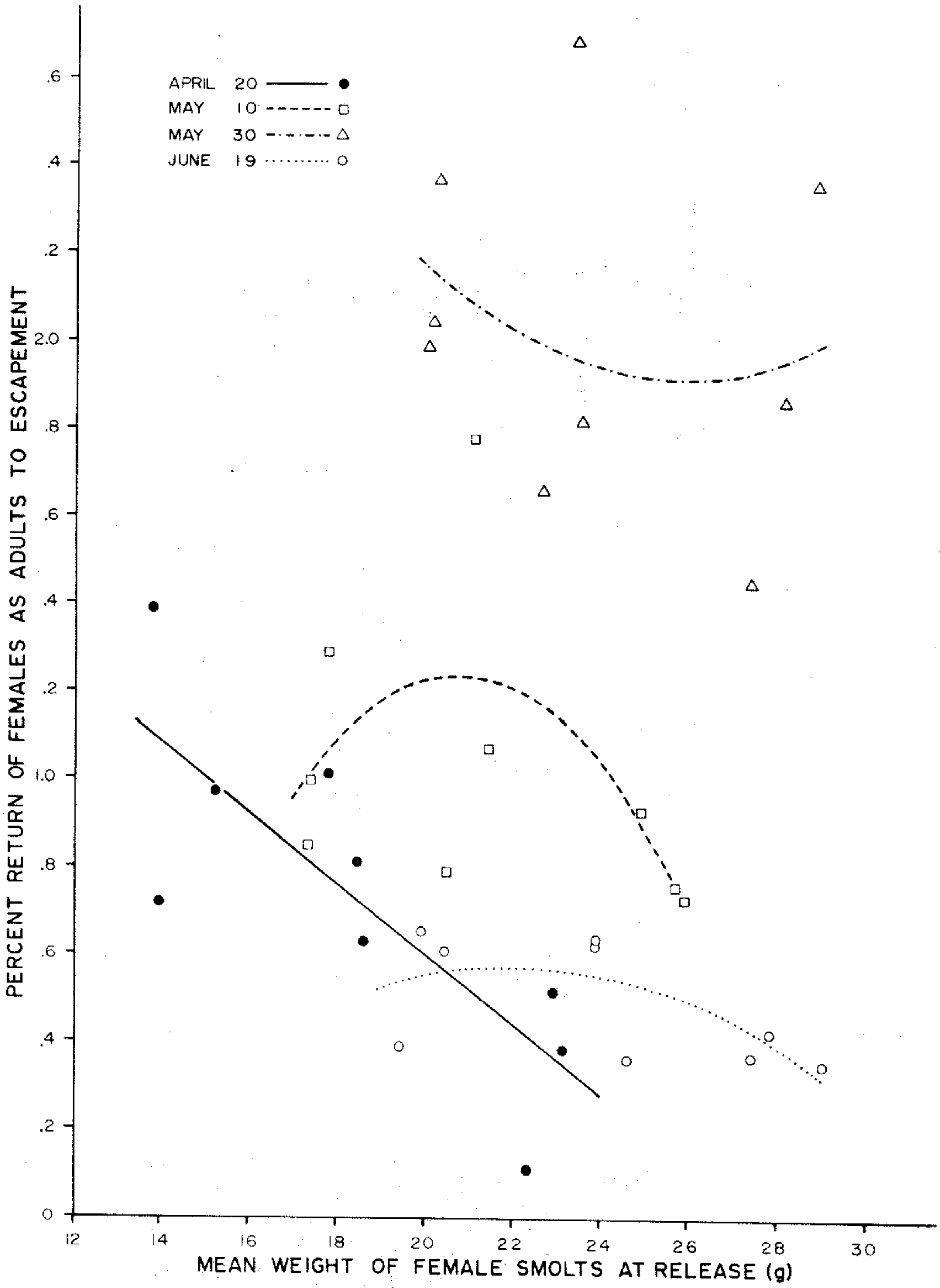

Fig. 12. Mean weights of female juveniles in release samples and returns of adult females as a percentage of female juveniles for each group; escapement returns only.

an additional year of ocean residence from the numbers of jacks recovered for each group[1]. The resulting theoretical numbers of surviving male adults were then divided into catch and escapement portions, using the observed adult catch : escapement ratio for each group. The escapement portion estimate was then added to the observed adult male escapement count.

Release	Size	Sex			Proportion male
		Male	Female	Male + Female	
April 20 (1)	small	42 (44)	56	98 (100)	.43 (.44)
	medium	31 (38)	44	75 (82)	.41 (.46)
	large	23 (30)	18	41 (48)	.56 (.63)
	Total	96 (112)	118	214 (230)	.45 (.49)
May 10 (2)	small	78 (81)	53	131 (134)	.60 (.60)
	medium	32 (39)	66	98 (105)	.33 (.37)
	large	24 (37)	39	63 (76)	.38 (.49)
	Total	134 (157)	158	292 (315)	.46 (.50)
May 30 (3)	small	109 (110)	112	221 (222)	.49 (.50)
	medium	83 (92)	110	193 (202)	.43 (.46)
	large	70 (97)	103	173 (200)	.40 (.49)
	Total	262 (299)	325	587 (624)	.45 (.48)
June 19 (4)	small	20 (20)	27	47 (47)	.43 (.43)
	medium	26 (27)	28	54 (55)	.48 (.49)
	large	25 (27)	19	44 (46)	.57 (.59)
	Total	71 (74)	74	145 (148)	.49 (.50)
Grand Total		563 (642)	675	1238 (1317)	.45 (.49)

The data of the above table were subjected to a 3-way (time of release X juvenile size X sex) contingency table analysis and Chi-square analyses to test uniformity of the sex ratio. This was done on both observed returns and on the returns with adjustment for jacks.

a) Data without adjustment for jacks

Three-way analysis indicated that while there were significant differences in the sex ratio, these differences were not consistently associated with either size or time. Subsequent Chi-square analyses showed

[1]Mortality was estimated using monthly instantaneous natural mortality rates derived from a Puget Sound coho study, as described by Ricker (1976).

that within 3 of the releases (1,3,4) there were no significant differences associated with juvenile size. For the second release, however, there was a highly significant difference in sex ratios ($p<.001$) with a high proportion of males in returns from small juveniles. Within each size category, among releases, the sex ratios differed significantly for small category juveniles only ($p=.049$), with a high proportion of males in returns from the second release.

Overall, the sex ratios (releases combined) differed significantly among sizes ($p=.019$) with a high proportion of males in returns from small juveniles. There were no significant differences in sex ratio among releases (sizes combined).

b) Data with adjustment for jacks

Allowance for jacks altered the analysis only slightly. Three-way analysis again indicated differences in sex ratio that were not consistently associated with either time or size. Within releases,there was still a significant size-associated difference ($p=.002$) for the second release only, with a high proportion of males still evident in returns from small category juveniles. Within each size category, sex ratios again differed significantly between releases for returns from small juveniles only ($p=.041$), again with a high proportion of males in returns from the second release.

Overall, there was again no significant difference in the sex ratios among releases (sizes combined). However, while the unadjusted data indicated overall differences associated with size (releases combined), these differences were not quite significant using the adjusted data ($p=.056$).

For both the unadjusted and adjusted data, the conclusions are that the sex ratios of the various groups in the escapement returns were uniform, with the exception of the returns from small category juveniles of the second release, which contained a significantly higher proportion of males than did other groups.

Excluding small category fish of the second release, the observed overall sex ratio of the escapement returns was 485 : 622 , or 43.8% male. This was tested (Chi-square) against the juvenile release sample ratio (which was uniform over all groups) of 2048♂: 1884♀, or 52.1%. The two ratios were found to be significantly different ($p<.001$). With adjustment for jacks, the return ratio was estimated as 561♂: 622♀, or 47.4% male, still significantly lower in males ($p=.005$) than the release ratio.

The sex ratio of returns from small category, second release juveniles was tested separately against the release ratio of 52.1%. Neither the observed ratio (78♂: 53♀, or 59.5% male) nor the adjusted ratio (81♂: 53♀, or 60.5% male) was found to be significantly different from the release ratio ($p=.093$ and $p=.057$, respectively).

In summary, examination of sex ratios in escapement returns indicates that, except for small category fish of the second release, the escapement ratios were equivalent and had a lower proportion of males than did the juveniles at time of release.

Size of returning fish[1]

a) Jacks

The average weight of jacks resulting from each release was inversely related to time of release, with jacks from earlier releases being larger on return. These average weights were April 20 - 0.520 kg; May 10 - 0.446 kg; May 30 - 0.351 kg; and June 19 - 0.309 kg (Tables 1b-4b, Fig. 13).

For the April 20 release there was a significant ($p<.05$) positive linear correlation (r^2=0.831) between the average weights of male juveniles and the average weights of returning jacks (Fig. 13; table 5). This tendency for larger juveniles to produce larger jacks was evident to a lesser degree in the May 10 and May 30 releases. The r^2 values of 0.691 and 0.664 respectively, indicate reasonable curvilinear fits to the data. The number of jacks resulting from the June 19 release was insufficient to allow similar comparisons.

b) Adults

As with the jacks, the average weights of adults in the escapement were inversely related to the time of release, those from earlier releases being larger on return. This was true for both sexes (Tables 1b-4b). For males, the average adult weight for returns from each release were April 20 - 3.00 kg; May 10 - 2.44 kg; May 30 - 2.03 kg; and June 19 - 1.60 kg. For females, the equivalent weights were 3.17, 2.87, 2.51, and 2.25 kg. The average weights of females were greater than those of males in all cases. For sexes combined, the average weights were 3.08, 2.68, 2.29, and 1.93 kg, in order of releases.

For males of the April 20 release there was a slightly curvilinear positive relationship between male juvenile release weight and weight of male adults on return (Fig. 14, Table 5, r^2=0.778). For the three later releases, greater adult weights are indicated from either medium or large juveniles (r^2 values of .149, .498, .796, in order of releases).

For females of the April 30, May 10, and June 19 releases (Fig. 15; Table 5) the largest adults tended to be from medium-sized juveniles (r^2 values of .700, .692, and .708, respectively). For the May 30 release there was a weak indication of slightly larger adults from larger juveniles (r^2=.318).

The relationships between juvenile size and weights of adults were also examined for the sexes combined (Fig. 16, Table 5). The curvilinear relationships for the April 20 and May 10 releases (r^2=.654 and .736, respectively) indicate returns of larger adults from either medium or large juveniles. For both the May 30 and June 19 releases there were weak indications of slightly heavier adults returning from medium sized juveniles (r^2=.530 and .269, respectively).

---

[1]Length observations are included in Tables 1b-4b but are not discussed in this paper since weight is the more important measure.

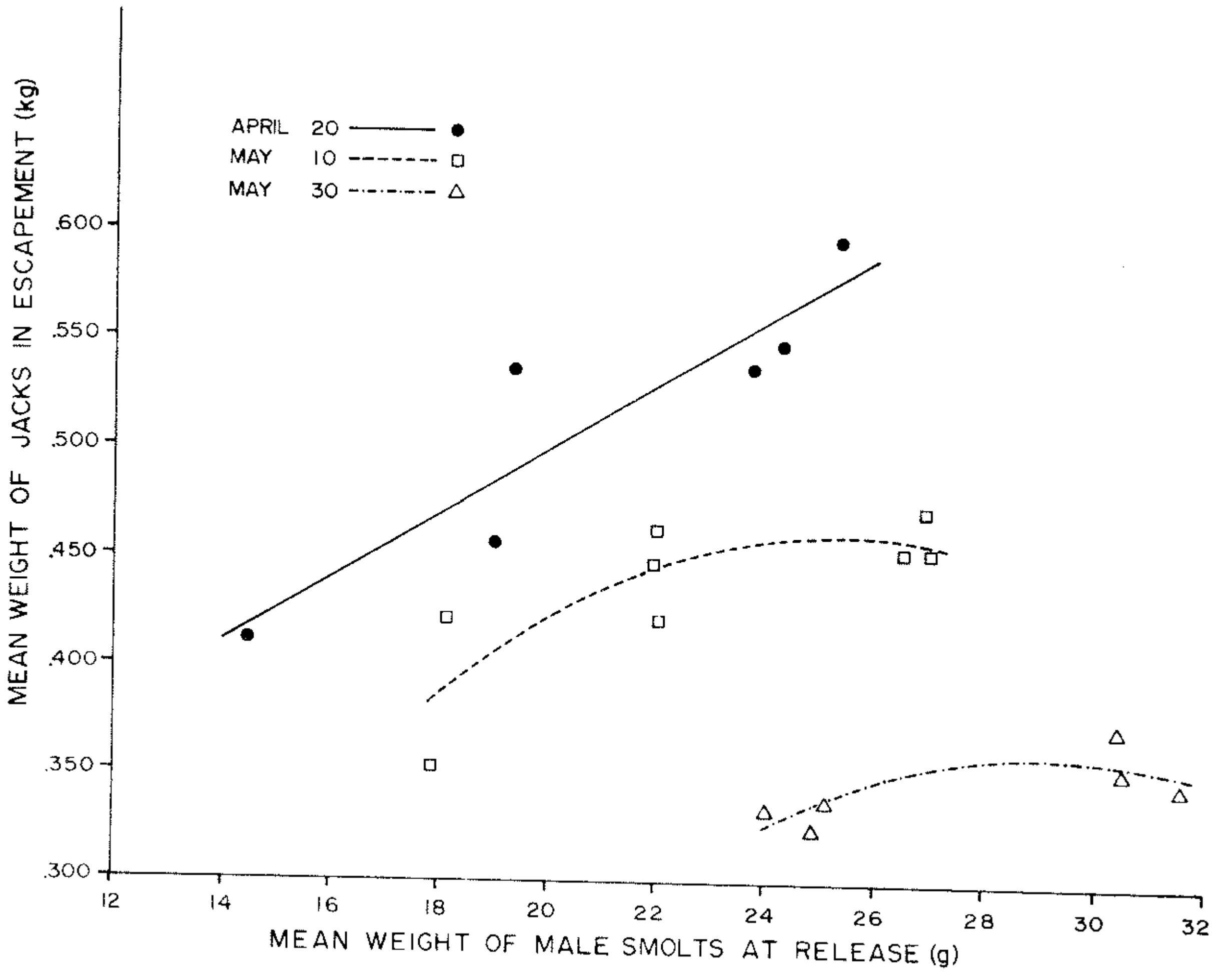

Fig. 13. Mean weights of male juveniles in release samples and the mean weight of jacks originating from each group in the escapement.

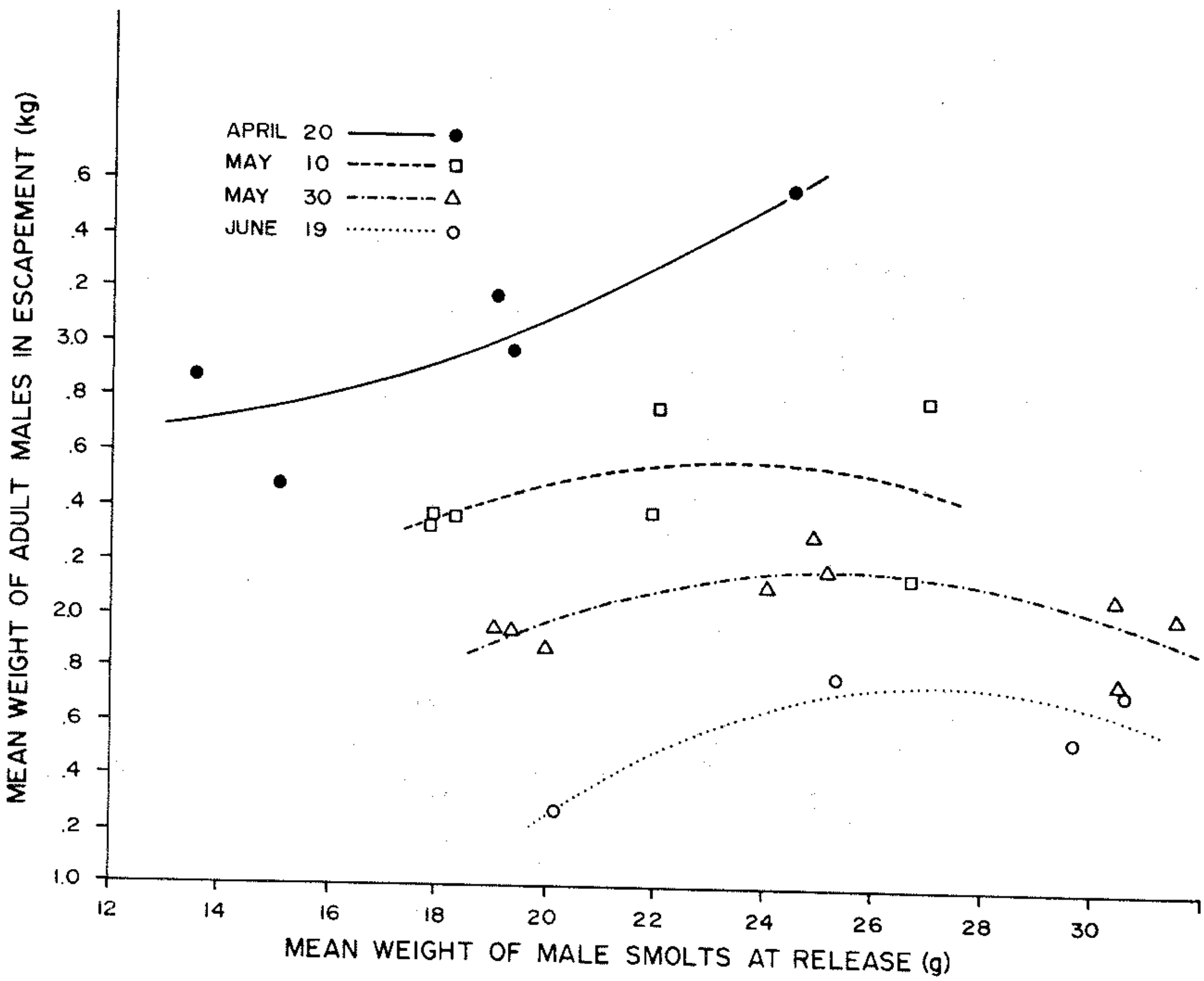

Fig. 14. Mean weights of male juveniles in release samples and the mean weights of adult males originating from each group in the escapement.

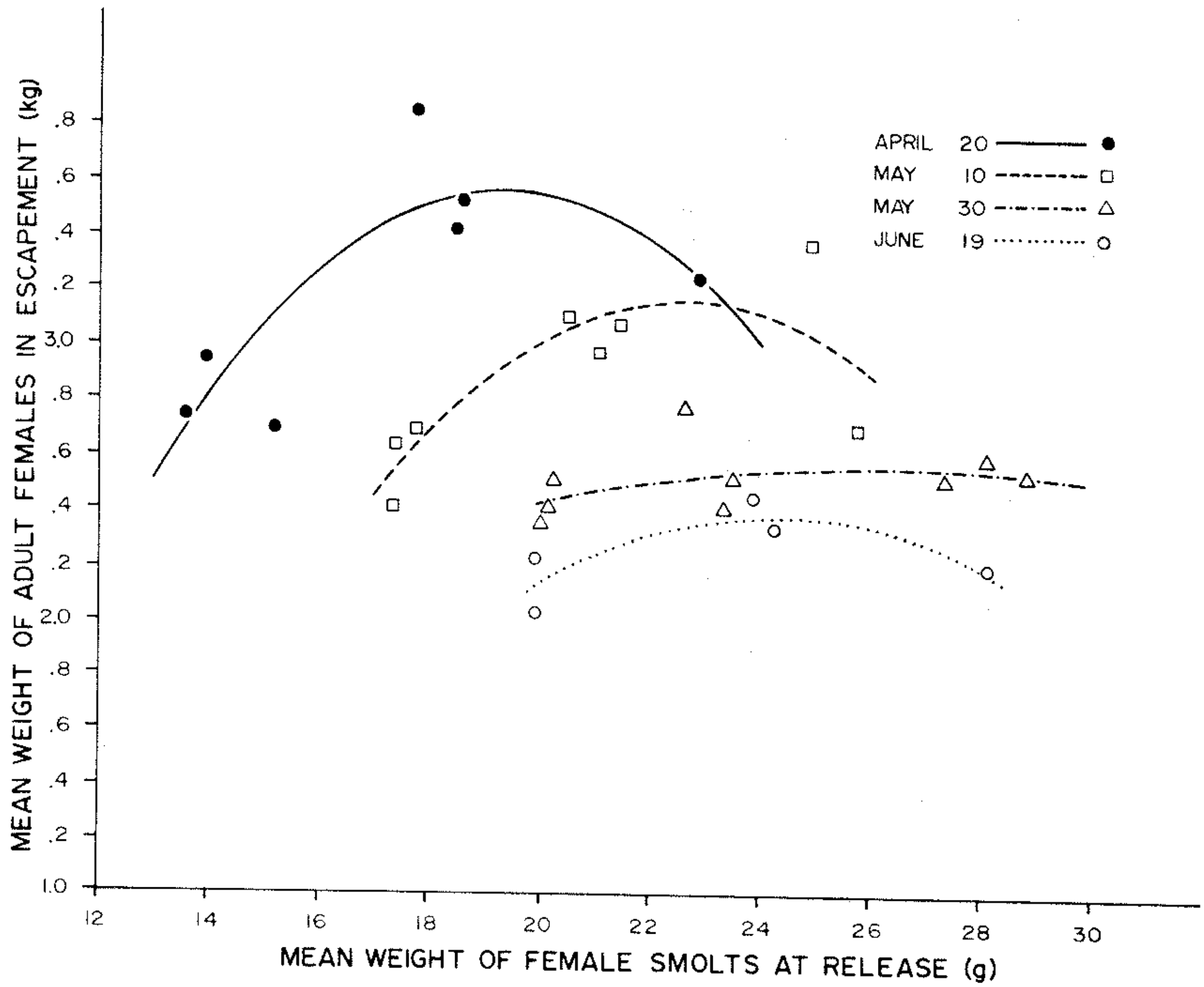

Fig. 15. Mean weights of female juveniles in release samples and the mean weights of adult females originating from each group in the escapement.

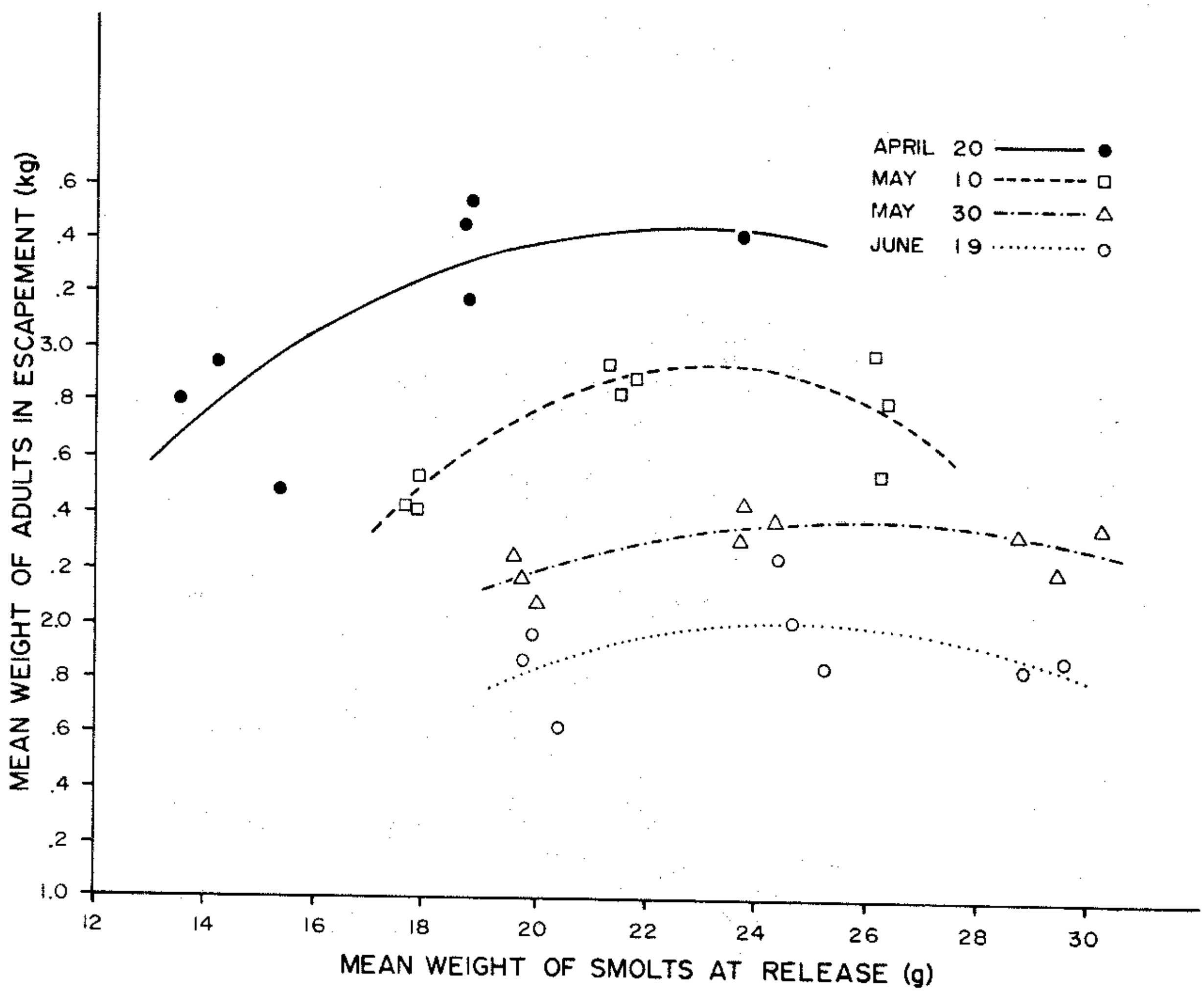

Fig. 16. Mean weights of juveniles in release samples (sexes combined) and the mean weights of adults (sexes combined) originating from each group in the escapement.

C. BIOMASS OF RETURNS (CATCH PLUS ESCAPEMENT)

Jacks

For a common release date (9 groups combined), the estimated average yield of jack flesh per 100,000 juveniles released was greatest (314.56 kg) for the May 30 release (Fig. 17; Tables 5,6). This was followed in decreasing order by the yields from the May 10, April 20, and June 19 releases (257.05, 178.84, and 19.59 kg, respectively).

Within each release there was a positive relationship between jack biomass and juvenile release weight (Fig. 17; Table 5). These relationships were curvilinear upward for the April 20, May 10, and May 30 releases with r^2 values of .84, .98, and .97, respectively. There was a less pronounced but significant ($p<.05$) positive linear correlation for the June 19 release (r^2=.53).

Adults (sexes combined)

For a common release date the average yield of adult flesh per 100,000 juveniles released was greatest (20,601 kg) for the May 30 release (Table 6). This was followed by the yields from releases made on May 10 (12,661 kg), April 20 (9,024 kg), and June 19 (4,126 kg).

Within three of the releases (April 20, May 30, June 19) there was little indication of any influence of juvenile size on resulting adult biomass (Fig. 18; Table 5, r^2 values of .10, .24, and .21, respectively). For the May 10 release there was a fairly strong negative relationship between juvenile size and adult biomass (r^2=.63).

Jack plus adult

The total (jack plus adult) yields of flesh per 100,000 smolts released was very similar to that observed for adults only, due to the relatively small contribution by jacks. For a common release date average yield was again greatest (20,916 kg) for the May 30 release (Table 6). This was followed by releases made on May 10 (12,918 kg), April 20 (9,203 kg), and June 19 (4,146 kg).

Within releases (Fig. 19; Table 5) there was little indication of any relationship of juvenile size to resulting biomass for the releases made on April 20 (r^2=.06), May 30 (r^2=.25), or June 19 (r^2=.21). For the May 10 release a fairly strong negative relationship was indicated (r^2=.58), with greater biomass resulting from release of small juveniles.

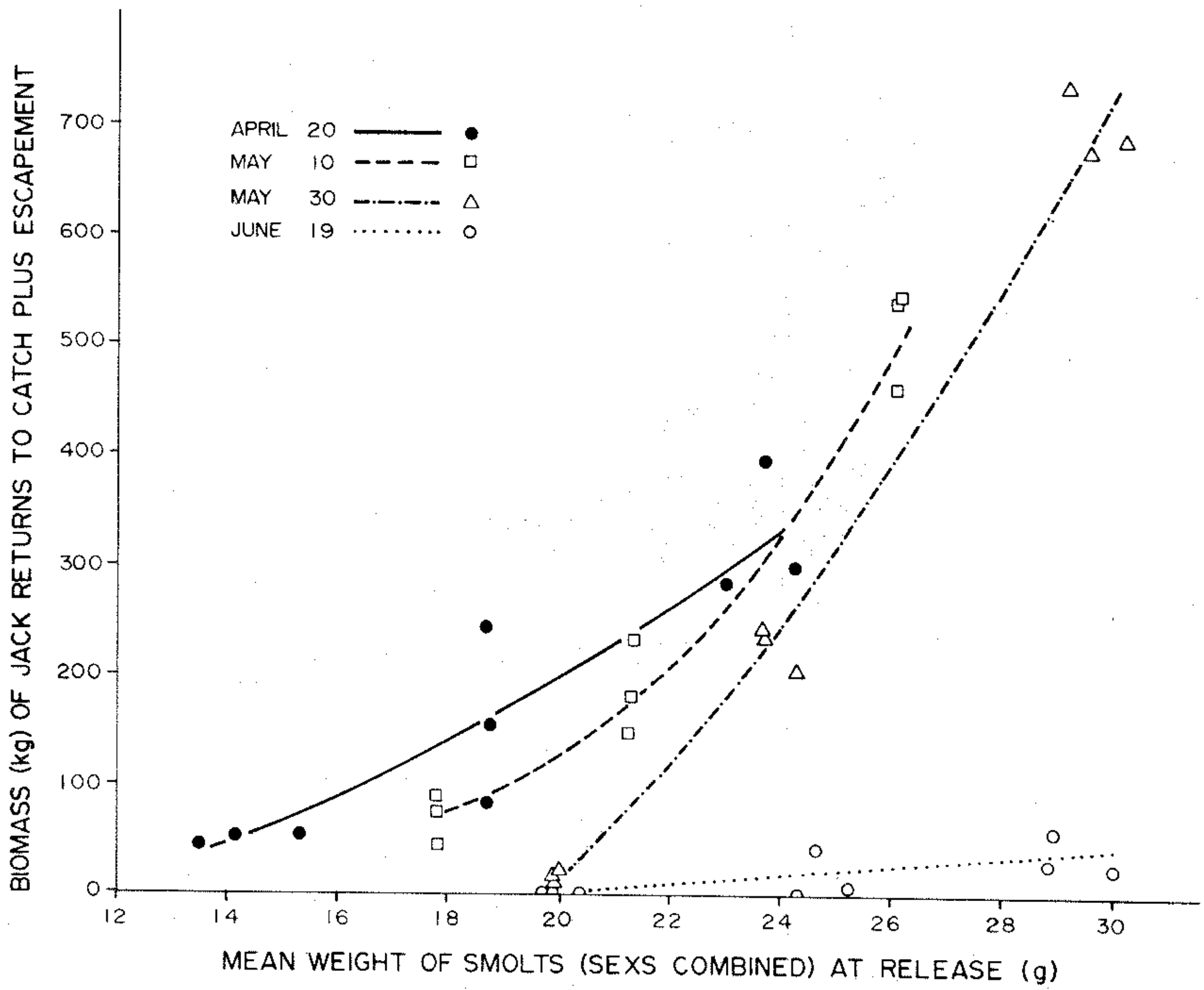

Fig. 17. Mean weights of juveniles in release samples (sexes combined) and the biomass (kg) of jack flesh per 100,000 juveniles released (catch plus escapement) for each group.

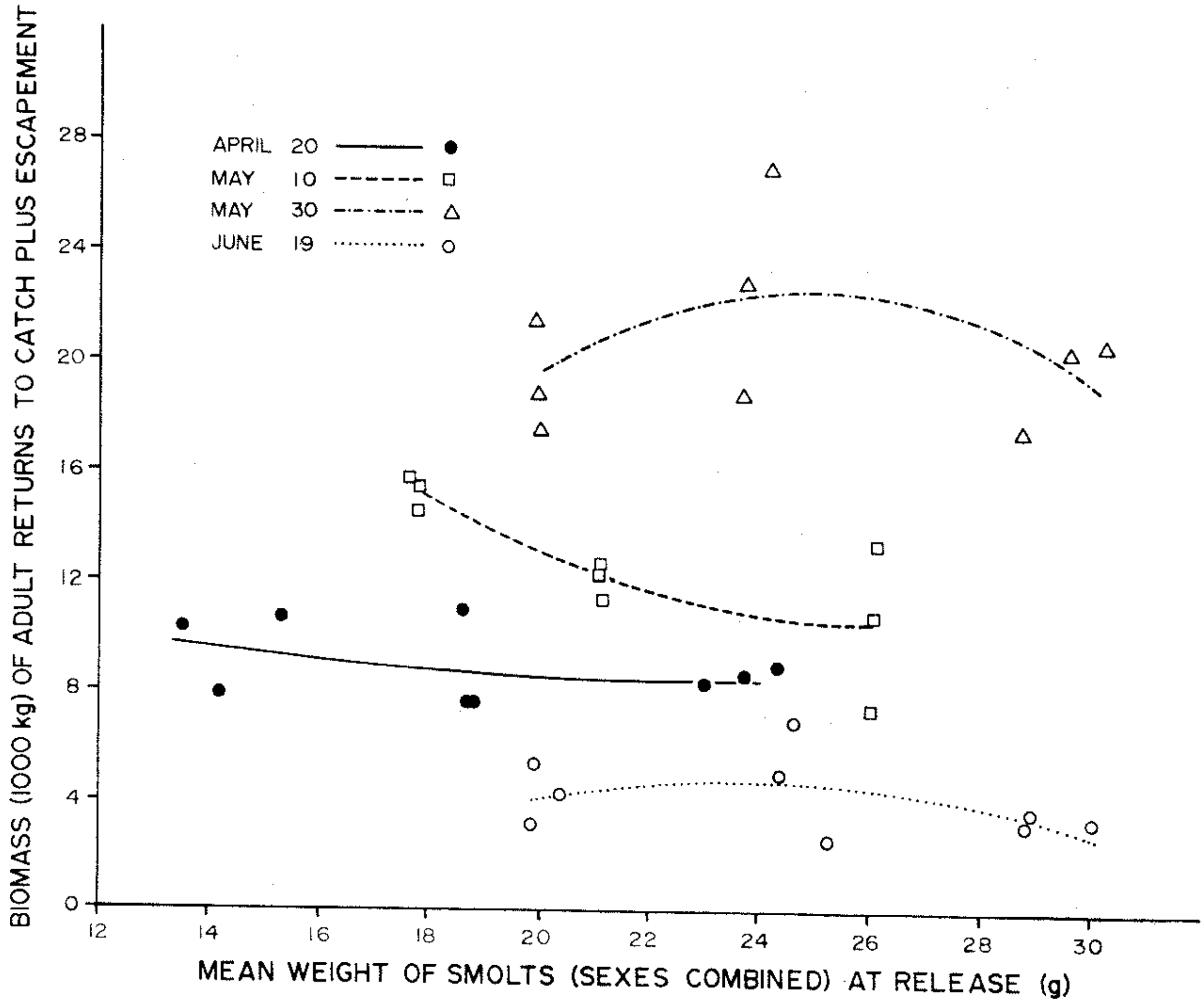

Fig. 18. Mean weights of juveniles in release samples (sexes combined) and the estimated biomass (kg) of adult flesh per 100,000 juveniles released (catch plus escapement) for each group.

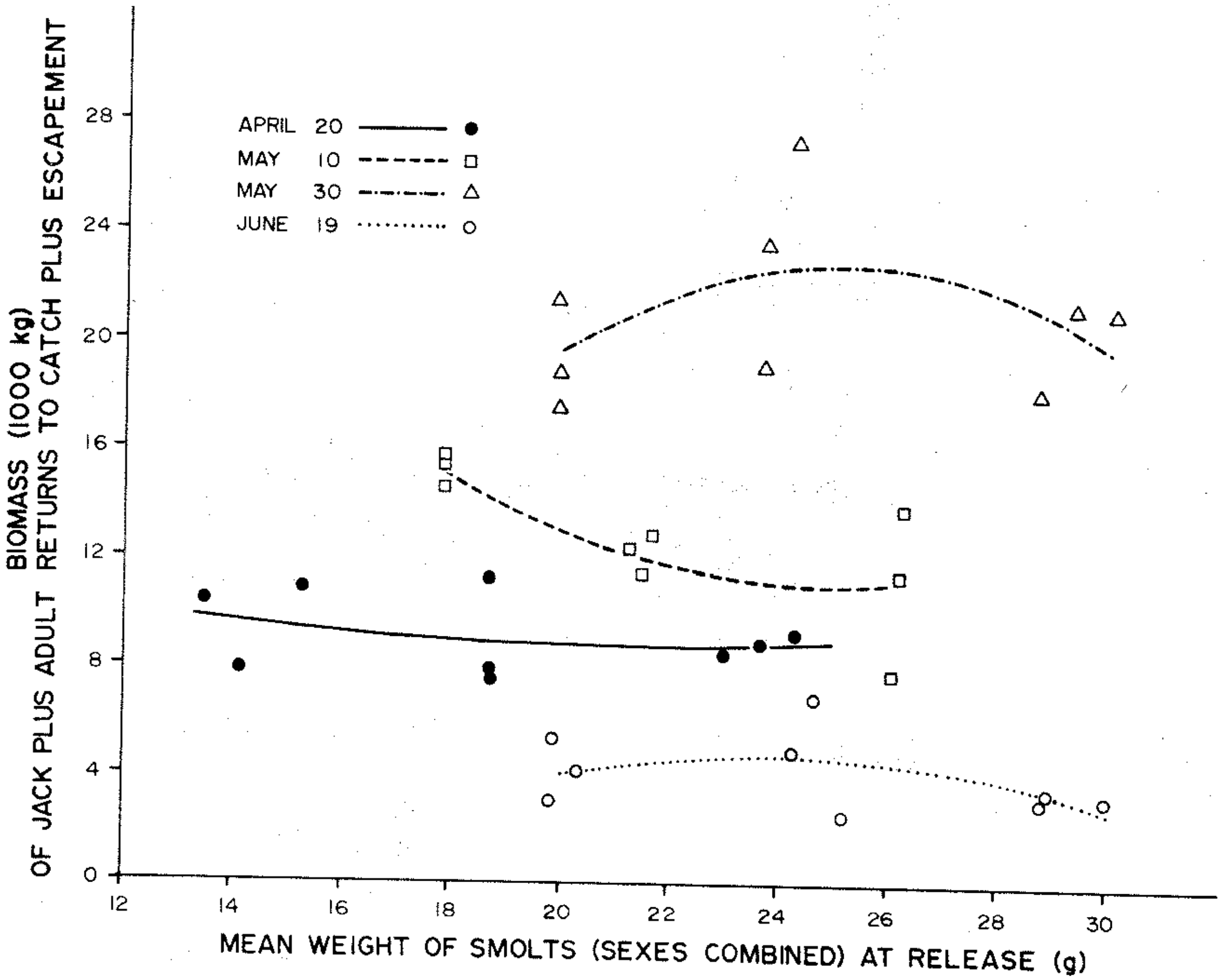

Fig. 19. Mean weights of juveniles in release samples (sexes combined) and the estimated biomass (kg) of jack plus adult flesh per 100,000 juveniles released (catch plus escapement) for each group.

Response surface analysis

a) Adults

Response surface analysis of adult biomass (catch plus escapement) is shown in Figure 20. Maximum production of 22,900 kg of adult flesh per 100,000 smolts released is predicted for release of 16.6 g juveniles on day 155 (June 3). The surface is very similar to that for % return of adults (predicted maximum returns from release of 15.7 g fish on day 156, Section A, Fig. 6). Once more, the predicted optimum release weight is less than that of any juveniles actually released around this date (minimum release weight on day 151 was 19.6 g) and should therefore be regarded with caution. As with the % return surface, the biomass contours tend to parallel the weight axis in indicating that the effects of release weight are relatively minor, since in ascending or descending the weight axis on a given date the biomass tends to remain on the same contour. The line of optimum release weight passing through the surface center shows the weight at which juveniles should be released on any given date in order to achieve maximum biomass of returns. Maximum production is indicated from release of progressively larger fish as the season progresses; however, the change in optimum weight is not substantial (about 5.5 g over the period of the releases).

Again, as with % returns, the surface indicates a strong effect of time of release. Before the optimum release date (day 155 or June 3) the biomass contours are quite widely separated, indicating a gradual increase in biomass production with advancing release date. Shortly after the optimum date is reached biomass of returns decreases very rapidly, as indicated by the closeness of the contours. The line of optimum time of release shows that the optimum release date remains essentially constant at June 3 regardless of juvenile size.

Tests of significance of the contribution of each factor to the response surface model showed that the contribution of size was not statistically significant ($F \approx 0.84$, dF=4,25, p=.52).

b) Jack + adult

Response surface analysis of jack plus adult biomass (catch plus escapement) is shown in Figure 21. Because of the comparatively small contribution of jacks to the total biomass this surface is almost identical to that presented for adult biomass, and the same comments regarding effects of time and size at release apply. Maximum biomass production of jacks plus adults (22,850 kg) is indicated for release of 16.8 g fish, again on day 155 (June 3). Tests of significance of the contribution of each factor to the response surface model showed the contribution of size to be non-significant (≈ 0.51, dF=4,25, p=.73), as was the case for adult only biomass.

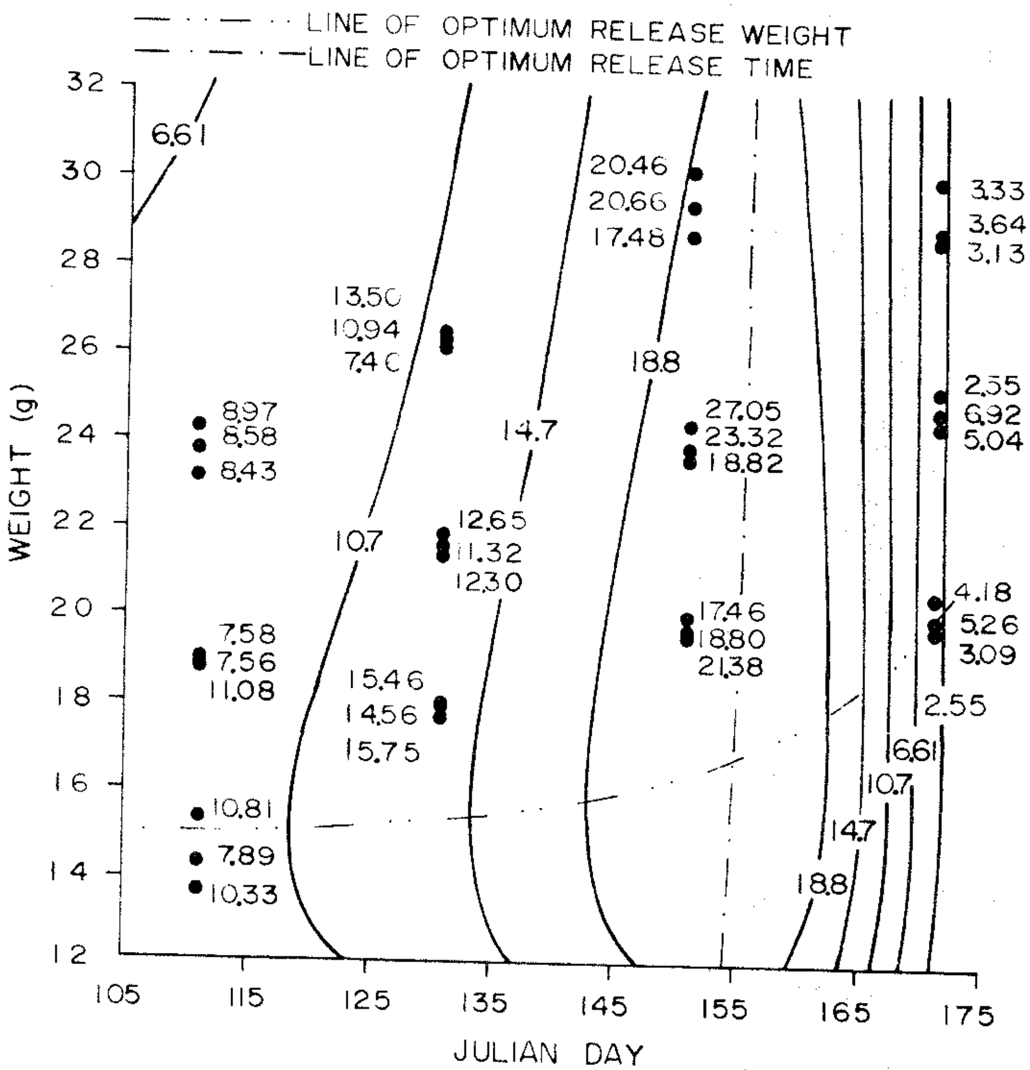

Fig. 20. Response surface showing influence of time at release (Julian days) and mean size at release (a) of juvenile coho on biomass of adult returns in thousands of kg per 100,000 juveniles released for each group. Contours indicate the biomass (kg) of adults from release of juveniles from various size-time combinations. The solid points indicate estimated biomass (kg) of adults from experimental groups released.

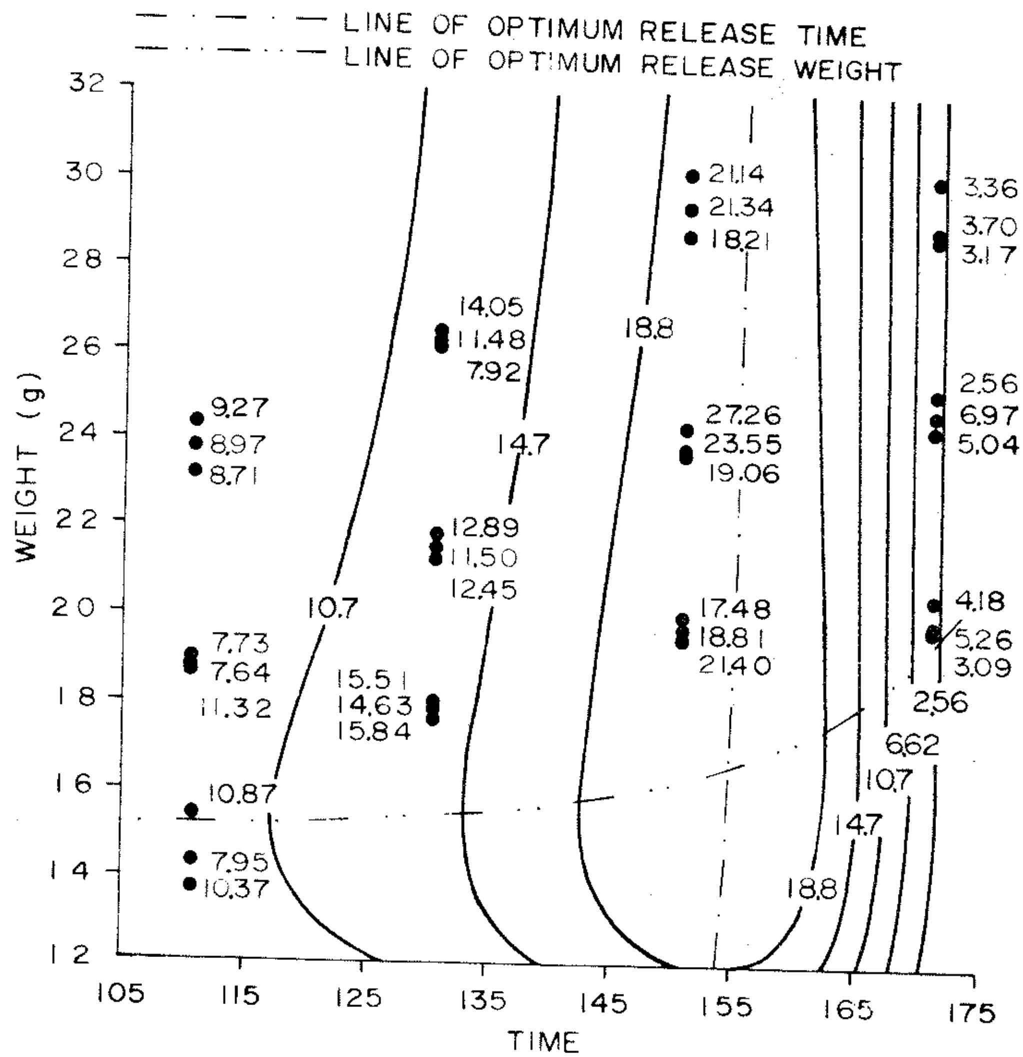

Fig. 21. Response surface showing influence of time at release (Julian days) and mean size at release (g) of juvenile coho on biomass of jack plus adult returns in thousands kg per 100,000 juveniles released for each group. Contours indicate the biomass (kg) of jacks plus adults from release of juveniles from various size-time combinations. The solid points indicate estimated biomass (kg) of jacks plus adults from experimental groups released.

D. DISTRIBUTION OF CATCH

Year of catch

Almost all fish taken in the fishery were caught as adults in 1981. Only 100 of the estimated total catch of 4,999 were caught in 1980, the year of release. Of these, 57 originated from juveniles of the first release, 28 from the second release, 15 from the third, and none from the fourth. By far the most (50) originated from large category juveniles of the first release. As discussed previously in the Methods section (under DATA COMPILATIONS, Fishery recoveries in year of release) the 1980 recoveries were divided into jack and immature categories. Only 13 of the 100 were judged to be jacks, 7 of which were from large category juveniles of the first release. It is interesting to note there were no U.S. recoveries in 1980.

Type of fishery

Contributions of the various groups to the 1981 (adult) commercial troll, net, and sport fisheries are given in Table 7. Most fish were taken by the net fishery (40.9%); the remainder were divided almost equally between the commercial troll and sport fisheries.

Time had a strong influence on relative contributions to the three types of fisheries. The contribution to the net fishery was fairly constant among releases, however, as juveniles were released progressively later, there was a decrease in their contribution to the commercial troll fishery (from 43% for the April 20 release to 17% for the June 19 release). Corresponding to this there was an increase in the contribution to the sport fishery (from 22% from the April 20 release to 43% for the June 19 release).

Geographic distribution

Detailed listings of where fish were recovered within each type of fishery are given in Tables 8, 9, and 10. Of the commercial troll caught fish, 80% were caught in the Central Coast and Northwest Vancouver Island fisheries. The remainder was taken mostly in the Georgia Strait and Southwest Vancouver Island fisheries. Small numbers were taken in the Northern troll (from the first two releases only), Alaska troll (first release only), and Washington-Oregon troll (last two releases only).

Most sport-caught fish (83%) were taken in the northern areas of Georgia Strait (Statistical Areas 13 and 14). Almost all the remainder was caught in the more central part of Georgia Strait (Statistical Areas 15-17). Less than 1% was recovered in U.S. waters (Washington) and none in Northern B.C. or Alaska.

The majority of the net-caught fish (88.6%) were taken in the Johnstone Strait fishery (Statistical Areas 12 and 13). A substantial number (5.7%) was taken in the Puget Sound (Washington state) fishery; the remaining 5.7% were caught mainly in the Juan de Fuca net fishery (3.3%) with only very small numbers from any other areas.

Table 11 shows the geographic distributions of the catch for the combined fisheries. The 16 commercial troll caught fish of uncertain origin from Table 9 are omitted. Considering the total catch (all sizes and releases combined) about 92% were taken in 3 areas-Johnstone Strait, Georgia Strait, and Central Coast plus Northwest Vancouver Island. Comparison of the distribution of the catches from each release shows a general trend. Fish from earlier releases appear to have an extended northward range with a relatively higher proportion of the catch being taken in more northerly areas (Alaska, North and Central Coast). In fact, the only Alaskan catches recorded are from the first release. It is also apparent that fish from later releases tended to contribute more heavily to the Georgia Strait fishery relative to the other fisheries than did those of earlier releases. This is in agreement with the increased sports catches of later releases, most of which occurred in Georgia Strait.

Differences in distribution associated with size are generally not large and are of questionable significance. The most apparent difference is a tighter geographic distribution of small fish from the first release relative to medium or large fish; no small category fish were recovered in more northerly or southerly areas.

DISCUSSION

The results show that the effects of size at release on adult returns (catch plus escapement) are relatively minor, the most noticable effect being slightly higher returns from smaller fish of earlier releases. The effect of time of release is of considerable importance however, and becomes quite critical after about June 10, when returns begin to decline sharply.

Maximum adult returns of 11.2% are predicted from release of 15.7 g juveniles on June 4 (day 156). It should be noted that this release weight is less than that of any juveniles released near the optimum time, and is extrapolated from trends within the tested range. For this reason it may be wise to use a conservative approach and aim for a release weight of about 20 g, which is approximately the lowest weight tested near the optimum date; predicted returns would be about 10.2%. The predicted optimum weight could perhaps be tested by release of a small experimental group.

Time, and particularly size, affected the proportion of jacks in the returns, early release and larger size increasing the proportion. A time-size combination for maximum production of jacks was not defined; however, within the tested ranges highest returns can be expected from release of 30 g juveniles on about May 8 (day 129). Time is not at all critical within the approximate period April 20 (day 111) to May 20 (day 141).

Considering returns of jacks plus adults, an optimum release date of June 4 (day 156) is again indicated. No optimum release weight was determined, but the optimum date is essentially the same for juveniles of any weight. On the optimum date, poorest returns (10.0%) are indicated for release of 24.4 g juveniles, with the suggestion of slightly higher returns at lesser or greater weights. At the approximate limits of the tested weight range on the optimum date, returns of about 10.5% are indicated for release of both 20 and 30 g juveniles. If the separate (i.e., adult only and jack only) response surfaces are examined, it can be seen that near the optimum release date of June 4 any increase in release weight would increase the number of jacks and concurrently reduce the number of adults. This has a considerable influence on the age composition of the combined (jack plus adult) returns. For example, for the optimum June 4 release date the separate surfaces indicate that 20 g juveniles would produce an adult return of about 10.2% and a jack return of about 0.1%. For 24.4 g juveniles (the point of lowest jack plus adult returns for a June 4 release) an adult return of about 9.5% and a jack return of about 0.3% are indicated. For 30 g juveniles, jack plus adult production would equal that for 20 g juveniles (≈10.3%) but in this case adult returns would be only 9.0% and jack returns about 1.3%. Because of the much lesser value of jacks, one arrives at the same optimum release strategy as was arrived at based on adult returns alone, i.e. release of approximately 20 g juveniles on June 4. Possibly a trial release of 15.7 g juveniles could be made, with predicted maximum adult returns of 11.2% and almost no jacks.

For both jacks and adults, fish from earlier releases were larger on return. There was also a pronounced tendency for larger juveniles to produce larger jacks; a similar but less pronounced correlation was observed for adults. If the criterion for maximum production is considered to be mass of flesh produced rather than numbers returning, these differences in weights of returning fish must be taken into account. Response surface analysis using biomass of returning adults predicts maximum production from release of 16.6 g juveniles on June 3 (day 155). These values are very close to the predicted optima for % returns of adults (15.7 g juveniles on June 4), and the response surfaces for each are in general very similar. It appears that differences in return rate tend to compensate for differences in size of adults, i.e. the higher returns of smaller adults represent a greater total biomass than do lesser returns of larger adults. Because of the comparatively small contribution of jacks to total biomass, the response surface for jack plus adult biomass is almost identical to that for adults only (predicted optima are 16.8 g juveniles, again on June 3). Note that the predicted optimum release weights of 16.6 and 16.8 g are both below the actual tested weight range for this date and, as discussed for % returns, a release weight of 20 g might be more appropriate until the lower weight is actually tested.

When assessing the effects of size at release it is important to realize that interpretations based on escapement returns alone could be misleading, since they can differ considerably from those based on catch or catch plus escapement. In particular, for certain releases, returns from smaller juveniles were markedly higher in the escapement than in the catch. Such differences appear to be attributable to selection by the fishery for fish originating from larger juveniles of the first three releases. Since larger juveniles produced larger adults, selection by the fishery for larger adults is indicated. It also appears very likely that there was selection by the fishery for males, since in all but one of the 36 groups released there were significantly fewer males observed in escapement returns than were observed in the juveniles at the time of release. An alternative explanation for this change in sex ratio would be sex related differences in natural (i.e., non-fishery) mortality; however, this possibility could not be examined owing to lack of information on the sexes of fish taken in the fishery.

Other interesting aspects of the fishery were observed. Very few fish were taken in the year of release, the few which were caught originated from larger juveniles of early releases. Since jacks from these groups were larger than those of other groups (based on hatchery returns), their capture in the fishery probably resulted from more of them reaching a vulnerable size in their first year, than fish of other groups. There were also differences in contributions to various types of fisheries. Overall, the highest proportion of fish was taken by the net fishery (40.9%) with commercial troll and sport sharing the remainder. However, while the proportion of net caught fish was approximately equivalent for all releases, time of release strongly influenced the relative proportions taken in the commercial troll and sport fisheries. For the first release more than twice as many fish were taken in the commercial troll as in the sport fishery. With progressively later releases increasingly greater proportions were taken in the sport fishery, and for fish of the last release twice as many fish were taken in the sport as in the commercial troll.

About 92% of the total catch occurred in 3 geographic areas - Johnstone Strait, Georgia Strait, and Central Coast plus Northwest Vancouver Island. The bulk of the catch within each of these areas was attributable to a different type of fishery in each case; net, sport, and commercial troll respectively. There was also a general trend suggesting that fish from later releases had a more extended northward range than those from earlier releases. It is of interest that, with the possible exception of 16 fish of uncertain origin, there were no recoveries from the West Coast of Vancouver Island and none from the Fraser River fishery, although a substantial number was taken in the Puget Sound net fishery.

The differences in distribution of various groups suggest the possibility of making releases designed to benefit particular fisheries. For example, these results indicate that an increasingly higher proportion of the Quinsam returns are recovered in the sport fishery as releases are made progressively later in the season; thus, it might appear desirable (if the goal were to enhance the sport fishery) to release fish at a late date. Care must be used in making such decisions, however. For the situation just mentioned, response surface analysis using the numbers recovered in the sport fishery indicated that the optimum time and size combination for maximum contribution to this fishery is essentially the same as that for total returns (combined fisheries plus escapement). It appears that the gains achieved by optimizing for total returns so far outweigh differences in the relative contribution to the sport fishery that in maximizing total returns the sports fishery contributions are maximized also; later releases are therefore not indicated.

A potentially complicating factor in this experiment is the possibility of biases associated with grading of juveniles to achieve size differences amongst the release groups. This is discussed in detail in the Rosewall report (Bilton et al. 1982), where it is pointed out there is accumulating evidence that hereditary factors are at least partly involved in rate of growth and age at return. If this were true the larger juveniles in a population might represent that segment genetically predisposed toward rapid growth, and possible early maturity. Thus, it might be suspected that there would be an inflated proportion of jacks amongst large category males. Although grading was used in the Rosewall study, differences in design from the present study (multiple ponds per release) allowed examination for possible effects of grading on the proportions of jacks and adults. It was concluded that there was little evidence that grading significantly affected the experimental results. Despite this it was recommended that where possible size differences be achieved through temperature control of growth rather than by grading. In the present study this alternative to grading was not possible and because of the simpler design, it was not possible to examine the data for effects of grading on the proportions of jacks and adults. It is assumed that if biases associated with grading are present they are minor, as was the case at Rosewall. In support of this assumption it is worth noting that one factor indicative of size-related selection that was present in the Rosewall study was not present here. At Rosewall there was a pronounced trend towards higher proportions of males among juveniles with increasing size category (Bilton 1978); this was not the case for Quinsam where the sex ratio of juveniles was uniform over all sizes and releases.

Another possibly complicating factor in the experiment was the high incidence of furunculosis and generally poor physical condition of the juveniles released on June 19. Although it is possible this may have contributed to the poor survival of this group, preliminary return data from the second series of releases in 1981 indicates results are very similar for the 2 years. Since furunculosis was not a problem in the second year it appears the disease problems encountered the first year did not strongly influence the results. Since there were no apparent differences in seawater adaptability among the various groups of juveniles at release, it appears this factor did not contribute to the observed differences in survival.

The results of this first Quinsam study show some similarities to the Rosewall study. At both locations jack production is favored by early release of large juveniles. Also, in both instances the size of jacks and adults was positively correlated with juvenile size and negatively correlated with time of release, the largest fish at maturity resulting from large, early release juveniles. While the two studies are similar in these aspects, they differ in others. Although time of release was the major influencing factor on adult returns for both, size at release had a much lesser effect on returns in the present study, with much less time - size interaction than was observed at Rosewall. Whereas optimum release weight for Quinsam increased by only about 2 g over the period of the releases, that for Rosewall increased by about 9 g over an equivalent period. There are also major differences in predicted optimum conditions for adult returns. For Quinsam, release of 15.7 g juveniles on June 4 (day 156) is indicated; for Rosewall, 25.1 g juveniles on June 22 (day 173). There is a very substantial difference in the magnitude of the predicted maximum returns, 11.2% vs 43.5%, respectively.

Normal production strategy at Quinsam has been release of approximately 25 g smolts at about mid-May. Examination of hatchery data for releases made from the 1974 to 1979 broods indicates average adult escapement returns of 1.13%. If a catch to escapement ratio of 4:1 is assumed (as observed in the present study) then the average adult return to the catch plus escapement would be 5.7%. The response surface in the present study indicates returns of about 5.0% for this time - size combination. Because of this close agreement it seems reasonable to assume that the maximum adult returns of about 10-11% predicted by this study are realistic.

As mentioned previously, preliminary data on returns from a second series of releases at Quinsam (1981) indicate very similar results for the 2 years, suggesting low annual variability. If the same is true for Rosewall, then the differences in return rate between Quinsam and Rosewall would appear to be site specific and not likely to be due to an unusual year at Rosewall at the time of the study there. This theory of site specific limiting factors peculiar to Quinsam is supported by the fact that even the predicted maximum return for Quinsam is considerably less than the observed production returns for the more southerly Georgia Strait hatcheries, which average about 25%.

What could these factors be? Perhaps the more northerly near shore environment is not as favorable as that of the southern regions; catch data for Rosewall suggests that fish tended to remain in Georgia Strait, whereas the majority of the Quinsam juveniles appear to migrate northward. This is only one possible explanation; others could include genetic differences in the stocks, undetected differences in smolt quality, estuary type, or any number of uncontrolled and possibly unrecognizable background variables.

In conclusion, these results strongly suggest that production of adult coho from Quinsam hatchery can be approximately doubled by releasing juveniles about 2 weeks later and approximately 5 g smaller than is the present hatchery practice. The required reduction in growth could perhaps be achieved through use of cooler water, that would have the additional benefits of increasing rearing capacity and reducing the likelihood of disease outbreaks. Other possible methods of growth reduction, such as restricted ration, feed 'diluters', and growth inhibitors might be tried. Further conclusions, and possibly confirmation of the present results, await completion and analysis of the second Quinsam study.

ACKNOWLEDGMENTS

The authors wish to express their appreciation to Mr. R. Reinhart and all other staff of the Quinsam hatchery for their help and co-operation in carrying out this study. They would also like to thank Drs. C. Clarke and H. Mundie for their helpful criticism of this manuscript and Messrs. S. McKinnell and J. Jensen for assistance with the response surface analyses.

REFERENCES

Bilton, H. T. 1978. Returns of adult coho salmon in relation to mean time and size at release of juveniles. Fish. Mar. Serv. Tech. Rep. 832: 72 p.

1980. Returns of adult coho salmon in relation to mean size 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 the Quinsam hatchery in the spring of 1980. Can. Data Rep. Fish. Aquat. Sci. 252: 23 p.

Bilton, H. T., D. F. Alderdice, and J. T. Schnute. 1982. 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.

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

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

Ricker, W. E. 1976. 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.

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

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

Table 1a. Estimated numbers of tagged coho smolts, by sex and size category, released at Quinsam hatchery on April 20, 1980 (Julian day 111). Numbers of jacks and adults in the escapement and fishery in 1980 and 1981, that originated from this release are shown, also returns as percentages of smolts released and adult catches as percentages of total adult returns.

		Smolts						Jacks				Adults									
		No. tagged			x̄ weight (g)			Escape-ment	Catch	Catch + Escapement		Escapement				Catch	Catch+ Escapement		%a Catch	Jacks + Adults (Catch + Escapement)	
												♂	♀	Total							
Tag code	Size group	♂	♀	♂+♀	♂	♀	♂+♀	No.	No.	No.	%	No.	No.	No.	%	No.	No.	%		No.	%
8-20-1	S	1514	2222	3736	14.57	13.91	14.18	5	0	5	0.13	11	16	28	0.75	72	100	2.68	72	105	2.81
8-20-7	S	2175	1515	3690	13.49	13.56	13.52	4	0	4	0.11	17	21	38	1.03	98	136	3.68	72	140	3.79
8-20-9	S	1833	1962	3795	15.43	15.15	15.28	5	0	5	0.13	14	19	33	0.87	132(2)	165(2)	4.35	80	170(2)	4.48
8-20-2	M	1953	1844	3797	19.02	18.44	18.74	7	0	7	0.18	9	15	25(1)	0.66	70(1)	95(2)	2.50	74	102(2)	2.68
8-20-5	M	2112	1683	3795	19.30	17.75	18.61	20	0	20	0.53	15	17	32	0.84	90	122	3.21	74	142	3.74
8-20-6	M	1877	1906	3783	18.96	18.55	18.76	11	0	11	0.29	7	12	19	0.50	62	81	2.14	77	92	2.43
8-20-3	L	1929	1829	3758	24.23	23.11	23.69	24	3(3)	27(3)	0.72	11	7	20(2)	0.53	74(6)	94(8)	2.50	77	121(11)	3.22
8-20-4	L	1970	1739	3769	23.72	22.27	23.03	17	3(3)	20(3)	0.53	7	2	10(1)	0.27	82(11)	92(12)	2.46	89	112(15)	2.99
8-20-8	L	2029	1750	3779	25.32	23.08	24.28	18	1(1)	19(1)	0.50	5	9	14	0.37	85(3)	99(3)	2.62	85	118(4)	3.12
Total		17392	16480	33872	19.58	18.46	19.03	111	7(7)	118(7)	0.35	96	118	219(4)	0.65	765(23)	984(27)	2.91	78	1102(34)	3.26

Notes: Numbers in parentheses are estimated from fishery recoveries in 1980 and are included in the associated value; see discussion in DATA COMPLILATION AND RELIABILITY, Fishery recoveries in year of release.

Escapement figures are true counts of hatchery returns, catch figures are fishery recoveries expanded to reflect sampling effort and fisherman "awareness", see discussion in MATERIALS AND METHODS.

[a]Adult catch as a percentage of total (catch plus escapement) adult returns. Fish assigned from the 1980 fishery (see preceeding note) are not included.

Table 2a. Estimated numbers of tagged coho smolts, by sex and size category, released at Quinsam hatchery on May 10, 1980 (Julian day 131). Numbers of jacks and adults in the escapement and fishery in 1980 and 1981 that originated from this release are shown, also returns as percentages of smolts released and adult catches as percentages of total adult returns.

Tag code	Size group	Smolts: No. tagged ♂	Smolts: No. tagged ♀	Smolts: No. tagged ♂+♀	Smolts: $\bar{x}$ weight (g) ♂	Smolts: $\bar{x}$ weight (g) ♀	Smolts: $\bar{x}$ weight (g) ♂+♀	Jacks: Escapement No.	Jacks: Catch No.	Jacks: Catch + Escapement No.	Jacks: Catch + Escapement %	Adults: Escapement ♂ No.	Adults: Escapement ♀ No.	Adults: Escapement Total No.	Adults: Escapement Total %	Adults: Catch No.	Adults: Catch+ Escapement No.	Adults: Catch+ Escapement %	%[a] Catch	Jacks + Adults (Catch + Escapement) No.	Jacks + Adults (Catch + Escapement) %
8-20-10	S	2034	1756	3790	18.27	17.23	17.83	6	0	6	0.16	23	15	38	1.00	189	227	5.99	83	233	6.15
8-20-15	S	2149	1629	3778	17.93	17.76	17.85	4	0	4	0.11	27	21	48	1.27	182	230	6.09	79	234	6.20
8-20-18	S	2073	1708	3781	17.83	17.36	17.62	10	0	10	0.26	28	17	45	1.19	199(1)	244(1)	6.45	81	254(1)	6.71
8-20-11	M	1976	1767	3743	21.97	20.46	21.26	12	0	12	0.32	8	14	22	0.59	134(3)	156(3)	4.17	86	168(3)	4.49
8-20-13	M	1904	1871	3775	22.06	21.43	21.75	21	0	21	0.56	12	20	33	0.87	132(1)	165(1)	4.37	80	186(1)	4.93
8-20-16	M	1960	1799	3759	21.94	21.04	21.51	14	0	14	0.37	12	32	45(1)	1.20	105(1)	150(2)	3.99	70	164(2)	4.36
8-20-12	L	2369	1399	3768	26.86	24.88	26.13	36	1(1)	37(1)	0.98	6	13	20(1)	0.53	74(1)	94(2)	2.49	79	131(3)	3.47
8-20-14	L	2116	1653	3769	26.50	25.89	26.23	45	0	45	1.19	8	12	21	0.56	140(3)	161(3)	4.27	87	206(3)	5.46
8-20-17	L	1913	1846	3759	27.00	25.70	26.36	45	0	45	1.20	10	14	24	0.64	156(2)	180(2)	4.79	87	225(2)	5.99
Total		18494	15428	33922	22.45	21.42	21.98	193	1(1)	194(1)	0.57	134	158	296(2)	0.87	1311(12)	1607(14)	4.74	82	1801(15)	5.31

Note: Figures in parentheses are estimated from fishery recoveries in 1980 and are included in the associated value; see discussion in DATA COMPLILATION AND RELIABILITY, Fishery recoveries in year of release.

Escapement figures are ture counts of hatchery returns, catch figures are fishery recoveries expanded to reflect sampling effort and fisherman "awareness", see discussion in MATERIALS AND METHODS.

[a]Adult catch as a percentage of total (catch plus escapement) adult returns. Fish assigned from the 1980 fishery (see preceeding note) are not included.

Table 3a. Estimated numbers of tagged coho smolts, by sex and size category, released at Quinsam hatchery on May 30, 1980 (Julian day 151). Numbers of jacks and adults in the escapement and fishery 1980 and 1981 that originated from this release are shown, also returns as percentages of smolts released and adult catches as percentages of total adult returns.

		Smolts						Jacks				Adults								Jacks + Adults (Catch + Escapement)	
		No. tagged			x̄ weight (g)			Escape-ment	Catch	Catch + Escapement		Escapement				Catch	Catch+ Escapement		%[a] Catch		
Tag code	Size group	♂	♀	♂+♀	♂	♀	♂+♀	No.	No.	No.	%	♂ No.	♀ No.	Total No.	Total %	No.	No.	%		No.	%
8-20-28	S	1775	1856	3631	19.98	19.98	19.98	2	0	2	0.06	34	37	72	1.98	231	303	8.34	76	305	8.40
8-20-32	S	1952	1708	3660	19.32	20.12	19.69	1	0	1	0.03	40	35	77	2.10	239	316	8.63	76	317	8.66
8-20-35	S	1948	1689	3637	19.01	20.19	19.56	2	0	2	0.05	35	40	75	2.06	269	344	9.46	78	346	9.51
8-20-29	M	1806	1807	3613	24.90	22.62	23.76	22	4	26	0.72	32	30	63	1.74	280	343	9.49	82	369	10.21
8-20-31	M	1765	1871	3636	25.13	23.54	24.31	22	0	22	0.61	23	34	59	1.62	352	411	11.30	86	433	11.91
8-20-34	M	1911	1709	3620	24.03	23.29	23.68	26	0	26	0.72	28	46	74	2.04	220(2)	294(2)	8.12	75	320(2)	8.84
8-20-30	L	1625	2063	3688	30.42	27.36	28.71	73	0	73	1.98	21	30	51	1.38	223	274	7.43	81	347	9.41
8-20-33	L	1940	1663	3603	30.46	28.09	29.37	68	1(1)	69(1)	1.92	29	31	61(1)	1.69	276(2)	337(3)	9.36	82	406(4)	11.27
8-20-36	L	1833	1778	3611	31.56	28.80	30.21	72	0	72	1.99	20	42	62	1.72	248	310	8.58	80	382	10.57
Total		16555	16144	32699	25.56	24.29	24.94	288	5(1)	293(1)	0.90	262	325	594(1)	1.82	2338(4)	2932(5)	8.97	80	3225(6)	9.87

Note: Numbers in parentheses are estimated from fishery recoveries in 1980 and are included in the associated value; see discussion in DATA COMPLILATION AND RELIABILITY, Fishery recoveries in year of release.

Escapement figures are true counts of hatchery returns, catch figures are fishery recoveries expanded to reflect sampling effort and fisherman "awareness", see discussion in MATERIALS AND METHODS.

[a]Adult catch as a percentage of total (catch plus escapement) adult returns. Fish assigned from the 1980 fishery (see preceeding note) are not included.

Table 4a. Estimated numbers of tagged coho smolts, by sex and size category, released at Quinsam hatchery on June 19, 1980 (Julian day 171). Numbers of jacks and adults in the escapement and fishery in 1980 and 1981 that originated from this release are shown, also returns as percentages of smolts released and adult catches as percentages of total adult returns.

		Smolts						Jacks				Adults									
		No. tagged			$\bar{x}$ weight (g)			Escape-ment	Catch	Catch + Escapement		Escapement				Catch	Catch+ Escapement		%[a] Catch	Jacks + Adults (Catch + Escapement)	
Tag code	Size group	♂	♀	♂+♀	♂	♀	♂+♀	No.	No.	No.	%	♂ No.	♀ No.	Total No.	%	No.	No.	%		No.	%
8-20-19	S	2108	1485	3593	20.36	20.43	20.39	0	0	0	0	11	9	20	0.56	72	92	2.56	78	92	2.56
8-20-24	S	1733	1793	3526	20.38	19.41	19.89	0	0	0	0	7	7	14	0.40	80	94	2.67	85	94	2.67
8-20-27	S	1460	1682	3142	19.60	19.91	19.76	0	0	0	0	2	11	13	0.41	39	52	1.65	75	52	1.65
8-20-20	M	1960	1603	3563	25.31	23.87	24.66	5	0	5	0.14	5	10	15	0.42	106	121	3.40	88	126	3.54
8-20-22	M	1929	1653	3582	25.71	24.60	25.20	1	0	1	0.03	10	6	10	0.46	33	49	1.37	67	50	1.40
8-20-25	M	1640	1884	3524	24.93	23.85	24.35	0	0	0	0	11	12	25	0.71	54	79	2.24	68	79	2.24
8-20-21	L	1912	1660	3572	29.64	27.84	28.81	4	0	4	0.11	13	7	20	0.56	40	60	1.68	67	64	1.79
8-20-23	L	1896	1638	3534	30.24	27.42	28.93	7	0	7	0.20	6	6	12	0.34	56	68	1.92	82	75	2.12
8-20-26	L	1813	1714	3527	31.01	29.03	30.05	3	0	3	0.09	6	6	12	0.34	50	62	1.76	81	65	1.85
Total		16451	15112	31563	25.19	23.91	24.58	20	0	20	0.06	71	74	147	0.47	530	677	2.14	78	697	2.20

Notes: Escapement figures are true counts of hatchery returns, catch figures are fishery recoveries expanded to reflect sampling effort and fisherman "awareness", see discussion in MATERIALS AND METHODS.

[a]Adult catch as a percentage of total (catch plus escapement) adult returns.

Table 1b. Average lengths and weights of jacks and adults that originated from the release of coho smolts as Quinsam hatchery on April 20, 1980 (Julian day 111) as sampled in the 1980 and 1981 escapement.

		Jacks						Adults																	
								♂						♀						Sexes combined					
Tag	Size	F. length (mm)[a]			Weight (kg)			H. length (mm)			Weight (kg)			H. length (mm)			Weight (kg)			H. length (mm)			Weight (kg)		
code	group	$\bar{x}$	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	x	S.D.	n
8-20-1	S	325.0	34.6	5	0.431	0.120	5	473.5	47.6	6	2.941	0.92	8	500.3	48.8	9	2.946	0.81	14	489.6	48.5	15	2.945	0.83	22
8-20-7	S	298.9	3.25	4	0.328	0.012	4	427.0	95.5	5	2.872	1.43	17	510.5	53.2	6	2.736	0.88	16	472.5	83.5	11	2.806	1.18	33
8-20-9	S	338.3	26.9	5	0.459	0.095	5	415.5	70.9	4	2.205	0.94	13	482.7	25.8	7	2.690	0.91	18	458.3	55.3	11	2.486	0.94	31
8-20-2	M	328.9	17.2	7	0.443	0.059	7	543.5	12.0	2	2.848	0.88	8	502.3	50.9	7	3.429	1.16	11	511.4	47.9	9	3.184	1.06	19
8-20-5	M	349.7	21.2	20	0.536	0.101	20	486.5	66.2	4	2.986	1.38	13	533.0	50.5	3	3.852	1.06	15	506.4	60.5	7	3.450	1.27	28
8-20-6	M	333.4	18.1	11	0.466	0.092	11	494.0	101.9	3	3.579	2.05	7	538.7	21.0	7	3.518	0.62	12	525.3	55.4	10	3.540	1.28	19
8-20-3	L	351.5	30.8	24	0.548	0.141	24	418.0	55.1	2	3.642	1.03	9	535.0	49.2	3	3.062	0.87	5	488.2	78.0	5	3.431	0.99	14
8-20-4	L	347.7	28.6	17	0.537	0.129	17	535.7	15.6	3	3.063	0.98	7	560.5	3.5	2	4.080	-	1	545.6	17.6	5	3.209	0.97	7
8-20-8	L	368.9	30.0	18	0.596	0.151	18	528.5	37.3	4	4.075	0.78	4	508.0	34.0	3	3.270	0.93	7	519.7	34.7	7	3.563	0.98	11
Total				111			111			33			86			47			99			80			184
Grand $\bar{x}$ (weighted)		347.0			0.520			476.1			3.00			512.4			3.17			497.4			3.08		

Notes:
[a]Length for jacks is fork length; that for adults is hypural length.

Table 2b. Average lengths and weights of jacks and adults sampled that originated from the release of coho smolts at Quinsam hatchery on May 10, 1980 (Julian day 131) as sampled in the 1980 and 1981 escapements.

		Jacks						Adults													
								♂						♀						Sexes combined					
Tag	Size	F. length (mm)[a]			Weight (kg)			H. length (mm)			Weight (kg)			H. length (mm)			Weight (kg)			H. length (mm)			Weight (kg)		
code	group	$\bar{x}$	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
8-20-10	S	315.8	44.3	6	0.410	0.158	6	454.4	48.9	7	2.367	1.06	21	520.3	42.5	4	2.420	0.69	13	466.8	66.3	12	2.431	0.95	35
8-20-15	S	324.1	8.0	4	0.436	0.049	4	447.4	51.9	12	2.385	0.98	20	502.8	21.2	7	2.698	0.79	20	467.8	50.5	19	2.539	0.89	40
8-20-18	S	305.4	25.4	10	0.353	0.077	10	451.7	49.6	11	2.332	1.07	25	464.7	62.4	7	2.638	0.81	14	456.8	53.5	18	2.442	0.98	39
8-20-11	M	334.0	14.2	12	0.464	0.064	12	536.5	21.9	2	2.756	1.08	8	508.5	65.6	6	3.105	1.16	10	494.9	68.8	8	2.950	1.12	18
8-20-13	M	323.1	25.6	21	0.422	0.118	21	445.0	37.5	5	2.782	1.29	10	512.4	41.9	8	3.083	0.86	17	486.5	51.6	13	2.895	1.08	28
8-20-16	M	328.0	30.3	14	0.448	0.122	14	448.0	86.7	5	2.398	1.16	10	504.7	42.9	9	2.981	0.90	31	484.4	65.1	14	2.839	0.99	41
8-20-12	L	336.6	22.4	36	0.469	0.091	36	509.5	16.3	2	2.054	1.10	5	514.3	44.0	3	3.387	0.76	12	512.4	32.3	5	2.995	1.05	17
8-20-14	L	332.6	17.2	45	0.453	0.074	45	479.7	92.1	3	2.233	1.27	7	463.2	59.3	5	2.607	0.63	11	469.4	67.1	8	2.561	0.99	19
8-20-17	L	331.6	22.7	44	0.454	0.086	44	507.3	31.3	4	2.800	1.12	10	529.1	43.8	7	2.844	0.57	8	521.2	39.6	11	1.819	0.90	18
Total				192			192			51			116			56			136			108			255
Grand $\bar{x}$ (weighted)		329.7			0.446			461.6			2.44			501.9			2.87			479.9			2.68		

Note:

[a]Length for jacks is fork length; that for adults is hypural length.

Table 3b. Average lengths and weights of jacks and adults sampled that originated from the release of coho smolts at Quinsam hatchery on May 30, 1980 (Julian day 151) as sampled in the 1980 and 1981 escapement.

		Jacks						Adults																	
								♂						♀						Sexes combined					
Tag	Size	F. length (mm)[a]			Weight (kg)			H. length (mm)			Weight (kg)			H. length (mm)			Weight (kg)			H. length (mm)			Weight (kg)		
code	group	$\bar{x}$	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	x	S.D.	n
8-20-28	S	280.5	31.8	2	0.297	0.09	2	408.7	58.2	11	1.884	0.81	32	470.5	30.0	13	2.365	0.56	30	442.2	54.1	24	2.098	0.76	63
8-20-32	S	320.0	-	1	0.430	-	1	425.7	42.0	19	1.953	0.66	32	459.5	30.7	10	2.422	0.87	31	437.0	40.6	30	2.178	0.79	64
8-20-35	S	301.3	27.2	2	0.349	0.08	2	451.9	43.3	16	1.960	0.57	32	487.8	40.8	13	2.520	0.78	27	468.0	45.3	29	2.260	0.74	69
8-20-29	M	296.4	16.4	21	0.325	0.06	21	437.2	66.2	15	2.310	1.09	28	486.5	35.9	11	2.671	0.68	27	458.0	59.9	26	2.457	0.94	56
8-20-31	M	299.9	23.3	22	0.337	0.08	22	425.2	36.0	5	2.186	0.85	20	477.0	78.7	8	2.523	1.03	31	458.9	66.5	14	2.394	0.96	52
8-20-34	M	299.2	16.3	26	0.334	0.06	26	438.3	61.6	13	2.123	1.01	21	475.9	40.3	18	2.429	0.82	37	460.2	52.9	31	2.318	0.90	58
8-20-30	L	309.2	20.5	73	0.372	0.08	73	446.8	71.8	8	2.108	0.83	17	481.2	65.2	9	2.525	0.75	24	465.0	68.5	17	2.352	0.80	41
8-20-33	L	306.3	20.4	68	0.353	0.07	68	444.8	48.4	13	1.784	0.67	25	497.5	36.3	8	2.603	0.84	27	464.9	50.6	21	2.210	0.86	52
8-20-36	L	302.3	22.3	72	0.346	0.08	72	420.5	51.8	6	2.042	0.64	17	487.9	33.8	13	2.545	0.73	36	466.6	50.5	19	2.384	0.74	53
Total				287			287			106			224			103			280			211			508
Grand $\bar{x}$ (weighted)		304.0			0.351			434.7			2.03			480.0			2.507			457.0			2.29		

Note:
[a]Length for jacks is fork length; that for adults is hypural.

Table 4b. Average lengths and weights of jacks and adults sampled that originated from the release of coho smolts at Quinsam hatchery on June 19, 1980 (Julian day 171) as sampled in the 1980 and 1981 escapement.

		Jacks						Adults																	
								♂						♀						Sexes combined					
Tag	Size	F. length (mm)[a]			Weight (kg)			H. length (mm)			Weight (kg)			H. length (mm)			Weight (kg)			H. length (mm)			Weight (kg)		
code	group	$\bar{x}$	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	x	S.D.	n
8-20-19	S	-	-	-	-	-	-	396.4	34.2	5	1.316	0.34	10	421.4	47.5	7	2.026	0.78	8	411.0	42.7	12	1.632	0.67	18
8-20-24	S	-	-	-	-	-	-	405.3	35.8	4	1.312	0.32	5	465.5	30.2	4	2.517	0.88	6	435.4	44.5	8	1.969	0.91	11
8-20-27	S	-	-	-	-	-	-	381.0	-	1	0.975	0.46	2	434.0	21.2	2	2.039	0.87	11	416.3	34.1	3	1.875	0.90	13
8-20-20	M	303.3	20.1	5	0.338	0.058	5	387.0	15.1	3	1.468	0.35	5	458.4	37.8	5	2.440	0.80	7	431.6	47.4	8	2.035	0.80	12
8-20-22	M	283.0	-	1	0.290	-	1	462.0	-	1	1.630	0.84	9	471.0	-	1	2.210	0.76	6	466.5	6.4	2	1.862	0.84	15
8-20-25	M	-	-	-	-	-	-	405.4	100.6	5	2.098	1.10	9	456.7	59.4	3	2.454	0.75	10	423.5	87.2	10	2.251	0.95	21
8-20-21	L	290.1	20.3	4	0.309	0.077	4	400.3	42.3	9	1.562	0.53	12	498.5	70.0	2	2.383	0.79	7	418.2	59.1	11	1.864	0.74	19
8-20-23	L	291.7	25.6	7	0.305	0.091	7	505.0	-	1	1.680	1.20	6	439.5	12.0	2	1.970	0.48	5	461.3	38.8	3	1.812	0.91	11
8-20-26	L	285.3	13.4	3	0.282	0.048	3	436.5	58.6	4	1.832	0.92	5	456.0	29.7	2	2.193	0.24	4	443.0	48.3	6	1.992	0.69	9
Total				20			20			33			63			28			64			63			129
Grand $\bar{x}$ (weighted)		292.9			0.309			408.7			1.596			450.0			2.248			427.4			1.93		

Note:

[a]Length for jacks is fork length; that for adults is hypural.

Table 5. The correlation coefficient (r) for linear models, coefficient of determination (r^2), and line of best fit describing various relationships betwen smolt size and jack and adult returns for the 9 groups released at Quinsam hatchery on each of four dates.

Life stage	Fig. no.	Relationship	Release date	Cor. coef. (r)	n	p[1]	r^2	Line of best fit[2]
Jacks	1	Av. juvenile weight and % return to catch plus escapement	Apr 20	0.85	9	<.01	0.730	$y = -0.4643 + 0.0419x$
		"	May 10	-	9	-	0.958	$y = 3.0312 -0.3447 + 0.0104X^2$
		"	May 30	-	9	-	0.980	$y = 0.4651 - 0.1668 + 0.0073x^2$
		"	June 19	0.74	9	<.05	0.550	$y = -0.2751 + 0.0137x$
Jacks	13	Av. juvenile weight and av. weight of jacks in escapement	Apr 20	0.91	6	<.02	0.831	$y = 0.2034 + 0.0148x$
		"	May 10	-	8	-	0.691	$y = -0.4270 + 0.0700x - 0.0014x^2$
		"	May 30	-	6	-	0.664	$y = -0.7394 + 0.0752x - 0.0013x^2$
Jacks	17	Av. + juvenile weight and biomass of returns to catch plus escapement	Apr 20	-	0	-	0.841	$y = 47.0417 - 6.4080x + 0.9328x^2$
		"	May 10	-	9	-	0.981	$y = 1224.86 - 144.841x + 4.4898x^2$
		"	May 30	-	0	-	0.968	$y = 7.0189 - 52.1255x + 2.4767x^2$
		"	June 19	0.73	9	<.05	0.540	$y = -83.7052 + 4.1870x$
Adults	11	Av. juvenile weight and % return to escapement	Apr 20	0.78	9	<.02	0.616	$y = 1.2583 - 0.0364x$
		"	May 10	-	9	-	0.945	$y = 10.9711 -0.8368x + 0.0165x^2$
		"	May 30	-	9	-	0.725	$y = 4.2312 - 0.1630x + 0.0021x^2$
		"	June 19	-	9	-	0.203	$y = -3.2044 + 0.2877x - 0.0055x^2$
Adults	12	Av. juvenile weight and % return to escapement	Apr 20	0.81	9	<.01	0.649	$y = 2.2207 - 0.0804x$
		"	May 10	-	9	-	0.338	$y = 7.3135 + 0.8222x - 0.0198x^2$
		"	May 30	-	9	-	0.062	$y = 6.9520 - 0.3921x + 0.0076x^2$
		"	June 19	-	9	-	0.441	$y = -2.0048 + 0.2333x - 0.0053x^2$
Adults	3	Av. juvenile weight and % + return to escapement	Apr 20	0.86	9	<.01	0.739	$y = 1.6249 - 0.0516x$
		"	May 10	0.82	9	<.01	0.670	$y = 2.3433 - 0.0674x$
		"	May 30	-	9	-	0.658	$y = 5.6640 - 0.2733x + 0.0046x^2$
		"	June 19	-	9	-	0.270	$y = 2.4983 + 0.2519x - 0.0052x^2$

Table 5 (cont'd)

Life stage	Fig. no.	Relationship	Release date	Cor. coef. (r)	n	p1	r^2	Line of best fit[2]
Adults	5	Av. + juvenile weight and % return + to catch plus escapement	Apr 20	-	9	-	0.384	$y = 8.9686 - 0.5562x + 0.0120x^2$
		"	May 10	-	9	-	0.766	$y = 38.4463 - 2.8606x + 0.0588x^2$
		"	May 30	-	9	-	0.136	$y = -9.0368 + 1.5295x - 0.0316x^2$
		"	June 19	-	9	-	0.191	$y = -5.1688 + 0.6657x - 0.0146x^2$
Adults	14	Av. juvenile weight and av. weight of in escapement	Apr 20	-	5	-	0.773	$y = 3.1124 - 0.0913x + 0.0045x^2$
		"	May 10	-	7	-	0.149	$y = -1.3145 + 0.3316x - 0.0071x^2$
		"	May 30	-	9	-	0.498	$y =- 2.1868 + 0.3437x - 0.0068x^2$
		"	June 19	-	4	-	0.796	$y = -5.1419 + 0.5289x - 0.0097x^2$
Adults	15	Av. juvenile weight and av. weight of in escapement	Apr 20	-	7	-	0.700	$y = -6.1807 + 1.0042x - 0.0259x^2$
		"	May 10	-	8	-	0.692	$y = 8.3868 + 1.0215x - 0.0226x^2$
		"	May 30	-	9	-	0.318	$y = 0.3423 + 0.1688x - 0.0032x^2$
		"	June 19	-	5	-	0.708	$y = -5.352 + 0.6376x - 0.0131x^2$
Adults	16	Av. + juvenile weight and av. weight of + in escapement	Apr 20	-	7	-	0.654	$y = 1.3478 + 0.4247x - 0.0094x^2$
		"	May 10	-	9	-	0.736	$y = -5.7212 + 0.7478x - 0.0161x^2$
			May 30	-	9	-	0.530	$y = -1.2921 + 0.2846x - 0.0055x^2$
		"	June 19	-	7	-	0.269	$y = -2.9030 + 0.3974x - 0.0080x^2$
Adults	18	Av. + juvenile weight and biomass of + returns to catch plus escapement	Apr 20	-	9	-	0.102	$y = 15843.1 - 642.170x + 14.2949x^2$
		"	May 10	-	9	-	0.627	$y = 59153.7 - 3774.40x + 73.4902x^2$
		"	May 30	-	9	-	0.245	$y = -54784.2 + 6230.84x - 125.384x^2$
		"	June 19	-	9	-	0.219	$y = -21156.8 + 2198.77x - 46.4823x^2$
Jacks + Adults	7	Av. + juvenile weight and % return of + to escapement	Apr 20	0.19	9	>.1	0.036	$y = 1.1606 - 0.0097x$
		"	May 10	-	9	-	0.474	$y = 5.7369 - 0.4457x + 0.0111x^2$
		"	May 30	-	9	-	0.943	$y = 6.1290 - 0.4401x + 0.0119x^2$
		"	June 19	-	9	-	0.382	$y = -2.8424 + 0.2713x - 0.0053x^2$

Table 5 (cont'd)

Life stage	Fig. no.	Relationship	Release date	Cor. coef. (r)	n	p[1]	r^2	Line of best fit[2]
Jacks + Adults	8	Av. + juvenile weight and % return of + to catch plus escapement	Apr 20	-	9	-	0.168	$y = 8.4881 - 0.5171x + 0.0122x^2$
		"	May 10	-	9	-	0.560	$y = 41.5436 - 3.2122x + 0.0694x^2$
		"	May 30	-	9	-	0.389	$y = -9.3419 + 1.4274x - 0.0255x^2$
		"	June 19	-	9	-	0.135	$y = -5.5128 + 0.6851x - 0.0147x^2$
Jacks + Adults	19	Av. + juvenile weight and biomass of + returns to catch plus escapement	Apr 20	-	9	-	0.061	$y = 15796.1 - 648.578x + 15.2277x^2$
		"	May 10	-	9	-	0.580	$y = 60378.6 - 3919.25x + 77.9803x^2$
		"	May 30	-	9	-	0.255	$y = -54709.1 + 6178.71x - 122.907x^2$
		"	June 19	-	9	-	0.212	$y = -21292.3 + 2207.27x - 46.569x^2$
Jacks + Adults	10	Av. + juvenile weight and percentage of jacks in total returns	Apr 20	0.95	9	<.01	0.911	$y = -22.8540 + 1.8308x$
		"	May 10	-	9	-	0.927	$y = 29.7653 - 4.2009x + 0.1500x^2$
		"	May 30	-	9	-	0.942	$y = -12.1988 - 0.1988x + 0.0418x^2$
		"	June 19	-	9	-	0.720	$y = 5.4964 - 0.9540x + 0.0336x^2$

[1]P is the significant level for a test of r, the correlation coefficient for linear models. A significant r indicates significant slope to the line.

[2]Linear or quadratic models.

Table 6. Estimated biomass (kg per 100,000 smolts released) for returns of of jacks, adults, and jacks plus adults (catch plus escapement) from smolts of different sizes released at Quinsam hatchery on four dates in 1980.

Release date	Tag code	Smolts: Size group	Smolts: x̄ weight (g)	Biomass (kg): Jacks	Biomass (kg): Adults	Biomass (kg): Adults + Jacks
Apr 20 (Julian day 111)	2020-1	S	14.18	53.56	7892.60	7946.16
	8-20-7	S	13.52	45.32	10326.08	10371.40
	8-20-9	S	15.28	53.56	10814.10	10867.66
	8-20-2	M	18.74	82.26	7560.00	7642.26
	8-20-5	M	18.61	242.21	11074.50	11316.71
	8-20-6	M	18.76	155.44	7575.60	7731.04
	8-20-3	L	23.69	394.56	8577.50	8972.06
	8-20-4	L	23.03	284.61	8425.50	8710.11
	8-20-8	L	24.28	298.00	8973.50	9271.50
	Average			178.84	9024.38	9203.22
May 10 (Julian day 131)	8-20-10	S	17.83	67.36	14561.69	14629.05
	8-20-15	S	17.85	46.31	15462.51	15508.82
	8-20-18	S	17.62	91.78	15750.90	15842.68
	8-20-11	M	21.26	148.48	12301.50	12449.98
	8-20-13	M	21.75	236.32	12651.15	12887.47
	8-20-16	M	21.51	180.56	11322.61	11503.17
	8-20-12	L	26.13	459.62	7457.55	7917.17
	8-20-14	L	26.23	539.07	10935.47	11474.54
	8-20-17	L	26.36	544.08	13503.01	14047.09
	Average			257.05	12660.71	12917.76
May 30 (Julian day 151)	8-20-28	S	19.98	20.64	17455.62	17436.26
	8-20-32	S	19.69	10.32	18796.14	18806.46
	8-20-35	S	19.56	17.20	21379.60	21396.80
	8-20-29	M	23.76	234.00	23316.93	23550.93
	8-20-31	M	24.31	205.57	27052.20	27257.77
	8-20-34	M	23.68	240.48	18822.16	19062.64
	8-20-30	L	28.71	736.56	17475.36	18211.92
	8-20-33	L	29.37	677.76	20663.50	21341.26
	8-20-36	L	30.21	688.54	20454.72	21143.26
	Average			314.56	20601.80	20916.37
June 19 (Julian day 171)	8-20-19	S	20.39	0	4177.92	4177.92
	8-20-24	S	19.89	0	5257.23	5257.23
	8-20-27	S	19.76	0	3093.75	3093.75
	8-20-20	M	24.66	46.06	6919.00	6965.06
	8-20-22	M	25.20	9.87	2550.94	2560.81
	8-20-25	M	24.35	0	5042.24	5042.24
	8-20-21	L	28.81	33.11	3131.52	3164.63
	8-20-23	L	28.93	60.20	3634.56	3694.76
	8-20-26	L	30.05	27.09	3331.68	3358.77
	Average			19.59	4126.54	4146.13

Table 7. Numbers[a] and percent ages of the total catch taken by the commercial troll, net and sport fisheries in 1981, by release and size group, for smolts released from Quinsam hatchery in 1980. S = small, M = medium, L = large, T = sizes combined.

Release date	Smolt: Size group	Smolt: $\bar{x}$ weight (g)		Type of fishery: Commercial Troll	Net	Sport	Total
Apr 20 (Julian day 111)	S	14.3	No.	110	106	84	300
			%	36.7	35.3	28.0	100.0
	M	18.7	No.	99	87	36	222
			%	44.6	39.2	16.2	100.0
	L	23.7	No.	114	65	44	223
			%	51.1	29.2	19.7	100.0
	T	19.0	No.	323	258	164	745
			%	43.4	34.6	22.0	100.0
May 10 (Julian day 131)	S	17.8	No.	151	279	140	570
			%	26.5	49.0	24.5	100.0
	M	21.5	No.	140	132	92	364
			%	38.5	36.3	25.2	100.0
	L	26.2	No.	134	173	56	363
			%	36.9	47.7	15.4	100.0
	T	22.0	No.	425	584	288	1297
			%	32.8	45.0	22.2	100.0
May 30 (Julian day 151)	S	19.7	No.	215	312	210	737
			%	29.2	42.3	28.5	100.0
	M	23.9	No.	271	326	253	850
			%	31.9	38.3	29.8	100.0
	L	29.4	No.	196	313	236	745
			%	26.3	42.0	31.7	100.0
	T	24.9	No.	682	951	699	2332
			%	29.2	40.8	30.0	100.0
June 19 (Julian day 171)	S	20.0	No.	20	71	99	190
			%	10.5	37.4	52.1	100.0
	M	24.7	No.	41	82	68	191
			%	21.5	42.9	35.6	100.0
	L	29.3	No.	31	57	60	148
			%	21.0	38.5	40.5	100.0
	T	24.6	No.	92	210	227	529
			%	17.4	39.7	42.9	100.0
Grand total			No.	1522	2003	1378	4903
			%	31.0	40.9	28.1	100.0

Note:

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

Table 8. Estimated numbers[a] and percentages of the commercial troll catch taken in different areas in 1981, for each release and size group of smolts released from Quinsam hatchery in 1980. S = small, M = medium, L = large, T = sizes combined.

Release date	Smolts: Size group	Smolts: $\bar{x}$ weight (g)		Fishing area[b]: A	N	C	NWV	SWV	GS	C/NWV	NWV/SWV	Wa	Ore	Total
Apr 20 (Julian day 111)	S	14.3	No.	0	0	58	48	0	3	1	0	0	0	110
			%	0	0	52.7	43.7	0	2.7	0.9	0	0	0	100.0
	M	18.7	No.	10	5	67	10	5	0	2	0	0	0	99
			%	10.1	5.05	67.7	10.1	5.05	0	2.0	0	0	0	100.0
	L	23.7	No.	6	5	64	10	20	8	0	1	0	0	114
			%	5.3	4.4	56.1	8.8	17.5	7.0	0	0.9	0	0	100.0
	T	19.0	No.	16	10	189	68	25	11	3	1	0	0	323
			%	5.0	3.1	58.5	21.1	7.7	3.4	0.9	0.3	0	0	100.0
May 10 (Julian day 131)	S	17.8	No.	0	0	70	53	8	19	1	0	0	0	151
			%	0	0	46.4	35.1	5.3	12.5	0.7	0	0	0	100.0
	M	21.5	No.	0	0	58	49	30	2	0	1	0	0	140
			%	0	0	41.5	35.0	21.4	1.4	0	0.7	0	0	100.0
	L	26.2	No.	0	12	59	43	13	5	0	2	0	0	134
			%	0	9.0	44.0	32.1	9.7	3.7	0	1.5	0	0	100.0
	T	22.0	No.	0	12	187	145	51	26	1	3	0	0	425
			%	0	2.8	44.0	34.2	12.0	6.1	0.2	0.7	0	0	100.0
May 30 (Julian day 151)	S	19.7	No.	0	0	65	85	28	30	1	0	6	0	215
			%	0	0	30.2	39.5	13.0	14.0	0.5	0	2.8	0	100.0
	M	23.9	No.	0	0	92	127	27	23	1	1	0	0	271
			%	0	0	33.9	46.9	9.9	8.5	0.4	0.4	0	0	100.0
	L	29.4	No.	0	0	93	76	7	13	3	1	0	3	196
			%	0	0	47.5	38.8	3.6	6.6	1.5	0.5	0	1.5	100.0
	T	24.9	No.	0	0	250	288	62	66	5	2	6	3	682
			%	0	0	36.8	42.2	9.1	9.6	0.7	0.3	0.9	0.4	100.0
June 19 (Julian day 171)	S	20.0	No.	0	0	20	0	0	0	0	0	0	0	20
			%	0	0	100.0	0	0	0	0	0	0	0	100.0
	M	24.7	No.	0	0	9	27	0	5	0	0	0	0	41
			%	0	0	22.0	65.8	0	12.2	0	0	0	0	100.0
	L	29.3	No.	0	0	14	12	0	2	0	1	2	0	31
			%	0	0	45.2	38.7	0	6.45	0	3.2	6.45	0	100.0
	T	24.6	No.			43	39	0	7	0	1	2	0	92
			%			46.7	42.4	0	7.6	0	1.1	2.2	0	100.0
Grand total			No.	16	22	669	540	138	110	9	7	8	3	1522
			%	1.0	1.4	44.0	35.5	9.1	7.2	0.6	0.5	0.5	0.2	100.0

Notes:

[a]Actual recoveries expanded to reflect sampling effort.

Footnotes: Table 8 (cont'd)

[b]Fishing areas:

Fishing areas	Statistical Areas
A - Alaska	
N - Northern Coast	
C - Central Coast	6-12, 30
NWV - northwest vancouver Island	25-27
SWV - Southwest Vancouver Island	23-24
GS - Georgia Strait	13-18, 29A, B & C
Wa - Washington	
Ore - Oregon	
C/NWV - Central Coast and/or Northwest Vancouver Is.	6-12, 30, 25-27
NWV/SWV - Northwest Vancouver Island and/or Southwest Vancouver Is.	25-27, 23-24

Table 9. Estimated numbers[a] and percent ages of sport caught fish taken in different areas[b] in 1981, for each release and size group of smolts relased from Quinsam hatchery in 1980. S = small, M = medium, L = large, T = sizes combined.

Release date	Smolts: Size group	Smolts: x̄ weight (g)		Fishing areas[b]: C	GS: 13	GS: 14	GS: 15	GS: 16	GS: 17	GS: 18	GS: 19	GS: 20	GS: 28	GS: 29	Wa[c]	Total
Apr 20 (Julian day 111)	S	14.3	No.	4	44	24	8	4	0	0	0	0	0	0	0	84
			%	4.8	52.4	28.5	9.5	4.8	0	0	0	0	0	0	0	100.0
	M	18.7	No.	4	20	4	8	0	0	0	0	0	0	0	0	36
			%	11.1	55.6	11.1	22.2	0	0	0	0	0	0	0	0	100.0
	L	23.7	No.	0	28	8	4	4	0	0	0	0	0	0	0	44
			%	0	63.6	18.2	9.1	9.1	0	0	0	0	0	0	0	100.0
	T	19.0	No.	8	92	36	20	8	0	0	0	0	0	0	0	164
			%	4.9	56.1	21.9	12.2	4.9	0	0	0	0	0	0	0	100.0
May 10 (Julian day 131	S	17.8	No.	4	64	52	8	8	0	0	4	0	0	0	0	140
			%	2.9	45.7	37.1	5.7	5.7	0	0	2.9	0	0	0	0	100.0
	M	21.5	No.	0	52	24	0	0	16	0	0	0	0	0	0	92
			%	0	56.5	26.1	0	0	17.4	0	0	0	0	0	0	100.0
	L	26.2	No.	4	36	8	0	4	4	0	0	0	0	0	0	56
			%	7.1	64.4	14.3	0	7.1	7.1	0	0	0	0	0	0	100.0
	T	22.0	No.	8	152	84	8	12	20	0	4	0	0	0	0	288
			%	2.8	52.8	29.2	2.8	4.1	6.9	0	1.4	0	0	0	0	100.0
May 30 (Julian day 151)	S	19.7	No.	0	119	67	4	0	20	0	0	0	0	0	0	210
			%	0	56.7	31.9	1.9	0	9.5	0	0	0	0	0	0	100.0
	M	23.9	No.	4	131	67	8	28	12	0	0	0	0	0	3	253
			%	1.6	51.8	26.5	3.2	11.0	4.7	0	0	0	0	0	1.2	100.0
	L	29.4	No.	4	135	64	16	4	8	0	0	0	0	0	5	236
			%	1.7	57.2	27.1	6.8	1.7	3.4	0	0	0	0	0	2.1	100.0
	T	24.9	No.	8	385	198	28	32	40	0	0	0	0	0	8	699
			%	1.3	55.0	28.3	4.0	4.6	5.7	0	0	0	0	0	1.1	100.0

Table 9 (cont'd)

Release date	Smolts: Size group	Smolts: $\bar{x}$ weight (g)		Fishing area[b]: C	GS: 13	14	15	16	17	18	19	20	28	29	Wa[c]	Total
June 19	S	20.0	No.	8	63	16	0	4	8	0	0	0	0	0	0	99
(Julian			%	8.1	63.6	16.2	0	4.0	8.1	0	0	0	0	0	0	100.0
day 171)	M	24.7	No.	0	40	16	0	4	4	0	0	0	4	0	0	68
			%	0	58.8	23.5	0	5.9	5.9	0	0	0	5.9	0	0	100.0
	L	29.3	No.	4	36	20	0	0	0	0	0	0	0	0	0	60
			%	6.7	60.0	33.3	0	0	0	0	0	0	0	0	0	100.0
	T	24.6	No.	12	139	52	0	8	12	0	0	0	4	0	0	227
			%	5.3	61.2	22.9	0	3.5	5.3	0	0	0	1.8	0	0	100.0
Grand total			No.	36	768	370	56	60	72	0	4	0	4	0	8	1378
			%	2.6	55.7	26.8	4.1	4.4	5.2	0	0.3		0.3		0.6	100.0

Notes:

[a]Actual recoveries expanded to reflect fisherman "awareness", see MATERIALS AND METHODS.

[b]Fishing areas are: Statistical area

- C - Central: 6-12, 30
- GS - Georgia Strait: 13-20, 28, 29, A, B, C
- Wa - Washington

[c]Caught in both Puget Sound and Ocean Fisheries.

Table 10 footnotes:

Notes:

[a]Actual recoveries expanded to reflect sampling effort.

[b]Fisheries area	Statistical Areas
N - Northern Coast	1-5
C - Central Coast	6-11
SWV - Southwest Vancouver Island	21-24
JF - Juan de Fuca	20
JS - Johnstone Strait	12-13
GS - Georgia Strait	14-18
Wa - Washington	

[c]All caught in Puget Sound.

Table 11. Estimated numbers[a] and percent ages of fish caught in different areas[b] for combined gear types (commercial troll plus net plus sport) in 1981, for each release and size group of smolts released from Quinsam hatchery in 1980. S = small, M = medium, L = large, T = sizes combined.

Release date	Smolt Size group	Smolt $\bar{x}$ weight (g)		Fishing area[b] A	N	C	NWV	SWV	JF	JS	GS	Wa	Or	Total
April 20 (Julian day 111)	S	14.3	No.	0	0	67	48	0	0	101	83	0	0	299
			%	0	0	22.4	16.1	0	0	33.8	27.8	0	0	100.0
	M	18.7	No.	10	5	71	10	5	4	77	32	6	0	220
			%	4.5	2.3	32.3	4.5	2.3	1.8	35.0	14.5	2.7	0	100.0
	L	23.7	No.	6	7	64	10	20	0	57	52	6	0	222
			%	2.7	3.2	28.8	4.5	9.0	0	25.7	23.4	2.7	0	100.0
	T	19.0	No.	16	12	202	68	25	4	235	167	12	0	741
			%	2.2	1.6	27.3	9.2	3.4	0.5	31.7	22.5	1.6	0	100.0
May 10 (Julian 131)	S	17.8	No.	0	5	74	53	9	6	256	155	11	0	569
			%	0	0.9	13.0	9.3	1.6	1.1	45.0	27.2	1.9	0	100.0
	M	21.5	No.	0	3	59	49	30	20	96	94	12	0	363
			%	0	0.8	16.3	13.5	8.3	5.5	26.4	25.9	3.3	0	100.0
	L	26.2	No.	0	12	65	43	13	0	157	57	14	0	361
			%	0	3.3	18.0	11.9	3.6	0	43.5	15.8	3.9	0	100.0
	T	22.0	No.	0	20	198	145	52	26	509	306	37	0	1293
			%	0	1.5	15.3	11.2	4.0	2.0	39.4	23.7	2.9	0	100.0
May 30 (Julian day 151)	S	19.7	No.	0	5	70	85	36	14	260	240	26	0	736
			%	0	0.7	9.5	11.5	4.9	1.9	35.3	32.6	3.5	0	100.0
	M	23.9	No.	0	0	100	127	27	11	285	269	29	0	848
			%	0	0	11.8	15.0	3.2	1.3	33.6	31.7	3.4	0	100.0
	L	29.4	No.	0	0	101	76	7	11	289	240	14	3	741
			%	0	0	13.6	10.3	0.9	1.5	39.0	32.4	1.9	0.4	100.0
	T	24.9	No.	0	5	271	288	70	36	834	749	69	3	2325
			%	0	0.2	11.7	12.4	3.0	1.5	35.9	32.2	3.0	0.1	100.0

Table 11 (cont'd)

Release date	Smolt Size group	Smolt $\bar{x}$ weight (g)		Fishing area[b] A	N	C	NWV	SWV	JF	JS	GS	Wa	Or	Total
June 19	S	20.0	No.	0	0	28	0	0	0	69	91	2	0	190
(Julian			%	0	0	14.7	0	0	0	36.3	47.9	1.1	0	100.0
day 171)	M	24.7	No.	0	0	9	27	0	0	79	73	3	0	191
			%	0	0	4.7	14.1	0	0	41.4	38.2	1.6	0	100.0
	L	29.3	No.	0	0	18	12	0	0	48	62	7	0	147
			%	0	0	12.2	8.2	0	0	32.7	42.2	4.8	0	100.0
	T	24.6	No.	0	0	55	39	0	0	196	226	12	0	528
			%	0	0	10.4	7.4	0	0	37.1	42.8	2.3	0	100.0
Grand total			No.	16	37	726	540	147	66	1774	1448	130	3	4887
			%	0.3	0.8	14.9	11.0	3.0	1.4	36.3	29.6	2.7	0.1	100.0

Notes:

[a]Actual recoveries expanded to reflect sampling effort and fisherman "awareness"; see MATERIALS AND METHODS.

[b]Fisheries area:	Statistical Areas
A - Alaska	
N - Northern coast	1-5
C - central Coast	6-11
NWV - Northwest Vancouver Island	25-27
SWV - Southwest Vancouver Island	23-24
JF - Juan de Fuca	20
JS - Johnstone Strait	12-13
GS - Georgia Strait	14-18
Wa - Washington	
Or - Oregon	

There were no confirmed recoveries from the West Coast of Vancouver Island, and none from the Fraser River.