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Effects of Culture Density and Size of Juveniles on Growth and Survival of Pond-Reared Coho Salmon Released from Quinsam Hatchery in 1983 and 1984

U. H. M. Fagerlund, J. R. McBride, B. S. Dosanjh, J. Van Tine and M. Greig

Department of Fisheries and Oceans
Biological Sciences Branch
West Vancouver Laboratory
4160 Marine Drive
West Vancouver, British Columbia V7V 1N6

May 1989

Canadian Technical Report of Fisheries and Aquatic Sciences No. 1689

Fisheries and Oceans | Pêches et Océans

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Canadian Technical Report of Fisheries and Aquatic Sciences

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Canadian Technical Report of

Fisheries and Aquatic Sciences No. 1689

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EFFECTS OF CULTURE DENSITY AND SIZE OF JUVENILES ON GROWTH AND SURVIVAL OF POND-REARED COHO SALMON RELEASED FROM QUINSAM HATCHERY IN 1983 AND 1984

by

U. H. M. Fagerlund, J. R. McBride, B. S. Dosanjh, J. Van Tine[1] and M Greig[2]

Department of Fisheries and Oceans

Biologicl Sciences Branch

West Vancouver Laboratory

4160 Marine Drive

West Vancouver, British Columbia V7V 1N6

[1]Department of Fisheries and Oceans

Operations Branch

Quinsam Hatchery

Campbell River, British Columbia V9W 5C1

[2]Malcolm Greig Computing

5685 Daffodil Drive

West Vancouver, British Columbia V7W 1P2

Cat. No. Fs 97-6/1689 ISSN 0706-6457

Correct citation for this publication:

Fagerlund, U. H. M., J. R. McBride, B. S. Dosanjh, J. Van Tine and M. Greig. 1989. Effects of culture density and size of juveniles on growth and survival of pond-reared coho salmon released from Quinsam Hatchery in 1983 and 1984. Can. Tech. Rep. Fish. Aquat. Sci. 1689: 41 p.

ABSTRACT

Fagerlund, U. H. M., J. R. McBride, B. S. Dosanjh, J. Van Tine and M. Greig. 1989. Effects of culture density and size of juveniles on growth and survival of pond-reared coho salmon released from Quinsam Hatchery in 1983 and 1984. Can. Tech. Rep. Fish. Aquat. Sci. 1689: 41 p.

Juvenile coho salmon (Oncorhynchus kisutch) were reared for 12 months in Burrows' ponds at four loading densities before release as smolts in 1983 and at six densities before release in 1984. A representative number of fish in each pond were provided with coded magnetic wire tags, small, medium and large size fish receiving separate codes.

The performance during hatchery residence of the fish released in 1983 has been reported previously (Fagerlund et al. 1984). During rearing of the fish released in 1984 attempts were made to minimize the differences in weight between ponds by modifying the feed intake. Consequently density did not have a statistically significant effect on weight or length of smolts, but density significantly affected condition factors and skewness in weight distribution. Mortality increased strongly with increasing density. Food conversion efficiency and proximate body composition were not affected by ponding density in contrast to the previous brood year.

The number of returning "jacks" increased strongly with increasing size of smolts. Adult returns were 5.0% and 9.0% of respective smolt releases. Return rates of adults were negatively correlated with initial ponding density in both brood years, but the correlation was statistically significant only in the second brood year. In both brood years there was a statistically significant positive correlation between adult return rate and mean smolt weight in ponds. However, there was a negative correlation between return rate and smolt weight of small, medium and large size fish within ponds. The ratio of adult males to females in the escapement was 1.31:1 and 0.98:1, respectively, in the two brood years. Females weighed 29.4% and 27.3% respectively, more than males. There was only a weak effect of density or size of smolts on the body weight of jacks and adults.

Key words: coho salmon, growth, smolt size, density, survival

RÉSUMÉ

Fagerlund, U. H. M., J. R. McBride, B. S. Dosanjh, J. Van Tine and M. Greig. 1989. Effects of culture density and size of juveniles on growth and survival of pond-reared coho salmon released from Quinsam Hatchery in 1983 and 1984. Can. Tech. Rep. Fish. Aquat. Sci. 1689: 41 p.

On a élevé de jeunes cohos (Oncorhynchus kisutch) pendant 12 mois dans quatre étangs de Burrows à densité de population différente avant de les libérer en 1984. Dans chaque étang, un échantillon représentatif a été muni de micromarques magnétiques, les poissons de petite, moyenne et grande taille ayant été codés différemment.

Le comportement pendant le séjour en station piscicole du poisson libéré en 1983 a déjà fait l'objet d'un rapport (Fagerlund et al. 1984). Au cours de la période d'élevage du poisson libéré en 1984, on a essayé de réduire les différences de poids entre les poissons des divers étangs en modifiant la quantité de nourriture. La densité n'a donc pas eu de conséquence statistique importante sur le poids ou la longueur des tacons, mais elle a considérablement affecté les coefficients de condition et d'asymétrie dans la répartition du poids. Le taux de mortalité augmentait considérablement avec la densité. Contrairement à l'année de génération précédente, la densité des étangs n'a pas affecté l'efficacité de la conversion alimentaire, ni la composition corporelle directe.

Le nombre de saumons précoces qui sont remontés augmentait considérablement lorsque la taille des tacons était plus grande. Les adultes qui sont remontés représentaient respectivement 5% et 9% des tacons libérés. Le taux de remontée des adultes était inversement proportionnel à la densité initiale de population des étangs pour les deux années de générations, mais l'écart a été particulièrement important, uniquement dans la deuxième année de génération. Dans les deux années de génération, il y avait un rapport proportionnel entre le taux de remontée des adultes et le poids moyen des tacons des étangs. Il y avait cependant un rapport inverse entre le taux de remontée et le poids des tacons de petite, moyenne et grande taille qui étaient dans les étangs. Le taux d'échappée des adultes mâles et femelles était de 1.31:1 et 0,98:1, pour les deux années de génération. Les femelles pesaient respectivement 29,4% et 27,3% de plus que les mâles. L'effet de la densité ou de la taille des tacons sur le poids des saumons précoces et des adultes a été minime.

Mots clés: coho, croissance, taille des tacons, densité, survie

INTRODUCTION

The effect of culture density on juvenile performance and ocean survival of three brood years of coho salmon raised in a cold water hatchery have previously been reported (Fagerlund et al. 1981, 1983; Perry et al. 1982; Sandercock and Stone, 1982). Subsequently similar density studies were carried out on two brood years of juvenile coho salmon raised at the warm water Quinsam hatchery and released in 1983 and 1984, respectively. Conditions of rearing and performance to release of the fish released in 1983 have been reported by Fagerlund et al. (1984). Ocean survival of certain groups from the 1983 release have also been reported as part of a larger study of the effects of time and size at release on ocean survival (Morley et al. 1988). In this report we describe the hatchery performance of the fish released in 1984 and provide data pertaining to the ocean survival and characteristics of returning jacks and adults from the two releases.

MATERIALS AND METHODS

SMOLTS RELEASED IN 1983

Details regarding methods of rearing of these fish have been reported by Fagerlund et al. (1984). Only a short description will be provided here. Coho fry were loaded at numbers ranging from 72,000 to 121,000 fish into four Burrows' ponds and reared for about 12 months before release at the end of May, 1983. In November, 1982, about 10,000 small, medium and large size fish from each of three ponds were fitted with coded wire tags, all groups receiving individual codes. In the case of the third pond, having a medium-low density (Pond 2), three replicate groups of 4,000 fish of each size were tagged, each group receiving a separate code.

SMOLTS RELEASED IN 1984

Materials and methods were similar to those used in the previous year. At the beginning of June, 1983, fish were collected from a number of rearing troughs and distributed randomly into six ponds at the densities shown in Table 1. Originally the aim was to create three replicated loading densities. However, a subsequent taking of inventory showed that the densities of replicates varied considerably. Nevertheless, data for juveniles have been analyzed as if there were three replicated densities. Data for returning jacks and adults, however, are presented individually for six densities. All groups were fed Oregon Moist Pellets according to the recommended feeding schedule; however, at the end of September low density groups were beginning to gain more weight than other groups. Consequently from then on rations of these groups were gradually reduced, as in the previous brood year, in an attempt to minimize size differences.

During the latter part of November, 1983, about 10,000 fish of each size (small, medium and large) and from each pond were marked by clipping the adipose fin and insertingnasal coded wire tags. The method for determining the length ranges for the three size groups have been described in our previous report. Shortly after tagging actual loading densities were established by a mark-recapture method determining the ratio of marked to unmarked fish in each pond.

Samples of fish were taken for analyses of body composition from time to time as noted in the tables. Size ranges for small, medium and large size fish in these samples were determined from the mean and standard deviation of length of 150 fish measured at the same time. In addition, on May 24, 1984, near the end of the rearing period 300 fish from each pond were removed and immediately frozen. At a later date nose tips were removed from the frozen fish and the wire tags were extracted and read in order to separate the fish into individual size and density groups for analyses.

Water temperature in the ponds decreased gradually from 12 C in June, 1983, to 8 C in December and again increased to 12 C before release. Flow rate was initially 1400 L min-1, increasing to 2300 L min-1 before release. Oxygen and ammonia levels were within acceptable levels when measured in April and May, 1984 (Table 2).

Condition factors are given as weight (g) x 1000 / length$^{3.25}$ (cm).

Total food consumption for a pond was determined as the sum of monthly values. Monthly values were obtained by dividing the amount of food supplied during a calender month by the median number of fish for that month.

"Dry composition" (Table 11) refers to the amount of a body constituent as percent of dry matter in a sample.

In the analyses of variance/covariance reported in Tables 3, 4, 6-11, the "replication within 'factors'" effect was treated as a random effect.

JACKS AND ADULTS

Data relating to the escapement to the hatchery were recorded by personnel from the hatchery and from Pacific Biological Station. Catch data from the Canadian and American fishery were obtained through the coastwide Mark Recovery Program and supplied by the Biological Services Division, Fisheries Branch of the Department of Fisheries and Oceans Canada. The Department applies a catch to sample ratio to commercial recoveries and an awareness factor to sports recoveries to arrive at "estimated" returns to the fisheries. The return data reported here were obtained by adjusting the estimated returns for numbers of released tagged fish.

Analysis of linear regression of return rate on smolt weight - Although return rate is basically a binomial response variable, and would normally call for a variance stabilizing transformation (e.g. $\sin^{-1}\sqrt{R/100}$) this was not done in the analyses as such a transformation would destroy the linearity of the regression and the comparisons of regression coefficients which was the primary objective of the analyses. There was approximately a 2 to 1 range in return rates, and hence for these values a 2 to 1 range in variability. The net result is that the F approximation to the distribution of the test statistic should be viewed as more of an approximation than usual; however, in most cases the significance is strong enough so that this does not result in a qualitative change in the findings.

RESULTS

PERFORMANCE OF JUVENILES RELEASED IN 1983

Please refer to our previous report for details regarding the performance of these juveniles. A summary is provided below.

Throughout the rearing period the weight of the fish held at the lowest density was significantly greater than that of all the other groups which had similar weights. However, it should be noted, that the deviating group was the heaviest group already at the start, although the difference in weight was not statistically significant at that time. Condition factors of fish raised at the two lowest densities showed in general a trend to lower values than those for the two other groups. Density did not affect skewness of either weight or length.

The correlation of condition factor on length was initially positive, but remained negative at subsequent sampling times.

In samples taken early in the rearing period for the analysis of body composition, increasing density was associated with increasing moisture content and decreasing lipid content, but these relationships were not statistically significant in samples taken in the following spring. Increasing size was associated with decreasing moisture content and increasing protein and lipid content in March, but not in May of 1983.

Although statistically significant differences in plasma cortisol concentrations between density groups were found in September and May a consistent trend was not apparent. On the other hand, increasing density was associated with small but significant increases in interrenal cell nuclear diameters.

In a seawater challenge test (Clarke and Blackburn, 1977) carried out on fish taken at the end of May, 1983, density or length of fish did not have an effect on the ability of the fish to regulate plasma sodium concentrations. During the summer of 1982 and spring of 1983 high mortalities occurred and these were positively correlated with ponding density.

PERFORMANCE OF JUVENILES RELEASED IN 1984

Commencing in September of 1983 differences in size between density groups appeared in that some density groups were growing faster than others. However, these differences were not consistently related to density (Table 1). Consequently, density effects on weight were not statistically significant ((ANOVA with density (N=3) and replicate as factors)), Table 3. Similar patterns in lengths were noted. However, density had a significant effect on condition factors, the lowest values occurring in the groups with the lowest densities. As noted in the Materials and Methods section attempts were made during rearing to reduce the differences in size with selective changes in the feeding schedules, but this was only moderately effective.

Weights of fish in samples taken on May 24, 1984 and subsequently frozen were somewhat lower than those in samples obtained a few days earlier from live fish (compare Tables 4 and 3), although they generally followed a similar trend. Lengths, on the other hand, were markedly lower in the previously frozen samples. This was expected, since freezing has been noted to constrict the vertebrate column. As a consequence all condition factors were elevated in the May 24 samples.

Monitoring the weight of tagged smolts in the samples of about 300 fish taken from each pond immediately before fish were released enabled us to assess the relative growth of the three size groups during the 6 months since the fish had been tagged. Table 5 shows the percent distribution of fish from each tagged size group at the time the samples were taken into equal numbered groups of small, medium and large size fish from each pond. Data are provided for all ponds combined and for each pond separately. The results suggest that for a considerable portion of the fish the size at the time of tagging in November did not forecast future growth rate. Thus, nearly 40% of "small" and "large" fish moved out of their respective size groups while 57.2% of "medium" size fish moved out of their size group. It should be noted, that the percentage of "small" tagged fish which retained their relative size was greatest at the three lowest densities; this was also reflected in a higher percentage of "large" marked fish amongst large fish at lower densities than at higher densities in the 6 month sample. A possible reason for this is that dominant fish may have been better able to maintain their social status at lower densities than at higher ones.

The overlapping of size of fish in the three size-groups at the time of release undoubtedly resulted in partly obscuring the relationship between smolt size and adult return rates (see below). Since the overlapping in growth rates may be assumed to continue during ocean residence it provides an explanation for the rather small differences between size groups in the size of jacks and adults.

Skewness in weight and length distribution followed generally the pattern seen in the previous brood year (Table 6). Skewness in weight was initially weakly positive but increased to strongly positive values after

October. Length distribution was initially weakly negative, but changed to weakly positive values after October. An ANOVA with density and time as factors showed a significant effect of density on weight distribution, the largest skewness occurring in the two low-density groups. Skewness in length was not affected by density. Time and density x time were significant for both weight and length.

An analysis of the correlation of condition factor on length in samples taken on May 24, 1984 showed that condition factors decreased significantly with increasing length of fish (Table 7). A similar relationship was observed in the previous years' release from Quinsam Hatchery (Fagerlund et al., 1984) and in fish raised in cold water at Capilano Hatchery (Fagerlund et al., 1983). The correlation was negative in all size-groups, but significantly more so in the "small" size-group. Density did not affect slope of the regression lines. The possible significance of the negative correlation for seawater readiness of the smolts has been discussed in the previous reports.

As in the previous brood year there were two periods of high mortalities, namely in the summer of 1983 and spring of 1984 (Table 1). In 1983 furunculosis was diagnosed. Furazolidone and sulphamerazine were administered orally from July 16-27, and mortalities gradually subsided during the following two months. Cold water disease was diagnosed in 1984, but mortalities were less severe, and no treatment was given. Total mortalities ranged from 3.02% to 18.6% of initial pond load and increased with increasing ponding density.

Total daily food consumption ranged from 37.5 to 41.4 g per fish (Table 1). The attempt to attain uniform growth by reducing food intake has been mentioned above. In contrast to the previous brood year, food conversion efficiency did not correlate well with ponding density, probably to some extent as a consequence of the manipulation of food intake.

Body composition was determined on four occasions; in July and October of 1983 and in February and May of 1984 (Tables 8-11). In October and February increasing size (length) of fish was correlated inversely with moisture content and directly with lipid content. In May a similar trend appeared, but differences in concentration of body constituents were not statistically significant. At no time were there significant differences in body composition between fish held at low, medium and high density. In contrast, in the previous brood year moisture content increased and lipid content decreased significantly with increasing density in September samples.

RETURNS FROM SMOLTS RELEASED IN 1983

Jacks

Jacks returned to Quinsam Hatchery in 1983 (Table 12). A very small number (5 fish / 10,000 released) were caught in the sports fishery. Jacks comprised 3.7% of the total returns from this brood. Density did not consistently influence return rates. At every density the return rate increased with size of smolts. "Large" smolts returned at rates ranging from 2.5 to 7.7 times that of "small" smolts. The average weight of jacks was 314 g (Table 16). There was a small but consistent increase in both weight and length of jacks with increasing smolt size, but density had no effect on size.

Adults

Return rates - Adults returned mainly in 1984 (Table 12). Only 8 fish (per 10,000 released), caught in the sports fishery, returned in the following year. The average total return was 5.0% (497 per 10,000) of released smolts. Escapement to the hatchery was 31.6% of adult returns. The sports fishery took the largest part, 42.9%, of fishery catches.

An analysis of regression of adult return rate on initial ponding density (Table 13, Fig. 1) showed a slight decrease in return rate with increasing density, but the correlation was not statistically significant because of large deviations from a straight-line relationship. However, the difference between slopes for size-groups was significant. In order to find a cause for the deviation we examined the samples of 300 smolts taken from each pond immediately before release and brought to the laboratory in a frozen state (Fagerlund et al. 1984). The coded nosetags in these samples identified fish as to size-group and pond. In the tagged samples the average weight of the medium-high-density group, the group with the highest return rate, was almost as large as that of the low-density group (Fig. 2). Adult return rate thus appeared to correlate better with average smolt weight in a pond than with density. Two analyses of linear regression of return rate on smolt weight were performed (Table 14, Fig. 2). In the first analysis, in which changes in smolt weight between ponds were considered, a significant positive correlation between return rate and smolt weight was found, and size-group had a significant effect on slopes. In the second analysis, in which differences in smolt weight within ponds were considered, a significant negative correlation between return rate and smolt weight was demonstrated, and there was a significant difference in slopes between ponds.

In exploring further the differences in performance of the fish in the four ponds it was noted that the medium-high-density group, the group with the highest return rate, had the highest condition factor of all groups. Furthermore, because of the strong weight gain of the fish in this pond, the food ration of this group was reduced in the later stages of rearing, resulting in a low food consumption (g food/g fish), and a relatively high food conversion efficiency (g weight gain/g food). Finally, the mortality rate in this pond was only 53.6% of that of the high-density pond, although the loading densities in the two ponds were similar. We do not have an explanation for these inconsistencies in performance of juveniles.

Ratio of returning males to females - The ratio of males to females in the total adult returns (Table 15) was calculated to be 1.31:1. At each density the ratio increased with size of juveniles, since size of juveniles affected female returns more than male returns. The effect of size on the ratio of males + jacks to females was even more pronounced, since the number of jacks increased with size. Density did not have a consistent effect on male to female ratio.

Weights and lengths of adults - The average weights of males and females (based on data from hatchery fish) was 1.70 kg and 2.20 kg, respectively (Table 16). Females thus weighed 29.4% more than males. They were also 10.0% longer. Weights and lengths of adults were not affected by ponding density in a consistent manner. The effect of size of juveniles within ponds was also mixed. Weights and lengths of males increased with smolt size at three of four densities, but for females a trend was not evident.

RETURNS FROM JUVENILES RELEASED IN 1984

Jacks

The majority of jacks returned to Quinsam Hatchery in 1984. A small number (max. 8 fish/10,000 released) was caught in the Canadian sports fishery (Table 17). These originated mainly from "large" smolts. Jacks comprised a larger portion of the total return from this brood, 13.1%, compared to 3.7% of the previous brood. Jack returns decreased strongly with increasing ponding density, in contrast to the previous years' return. In both years return rates of jack increased with increasing smolt size at each density; thus, "large" smolts returned at rates ranging from 3.2 to 5.7 times that of "small" smolts.

The average weight of jacks was 335 g (Table 21). As in the previous year there was a small but consistent increase in both weight and length of jacks with increasing smolt size, but density did not have a consistent effect.

Adults

Adult return rates - Adults returned mainly in 1985 (Table 17), with the exception of a small number returning in 1986 to the sports fishery. The average total return was 9.04% (904 per 10,000) of released smolts. Of these 19.7% returned to the hatchery. The sports fishery took the largest part, 55.5%, of fishery catches.

There was a statistically significant negative correlation between adult return rate and initial ponding density (Table 18, Fig. 3), in contrast to the previous year, when the correlation was not significant. However, the difference between size-groups was not significant, also in contrast to the previous years' results.

As in 1984 some ponds strongly deviated from the negative correlation of adult return rate with ponding density and consequently we again examined the effect of smolt weight by performing two analyses of regression of return rate on smolt weight (Table 19, Fig. 4). As in the previous year, when differences in smolt weight between ponds were considered there was a significant positive correlation between return rate and smolt weight of individual ponds. The effect of size-group was again significant and the interaction of size-group and smolt weight was not significant.

When differences in smolt weight within ponds were examined the correlation of adult return rate and smolt weight was significant and negative, as in the 1984 returns. Again the pond effect was significant and the interaction was not significant.

In reviewing the effect of density on adult return rates in this year it appears that the return rate of pond 3 shows the greatest deviation from the observed trend. However, the return rate of fish from this pond is well correlated with smolt weight, as shown above, since the pond had the lowest weight gain of all ponds. This occurred despite a relatively high food consumption. Also, the mortality rate of this group was high, when assessed on the basis of loading density.

Ratio of returning males to females - The ratio of males to females in the total adult returns was 0.98:1 (Table 20). In contrast to the previous year size of smolts did not have a consistent effect on the ratio, but there was a trend to higher ratios at higher densities.

Weights and lengths of adults - The average weights of males and females (based on hatchery data) was 2.31 and 2.94 kg, respectively (Table 21). These values are substantially higher than those for the previous brood year. Females thus weighed 27.3% more than males. They were also 9.2% longer.

Weights and lengths of adults were only weakly affected by ponding density. Generally a small increase in weight and length of adults was associated with increasing size (length) of smolts.

CONCLUSIONS

In a program to provide guidelines for setting ponding densities in Canadian west coast coho hatcheries juvenile survival to adulthood has been monitored for 3 brood years at Capilano Hatchery and 2 brood years at Quinsam Hatchery. There are important differences between the two hatcheries, the former being fed by cold water from the Capilano River and the latter mainly by ground water which maintains a relatively stable temperature. As a consequence, growth rates at Capilano are low and smolts often do not reach 15 g, while those at Quinsam often exceed 20 g under similar rearing regimes. One of the effects of the higher temperature at Quinsam is a higher disease incidence, which in our studies resulted in mortalities reaching 30% in some ponds. On the other hand the larger smolts should have a greater chance to survive predator attacks at time of entry into salt water and during subsequent ocean life. However, a comparison of survival rates between smolts from the two hatcheries in our studies show that the smaller Capilano smolts had a higher average survival rate with a range of 9.89 to 20.16%, depending on density and release year, compared to a range of 4.52 to 13.65% for Quinsam smolts held at similar densities.

The results presented here demonstrate in two brood years of Quinsam coho a statistically significant negative correlation between adult return rate and initial pond density. There was also a significant positive correlation between adult return rate and mean smolt weight when ponds were compared, which could be anticipated, since smolt weight tended to decrease with increasing pond density. However, an inverse relationship was found when return rates were correlated with smolt weight within ponds. We also carried out similar analyses with data for the combined returns of adults and jacks. These data have not been reported here. They show correlations similar to those for adult returns, with the exception that the correlation between return rate and smolt weight became positive in the second release year, in which there was a strong increase in number of jacks with increase in smolt size within a pond.

A significant decrease in adult return rate with increasing smolt weight within a pond has also been found by Bilton et al. (1988) in coho from two brood years released from Quinsam Hatchery. These results and those shown above contrast with results from the study carried out at Capilano Hatchery (Fagerlund et al. 1983) in which adult return rates increased with smolt weight within a pond. Data obtained in that study suggested that competition within a pond resulted in smaller fish being disadvantaged and therefore of inferior quality. There was evidence for similar differences between size-groups in the Quinsam studies (body composition, correlation of condition factor with length). The contrasting results from the two hatcheries therefore do not appear to be caused by factors related to the condition of the smolts, but perhaps to the characteristics of the environment into which the fish are released, e.g. the relative size of smolts and predators or smolts and food organisms. The reversal in the relationship between adult return rate and smolt weight, when return rates of individual ponds are compared may, however, be related to smolt condition. The decrease in mortality at lower densities suggests a decrease in stress level and consequently an increase in scope for survival, which may override the otherwise negative effect of the increase in size associated with lower densities.

ACKNOWLEDGEMENTS

This study was assisted by R. Reinhardt and staff at Quinsam Hatchery; by R. B. Morley and D. Brouwer; by staff from the Diagnostic Services Unit of the Pacific Biological Station; by S. N. Williscroft who provided return data and by M. Booth for finalizing the manuscript. We are grateful to T. Perry for reviewing the manuscript.

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TABLE 1. Number of fish ponded and performance data for groups of coho juveniles released in 1984.

	Density					
	1	2	3	4	5	6
	Low		Medium		High	
No. of fish ponded						
assumed	60,000	60,000	90,000	90,000	120,000	120,000
actual	51,850	56,780	76,767	83,066	98,756	101,738
Mortalities (%)*						
June-Nov.	2.77	5.56	10.66	7.54	16.90	17.95
Dec.-May	0.25	0.23	1.75	0.39	2.06	0.65
Weight gain (g)						
June-Oct.	9.73	8.44	8.33	8.20	8.78	8.51
Nov.-May	10.00	12.23	8.50	12.83	9.95	9.72
Food consumption (g/fish)						
June-Oct.	13.78	12.77	14.25	12.72	15.00	13.54
Nov.-May	24.23	24.70	25.74	25.52	26.40	26.92
Food conversion efficiency (g gain/g food)						
June-Oct.	0.71	0.66	0.59	0.65	0.59	0.63
Nov.-May	0.41	0.50	0.33	0.48	0.38	0.36

* Percent of actual initial density.

TABLE 2. Dissolved oxygen (mg L^{-1}), oxygen saturation (%), total ammonia content (mg L^{-1}) and pH of water entering and leaving density ponds.

		Density					
	Intake	1	2	3	4	5	6
April 24, 1984							
Dissolved oxygen	11.5	11.1	10.7	10.7	10.6	10.1	10.7
Saturation	100	96	93	93	92	88	93
Total ammonia	0	0.003	0.009	0.016	0.020	0.024	0.040
pH	7.43	7.47	7.64	7.55	7.38	7.45	7.30
May 9, 1984							
Dissolved oxygen	11.3	10.7	10.5	10.1	10.0	9.6	10.0
Saturation	100	95	93	89	88	85	88
Total ammonia	0	0.024	0.037	0.033	0.042	0.057	0.045
pH	7.51	7.44	7.49	7.44	7.41	7.41	7.43

TABLE 3. Weights and condition factors of coho juveniles raised at Quinsam Hatchery and released in 1984. Values are means and standard deviations of 300 fish, 150 from each of 2 replicate groups (except 125 fish in July).

	Density							
	Low		Medium		High		All densities	
Sampling date	X	SD	X	SD	X	SD	X	SD
Body weight (g)								
July 6, 1983	3.0	0.9	3.1	0.9	3.0	0.8	3.0	0.8
Oct. 26, 1983	10.9	2.9	10.1	2.6	10.4	2.5	10.5	2.7
Feb. 15, 1984	16.1	3.9	14.9	4.2	13.9	3.7	15.0	4.1
May 22, 1984	22.3	6.0	21.5	4.8	20.9	4.6	21.6	5.2
	(21.9, 22.7)*		(19.8, 23.2)		(21.1, 20.7)			
Condition factor								
July 6, 1983	7.27	0.45	7.24	0.47	7.18	0.52	7.23	0.48
Oct. 26, 1983	6.64	0.49	6.61	0.43	6.70	0.54	6.65	0.49
Feb. 15, 1984	6.12	0.42	6.06	0.46	6.08	0.46	6.09	0.45
May 22, 1984	4.91	0.49a**	5.09	0.75b	5.09	0.55b	5.03	0.61
	(4.93, 4.89)*		(5.06, 5.13)		(5.12, 5.06)			

* Means for replicates 1 and 2, respectively.

** Two-factor ANOVA's (density and replicate nested within density) showed significant effects of replicate only on both body weight and condition factor at the first three time points. However, in May, 1984 the affect of density but not replicate on condition factor was significant. Tukey's multiple range test, $\alpha = 0.05$

TABLE 4. Numbers, weights, lengths and condition factors of tagged coho smolts. Samples were removed on May 24 and stored frozen before measurements were taken. All fish were released on June 1, 1984.

Tag code	Density	Size group	No. of tagged fish released	Weight (g) X	Weight (g) SD	Length (cm) X	Length (cm) SD	Condition factor X	Condition factor SD	Sample size	Tag loss after 150 d (%)
8-22-38	1	Small	9686	18.5	2.9	12.3	0.6	5.34	0.43	89	
8-22-39	1	Medium	9636	21.1	3.5	12.8	0.6	5.30	0.37	97	3.20
8-22-40	1	Large	9637	24.9	5.1	13.4	0.8	5.33	0.53	97	
8-22-29	2	Small	9401	18.5	3.1	12.2	0.7	5.45	0.48	106	
8-22-30	2	Medium	9672	22.5	4.0	13.0	0.8	5.39	0.36	96	4.24
8-22-31	2	Large	9419	26.4	5.3	13.6	0.8	5.37	0.39	92	
8-22-32	3	Small	9153	16.1	3.2	11.8	0.7	5.31	0.56	80	
8-22-33	3	Medium	9111	18.6	4.2	12.4	0.8	5.20	0.56	90	6.78
8-22-34	3	Large	9122	21.2	4.2	12.9	0.8	5.16	0.50	98	
8-22-41	4	Small	9800	20.0	3.2	12.4	0.7	5.64	0.47	91	
8-22-42	4	Medium	9784	21.9	3.1	12.8	0.6	5.54	0.43	106	1.99
8-22-43	4	Large	9830	25.1	4.6	13.3	0.8	5.48	0.47	96	
8-22-35	5	Small	8731	18.3	3.3	12.1	0.9	5.51	0.67	89	
8-22-36	5	Medium	8686	20.3	3.1	12.5	0.6	5.53	0.47	72	10.74
8-22-37	5	Large	8778	23.0	4.0	13.0	0.8	5.53	0.49	69	
8-22-44	6	Small	9843	18.2	2.5	12.2	0.5	5.30	0.40	108	
8-22-45	6	Medium	9795	19.5	2.8	12.5	0.5	5.22	0.40	102	1.30
8-22-46	6	Large	9817	22.4	4.1	13.1	0.7	5.26	0.43	93	

Three-factor ANOVA's (density (N = 3), size group and replicate nested within density) showed no effects of density on weight, length or condition factor, but the effect of density x size-group on weight and length was significant. Tukey's multiple range test showed that weight and length in "medium" and "large" size-groups were significantly larger in low density ponds than in medium and high density ponds.

TABLE 5. Size (length) distribution (%) of tagged fish from three size groups in samples of 300 fish taken from each pond 6 months after tagging. Data are shown for all ponds combined and for each individual pond. Densities are given in Table 1.

Density	Tagging size	Size after 6 months		
		Small	Medium	Large
	Small	56.8	32.5	10.7
1 - 6	Medium	27.5	42.8	29.3
	Large	10.5	29.0	60.6
		94.8	104.3	101.0
	Small	61.8	30.3	7.9
1	Medium	25.8	47.4	26.8
	Large	11.3	18.6	70.1
	Total	98.9	96.3	104.8
	Small	67.0	28.3	4.7
2	Medium	21.9	43.8	34.4
	Large	4.3	33.7	62.0
	Total	93.2	105.8	101.1
	Small	58.8	35.0	6.3
3	Medium	30.0	41.1	28.9
	Large	10.2	32.7	57.1
	Total	99.0	108.8	92.3
	Small	56.0	28.6	15.4
4	Medium	29.2	44.3	26.4
	Large	11.5	31.3	57.3
	Total	96.7	104.2	85.1
	Small	53.9	29.2	16.9
5	Medium	27.8	43.1	29.2
	Large	14.5	29.0	56.5
	Total	96.2	101.3	102.6
	Small	44.4	42.6	13.0
6	Medium	30.4	37.3	32.4
	Large	11.8	29.0	59.1
	Total	86.6	108.9	104.5

TABLE 6. Skewness (g_1) in weight and length in samples of coho juveniles. Sample size was 125 in July, 1983 and 150 at all other times. Values are means ± SD of replicate ponds.

Time	Initial density Low	Medium	High	All ponds Mean	SD
Weight					
July 6, 1983	0.38	0.39	0.35	0.37[a]*	0.18
Oct. 26, 1983	0.03	0.20	0.43	0.22[a]	0.27
Feb. 15, 1984	0.82	0.95	1.10	0.96[b]	0.23
May 22, 1984	1.90	0.64	0.71	1.08[b]	0.69
All times Mean	0.78[c]	0.54[a]	0.65[b]		
SD	0.77	0.36	0.40		
Length					
July 6, 1983	- 0.14	- 0.21	- 0.24	- 0.19[a]	0.16
Oct. 26, 1983	- 1.04	- 0.39	- 0.19	- 0.54[a]	0.42
Feb. 15, 1984	0.26	0.46	0.37	0.36[b]	0.17
May 22, 1984	0.87	0.33	0.36	0.52[b]	0.32
All times Mean	- 0.01	0.05	0.08		
SD	0.76	0.42	0.33		

* ANOVA's followed by Tukey's test, $\alpha = 0.05$.

Probability levels (P):

	Weight	Length
Density	0.00	0.68
Time	0.00	0.00
Density x time	0.04	0.02
Replicate (density)	1.00	0.44

TABLE 7. Linear regression of condition factor on length of tagged smolts. Samples consisted of 100 fish from each size-group within a pond.*

Initial density	Size-group Small Slope	SE	Medium Slope	SE	Large Slope	SE	All sizes Slope	SE
Low	- 0.25	0.05	- 0.12	0.05	- 0.12	0.04	- 0.15	0.02
Medium	- 0.12	0.05	- 0.14	0.04	- 0.12	0.04	- 0.16	0.02
High	- 0.42	0.05	- 0.22	0.06	- 0.27	0.05	- 0.28	0.03
All densities	- 0.30[a]	0.03	- 0.19[b]	0.03	- 0.19[b]	0.02	- 0.22	0.02

* A 3-factor analysis of covariance (density, size, replicate nested within density and a single covariate, length) was performed with replicate being treated as a random factor. The analysis showed that the effect of length on condition factor was significant ($P = 0.008$). Size and replicate had significant effects on slopes at $P = 0.01$ and $P = 0.008$, respectively, but density did not affect slopes ($P = 0.4$). Values carrying identical superscripts are not significantly different (Bonferroni's test, $\alpha = 0.05$).

TABLE 8. Body composition (%) of juvenile coho taken July 6, 1983 from Quinsam Hatchery. Values are means and standard errors of the mean (SEM) or standard deviations (SD) of 10 samples from each of two replicate ponds. Each sample consisted of 8 fish. "Dry composition" is the content of a constituent as percent of dry matter. Two-factor ANOVA's ($\alpha = 0.05$) (density and replicate nested within density) did not indicate significant differences between density groups.

	Density Low	Medium	High	SEM	All densities Mean	SD
Moisture	76.69	76.83	77.05	0.12	76.85	0.53
Protein	14.71	14.51	14.53	0.09	14.58	0.42
Lipid	5.87	5.92	5.97	0.08	5.92	0.37
Ash	2.20	2.20	2.10	0.03	2.16	0.16
Dry protein	63.12	62.65	63.30	0.43	63.02	1.92
Dry lipid	25.19	25.53	26.01	0.32	25.57	1.46
Dry ash	9.43	9.48	9.13	0.14	9.35	0.70

TABLE 9. Body composition (%) of juvenile coho taken October 26, 1983 from Quinsam Hatchery. Values are means and standard errors of the mean (SEM) or standard deviations (SD) of eight samples from each of two replicate ponds. Each sample consisted of four fish.

	Density Low	Medium	High	All densities
Moisture				
Small	71.97	72.31	71.63	71.97[b*]
Medium	71.07	71.77	71.39	71.41[ab]
Large	71.02	71.27	70.44	70.91[a]
SEM		0.19		0.11
All sizes	71.35	71.78	71.15	71.43
SEM		0.11		0.96 (SD)
Protein				
Small	16.77	16.80	16.94	16.84
Medium	16.85	16.92	17.01	16.93
Large	16.77	16.86	17.19	16.93
SEM		0.11		0.07
All sizes	16.79	16.86	17.05	16.90
SEM		0.07		0.53
Lipid				
Small	8.38	8.27	8.64	8.43[a]
Medium	9.16	8.86	9.09	9.04[b]
Large	9.40	9.53	9.64	9.52[c]
SEM		0.13		0.08
All sizes	8.98	8.88	9.12	9.00
SEM		0.08		0.72 (SD)
Ash				
Small	2.44	2.42	2.44	2.43[b]
Medium	2.30	2.35	2.40	2.35[ab]
Large	2.38	2.33	2.30	2.33[a]
SEM		0.05		0.03
All sizes	2.37	2.36	2.38	2.37
SEM		0.03		0.22 (SD)

* Three-factor ANOVAs (density, size and replicate nested within density) showed significant effects as follows ($\alpha = 0.05$):

Body constituent	Variable
Moisture	Size
Protein	Rep (density)
Lipid	Size
Ash	Rep (density), size

TABLE 10. Body composition (%) of juvenile coho taken February 15, 1984 from Quinsam Hatchery. Values are means and standard errors of the mean (SEM) or standard deviations (SD) of ten samples from each of two replicate ponds. Each sample consisted of three fish.

	Density Low	Medium	High	All densities
Moisture				
Small	73.38	73.99	73.45	73.62[c]
Medium	72.76	72.73	73.34	72.94[b]
Large	72.43	72.12	72.16	72.24[a]
SEM		0.14		0.08
All sizes	72.85	72.95	72.99	72.93
SEM		0.08		0.97 (SD)
Protein				
Small	16.49	16.44	16.51	16.48
Medium	16.55	16.54	16.85	16.65
Large	16.52	16.66	16.79	16.69
SEM		0.08		0.04
All sizes	16.55	16.55	16.72	16.61
SEM		0.04		0.39 (SD)
Lipid				
Small	7.58	6.72	7.03	7.11[a]
Medium	8.29	8.16	7.58	8.00[b]
Large	8.54	8.77	8.55	8.61[c]
SEM		0.14		0.08
All sizes	8.14	7.88	7.71	7.91
SEM		0.08		0.94 (SD)
Ash				
Small	2.43	2.52	2.53	2.49
Medium	2.42	2.27	2.40	2.36
Large	2.37	2.43	2.46	2.42
SEM		0.04		0.03
All sizes	2.40	2.41	2.47	2.43
SEM		0.03		0.22 (SD)

* Three-way ANOVAs (density, size and replicate nested within density) showed significant effects as follows ($\alpha = 0.05$):

Body constituent	Variable
Moisture	Rep (density), size, rep (density) x size
Protein	Rep (density) x size
Lipid	Size, rep (density) x size
Ash	Rep (density) x size

TABLE 11. Body composition (%) of juvenile coho taken shortly before release May 24, 1984 from Quinsam Hatchery. Values are means and standard errors of the mean (SEM) or standard deviations (SD) of eight samples from each of two replicate ponds. Each sample consisted of four fish. For method of calculating "dry composition" see Materials and Methods.

	Density Low	Medium	High	All densities
Moisture				
Small	77.74[c*]	76.74[ab]	76.78[ab]	77.09
Medium	77.29[bc]	76.89[ab]	76.49[ab]	76.89
Large	76.90[ab]	76.79[ab]	76.86[ab]	76.85
SEM		0.16		0.09
All sizes	77.31	76.81	76.71	76.94
SEM		0.09		0.76 (SD)
Protein				
Small	16.50	17.42	17.34	17.09
Medium	16.90	17.66	17.14	17.23
Large	16.95	17.59	17.24	17.26
SEM		0.13		0.08
All sizes	16.78	17.56	17.24	17.19
SEM		0.08		0.76 (SD)
Lipid				
Small	2.84	2.95	3.12	2.97
Medium	3.17	2.88	3.17	3.02
Large	3.30	3.15	3.13	3.19
SEM		0.11		0.06
All sizes	3.10	3.00	3.14	3.08
SEM		0.06		0.49 (SD)
Ash				
Small	2.28	2.64	2.50	2.47
Medium	2.32	2.67	2.59	2.53
Large	2.72	2.62	2.57	2.64
SEM		0.07		0.04
All sizes	2.44	2.64	2.55	2.54
SEM		0.04		0.32 (SD)
Dry protein				
Small	74.11[ab]	74.92[abc]	74.69[abc]	74.57
Medium	74.37[abc]	76.48[c]	72.95[a]	74.60
Large	73.34[a]	75.85[bc]	74.59[abc]	74.60
SEM		0.63		0.36
All sizes	73.94	75.75	74.08	74.59
SEM		0.36		3.08 (SD)

TABLE 11 (con't)

	Density Low	Medium	High	All densities
Dry lipid				
Small	12.72	12.68	13.44	12.95
Medium	13.93	12.45	13.45	13.28
Large	14.25	13.55	13.49	13.76
SEM		0.44		0.25
All sizes	13.63	12.89	13.46	13.33
SEM		0.25		1.90 (SD)
Dry ash				
Small	10.24	11.36	10.74	10.78
Medium	10.20	11.55	11.03	10.93
Large	11.79	11.29	11.09	11.39
SEM		0.29		0.16
All sizes	10.75	11.40	10.96	11.03
SEM		0.16		1.30 (SD)

* Three-factor ANOVA's (density, size and replicate nested within density)showed significant effects as follows ($\alpha = 0.05$):

Body constituent	Variable
Moisture	Rep (density), density x size
Protein	Rep (density)
Lipid	Nil
Ash	Nil
Dry protein	Rep (density), density x size
Dry lipid	Nil
Dry ash	Nil

TABLE 12. Numbers of adults (1984 and 1985 returns) and jacks (1983 returns) originating from smolts released 1983 from Quinsam Hatchery. Values represent estimated (see text) returns per 10,000 tagged fish released. The 1985 return consisted of 8 four year old fish (per 10,000 released) caught in the Canadian sports fishery.

		Adults							Jacks	
		Canadian fishery								
Initial no. in pond	Size	Troll	Net	Sports	U.S. fishery	Fishery total	Escapement	Total	Total	Grand total
72,988	Small	110	89	179	12	390	226	616	11	627
	Medium	121	113	153	5	392	210	602	22	624
	Large	98	73	160	0	331	136	467	50	517
Pond mean		110	92	164	6	371	191	562	28	589
89,506	Small	160	77	193	5	435	170	605	3	608
	Small	150	63	93	5	311	148	459	0	459
	Small	164	98	88	0	350	189	539	5	544
Size mean		158	79	125	3	365	169	534	3	537
	Medium	77	58	92	0	227	121	348	3	351
	Medium	116	35	88	0	239	151	390	16	406
	Medium	107	96	125	0	328	125	453	24	477
Size mean		100	63	102	0	265	132	397	14	411
	Large	86	91	74	0	251	98	349	20	369
	Large	124	41	100	0	265	112	377	24	401
	Large	97	32	137	10	276	155	431	25	456
Size mean		102	55	104	3	264	122	386	23	409
Pond mean		120	66	110	2	298	141	439	13	452

Table 12 (con't)

117,434	Small	173	86	234	10	503	214	717	10	727
	Medium	116	90	221	3	430	157	587	13	600
	Large	109	63	138	0	310	111	421	35	456
Pond mean		133	80	198	4	414	161	575	19	594
121,326	Small	101	62	143	0	306	186	492	10	502
	Medium	119	61	97	0	277	113	390	15 (5)*	405
	Large	75	76	98	3	252	101	353	25	378
Pond mean		98	66	113	1	278	133	412	17	428
Overall mean		115	76	146	3	340	157	497	19	516

* The number for total jacks includes five fish (bracketed) caught in the sports fishery.

TABLE 13. Linear regression of return rate of adults on pond density (in 1000's of fish), 1983 smolt release. In the case of pond 2 three replicates were used. A one-way analysis of covariance with comparison of slopes was performed using size-group as the factor and density as the covariate.

Analysis of covariance

Source	F	P
Size group	4.9	0.028
Density	0.1	0.748
Size group x density	0.1	0.882

Return rates and covariate slopes

		Size group			
		Small	Medium	Large	All sizes
Return rate	Mean	571.3	461.7	399.7	477.6
	SD	94.1	108.3	47.4	109.8
Slope		0.5	- 0.6	- 1.1	- 0.4
	SE	2.3	2.3	2.3	1.3

TABLE 14. Linear regression of return rate of adults on weight of smolts, 1983 smolt release. Two separate one-way analyses of covariance (with comparisons of slopes) were performed. The first (A) used size group as the factor with smolt weight as the covariate, and the second (B) used pond as the factor with smolt weight as the covariate.

A. Individual lines for each size. For pond 2 three replicates were used for each size.

Analysis of covariance

Source		F	P
Size group	(adjd. for sm.v.)	10.0	0.003
Smolt weight	(adjd. for s.g.)	8.5	0.012
Size group x smolt weight	(adjd. for sm.v and s.g.)	1.1	0.357

Return rates and covariate slopes

		Size group			
		Small	Medium	Large	All sizes
Return rate	Mean	571.3	461.7	399.7	477.6
	SD	94.1	108.3	47.4	109.8
Slope		- 0.61	61.7	27.6	39.6
	SE	46.7	20.9	19.3	13.5

B. Individual lines for each pond. For pond 2 average values of three replicates were used.

Analysis of covariance

Source		F	P
Pond number	(adjd. for sm.v.)	6.8	0.010
Smolt weight	(adjd. for p.n.)	3.0	0.005
Pond x smolt weight	(adjd. for sm.v and p.n.)	1.5	0.353

Return rates and covariate slopes

		Pond number				
		1	2	3	4	All ponds
Return rate	Mean	561.7	439.0	575.0	411.7	496.8
	SD	82.3	82.5	148.0	72.0	114.5
Slope		- 17.7	- 21.5	- 40.9	- 28.0	- 26.3
	SE	7.5	9.9	8.7	12.6	4.6

TABLE 15. Calculated total numbers of males and females originating from the 1983 release of coho smolts. The numbers of adult males and females was obtained by applying the ratio of males to females found in the escapement (♂/♀ column) to the total numbers of adults. Numbers of sexed fish in the escapement are shown in brackets.

Initial no. per pond	Size group	♂/♀	♂	Jacks	♂ + jacks	♀
72,988	Small	1.06 (165)	317	11	328	299
	Medium	1.11 (152)	317	22	339	285
	Large	1.55 (101)	284	50	334	183
Pond mean		1.20	306	28	334	256
89,506	Small	1.35 (54)	348	3	351	257
	Small	1.04 (47)	234	0	234	225
	Small	1.61 (60)	333	5	338	206
Size mean		1.33	305	3	308	229
	Medium	1.18 (37)	188	3	191	160
	Medium	1.10 (44)	202	16	218	188
	Medium	2.36 (37)	318	24	342	135
Size mean		1.47	236	14	250	161
	Large	3.00 (32)	262	20	282	87
	Large	1.77 (36)	241	24	265	136
	Large	1.23 (49)	238	25	263	193
Size mean		1.78	247	23	270	139
Pond mean		1.49	263	13	276	176
117,434	Small	1.11 (158)	377	10	387	340
	Medium	1.32 (116)	334	13	347	253
	Large	1.42 (87)	247	35	282	174
Pond mean		1.25	319	19	339	256
121,326	Small	1.10 (122)	258	10	268	234
	Medium	1.55 (74)	237	15	252	153
	Large	1.64 (66)	219	25	244	134
Pond mean		1.37	238	17	255	174
Overall mean		1.31	282	19	301	216

* Means for ♂/♀ were derived from ♂ and ♀ means.

TABLE 16. Weights and lengths of jacks and adults (1983 smolt release) sampled at the hatchery or in the commercial fishery. Values for males plus females and "pond" and "size" means are weighted by numbers for total returns and thus assume that the male to female ratio in hatchery returns applies to total returns. Escapement lengths are hypural-post orbital but fishery lengths are fork lengths. Fish sampled in the fishery were not sexed.

		Hatchery																		Fishery		
		Weight (kg)									Length (mm)									Weight (kg)	Length (mm)	
Initial no. in pond	Size group	Jacks			♂			♀			Jacks			♂			♀					
		$\bar{X}$	SD	No.	$\bar{X}$	SD	No.	$\bar{X}$	SD	No.	$\bar{X}$	SD	No.	$\bar{X}$	SD	No.	$\bar{X}$	SD	No.	$\bar{X}$	$\bar{X}$	No.
72,988	Small	0.28	0.07	8	1.69	0.86	27	2.25	0.56	27	232	16	10	409	52	68	464	47	67	1.96	535	47
	Medium	0.30	0.06	16	1.62	0.49	32	2.34	0.62	32	243	12	18	424	46	63	469	40	63	1.96	524	50
	Large	0.33	0.07	41	1.97	1.09	21	2.29	0.63	15	244	16	47	423	64	48	463	45	34	2.10	528	37
Pond mean		0.315			1.76			2.29			242			418			465			2.00	529	
89,506	Small	-	-	-	1.81	0.67	10	2.31	0.31	4	196	-	1	414	49	22	457	46	15	2.02	527	21
	Small	-	-	-	1.54	0.37	6	2.10	0.60	13	244	-	1	409	52	15	460	43	21	1.81	515	27
	Small	0.28	-	1	1.33	0.42	16	2.25	0.70	8	237	10	2	406	47	31	451	47	21	1.68	525	20
Size mean		0.280			1.57			2.23			222			410			457			1.83	524	
	Medium	0.23	-	1	1.75	0.65	10	2.12	0.88	7	250	-	1	434	72	18	441	45	15	1.92	541	16
	Medium	0.27	0.05	5	1.17	0.18	3	2.47	1.13	10	235	12	6	419	57	18	473	53	20	1.79	507	10
	Medium	0.32	0.07	8	1.76	0.70	12	2.05	-	1	244	19	8	419	45	25	457	37	8	1.85	541	16
Size mean		0.295			1.59			2.24			241			423			458			1.85	530	
	Large	0.28	0.07	8	1.59	0.87	5	1.84	0.14	2	238	14	8	410	57	19	469	21	7	1.64	511	16
	Large	0.32	0.05	10	1.53	0.76	7	1.53	0.04	2	237	16	10	404	47	19	458	45	13	1.53	530	13
	Large	0.31	0.06	9	2.03	1.13	12	2.62	1.20	4	244	18	10	441	62	22	478	51	18	2.30	519	12
Size mean		0.305			1.71			2.10			240			418			469			1.88	520	
Pond mean		0.300			1.62			2.20			239			416			461			1.85	525	
117,434	Small	0.31	0.11	8	1.66	0.68	26	2.21	0.75	31	238	24	9	416	51	68	464	46	63	1.92	537	55
	Medium	0.30	0.08	12	1.74	0.66	22	2.10	0.68	17	237	17	12	428	49	54	461	42	40	1.90	526	47
	Large	0.33	0.08	31	1.47	0.80	12	1.97	0.58	14	244	17	32	418	58	40	454	42	32	1.68	519	38
Pond mean		0.320			1.64			2.12			241			421			460			1.86	527	
121,326	Small	0.31	0.11	8	1.62	0.65	19	1.99	0.65	25	238	24	9	415	52	54	444	40	49	1.80	522	30
	Medium	0.30	0.08	12	1.91	0.89	15	2.11	0.80	9	237	17	12	418	62	37	455	45	20	1.99	529	29
	Large	0.33	0.08	31	1.94	0.80	14	2.59	0.69	11	244	17	32	434	50	34	464	49	21	2.19	525	30
Pond mean		0.317			1.81			2.18			241			422			452			1.95	525	
Overall mean		0.310			1.70			2.20			241			419			461			1.91	525	

TABLE 17. Numbers of adults (1985 and 1986 returns) and jacks (1984 returns) originating from smolts released in 1984 from Quinsam Hatchery. Values represent estimated (see text) returns per 10,000 tagged fish released. The 1986 return consisted of 4 four year old fish (per 10,000 released) caught in the Canadian sports fishery.

		Adults							Jacks	
		Canadian fishery			U.S.	Fishery				Grand
Initial no. in pond	Size group	Troll	Net	Sports	fishery	total	Escapement	Total	Total	total
51,850	Small	127	179	518	22	846	204	1050	66	1116
	Medium	145	143	420	17	725	222	947	126	1073
	Large	145	194	461	3	803	171	974	326	1300
Pond mean		139	172	466	14	791	199	990	173	1163
56,601	Small	160	179	576	18	933	265	1198	86	1284
	Medium	189	217	572	8	986	224	1210	187	1397
	Large	118	209	420	2	749	189	938	476 (2)*	1414
Pond mean		156	202	523	9	889	226	1115	250	1365
Low density mean		148	187	495	12	840	213	1053	212	1264
76,767	Small	152	131	313	8	604	157	761	31	792
	Medium	106	163	356	1	626	134	760	73	833
	Large	110	156	285	12	563	146	709	178	887
Pond mean		123	150	318	7	598	146	743	94	837
83,066	Small	153	179	372	17	721	220	941	70	1011
	Medium	147	240	381	4	772	201	973	127	1100
	Large	110	184	365	46	705	148	853	228 (6)	1081
Pond mean		137	201	373	22	733	190	922	142	1064
Medium density mean		130	176	346	15	665	168	833	118	951

TABLE 17 (con't)

98,756	Small	94	182	361	21	658	178	836	45	881
	Medium	99	200	403	20	722	147	869	54 (4)	923
	Large	118	230	395	2	745	161	906	158 (8)	1064
Pond mean		104	204	386	14	708	162	870	86	956
101,738	Small	122	159	366	6	653	153	806	30	836
	Medium	126	170	395	3	694	158	852	46	898
	Large	117	160	281	7	565	127	692	126	818
Pond mean		122	163	347	5	637	146	783	67	851
High density mean		113	184	367	10	673	154	827	77	903
Overall mean		130	182	403	12	726	178	904	136	1039

* Numbers in brackets are those of jacks caught in the Canadian sports fishery. These are included in the jack totals.

TABLE 18. Linear regression of return rate of adults on pond density (in 1000's of fish), 1984 smolt release. A one-way analysis of covariance (with comparison of slopes) was performed using size-group as the factor and density as the covariate.

Analysis of covariance

Source	F	P
Size group	1.0	0.384
Density	9.3	0.010
Size group x density	0.3	0.750

Return rates and covariate slopes

		Size group			
		Small	Medium	Large	All sizes
Return rate	Mean	932.0	935.2	845.3	904.2
	SD	166.8	154.3	119.2	145.6
Slope		- 6.2	- 4.2	- 3.5	- 4.7
	SE	2.6	2.6	2.6	1.5

TABLE 19. Linear regression of return rate of adults on weight of smolts, 1984 smolt release. Two separate one-way analyses of covariance (with comparison of slopes) were performed as for the 1983 release.

A. Individual lines for each size.

Analysis of covariance

Source		F	P
Size group	(adjd. for sm.v.)	7.0	0.010
Smolt weight	(adjd. for s.g.)	12.1	0.005
Size group x smolt weight	(adjd. for sm.v and s.g.)	0.6	0.559

Return rates and covariate slopes

		Size group			
		Small	Medium	Large	All sizes
Return rate	Mean	932.0	935.0	845.3	904.2
	SD	166.8	154.3	119.2	145.6
Slope		61.6	95.9	48.0	64.6
	SE	40.8	34.7	26.2	18.6

B. Individual lines for each pond.

Analysis of covariance

Source		F	P
Pond number	(adjd. for sm.v.)	15.0	0.002
Smolt weight	(adjd. for p.n.)	7.7	0.032
Pond x smolt weight	(adjd. for sm.v and p.n.)	1.1	0.446

Return rates and covariate slopes

		Pond number						All
		1	2	3	4	5	6	sizes
Return rate	Mean	990.3	1115.3	743.3	922.3	870.3	783.3	904.2
	SD	53.4	153.7	29.7	62.1	35.0	82.4	145.6
Slope		- 10.5	- 32.8	- 10.3	- 19.4	14.8	- 31.8	- 17.9
	SE	14.1	11.5	17.7	17.5	19.2	21.0	6.4

TABLE 20. Calculated total numbers of males and females originating from the 1984 release of coho smolts. The numbers of adult males and females was obtained by applying the ratio of males to females found in the escapement (♂/♀ column) to the total numbers of adults. Numbers of sexed fish in the escapement are shown in brackets.

Initial no. per pond	Size group	♂/♀	♂	Jacks	♂ + jacks	♀
51,850	Small	0.95 (185)	512	66	578	538
	Medium	0.84 (199)	432	126	558	515
	Large	0.94 (155)	472	326	798	502
Pond mean		0.91	472	173	645	518
56,601	Small	0.81 (231)	536	86	622	662
	Medium	0.81 (203)	541	187	728	669
	Large	0.86 (164)	434	476	910	504
Pond mean		0.82	504	250	763	612
Low density mean		0.86	488	212	704	565
76,767	Small	1.23 (134)	420	31	451	341
	Medium	1.19 (114)	413	73	486	347
	Large	1.14 (124)	378	178	556	331
Pond mean		1.19	404	94	498	340
83,066	Small	0.87 (202)	438	70	508	503
	Medium	1.10 (185)	510	127	637	463
	Large	0.81 (136)	382	228	610	471
Pond mean		0.93	443	142	585	479
Medium density mean		1.03	424	118	542	410
98,756	Small	1.23 (145)	461	45	506	375
	Medium	0.90 (120)	412	54	466	457
	Large	1.03 (132)	460	158	618	446
Pond mean		1.04	444	86	530	426
101,738	Small	0.97 (140)	397	30	427	409
	Medium	1.30 (145)	482	46	528	370
	Large	1.04 (116)	353	126	479	339
Pond mean		1.10	411	67	478	373
High density mean		1.07	428	77	504	400
Overall mean		0.98	447	136	583	458

TABLE 21. Weights and lengths of jacks and adults (1984 smolt release) sampled at the hatchery or in the commercial fishery. Values for males plus females and "pond", "density and "overall" means are weighted by numbers for total returns and thus assume that the male to female ratio in hatchery returns applies to the total returns. Escapement lengths are hyperal-post orbital but fishery lengths are fork lengths. Fish sampled in the fishery were not sexed.

		Hatchery																		Fishery		
		Weight (kg)									Length (mm)									Weight (kg)	Length (mm)	
Initial no.		Jacks			♂			♀			Jacks			♂			♀					
per pond	size	X	SD	No.	X	SD	No.	X	SD	No.	X	SD	No.	X	SD	No.	X	SD	No.	X	X	No.
51,850	Small	0.336	0.13	16	2.43	1.13	51	2.62	0.73	50	238	22	37	461	55	88	491	41	93	2.53	584	71
	Medium	0.351	0.07	28	2.11	0.96	50	2.99	0.85	47	248	33	58	449	61	88	499	42	102	2.59	587	67
	Large	0.353	0.08	82	2.62	1.23	36	2.82	0.99	36	247	16	165	464	61	70	491	47	76	2.72	590	82
Pond mean		0.350			2.40			2.81			246			458			494			2.61	586	
56,601	Small	0.333	0.05	27	2.17	0.90	46	2.98	0.94	57	241	12	42	453	54	100	495	46	121	2.61	586	72
	Medium	0.332	0.05	41	2.35	1.02	39	2.95	0.80	45	244	14	94	460	60	81	504	44	108	2.68	590	77
	Large	0.359	0.07	131	2.64	0.85	36	3.02	0.85	46	248	15	232	470	53	74	502	41	86	2.84	580	71
Pond mean		0.349			2.37			2.98			246			460			500			2.70	586	
Low density mean		0.349			2.39			2.90			246			459			497			2.65	586	
76,767	Small	0.287	0.04	6	2.30	0.87	27	2.60	0.86	32	227	10	10	454	54	68	484	47	57	2.43	584	54
	Medium	0.340	0.08	15	2.00	1.00	34	3.02	0.93	22	245	14	34	443	59	59	497	44	51	2.47	584	57
	Large	0.355	0.07	48	2.28	0.93	27	3.18	0.98	25	245	13	90	461	55	64	499	51	52	2.94	600	62
Pond mean		0.326			2.19			2.93			243			452			493			2.61	589	
83,066	Small	0.348	0.07	20	2.30	1.00	50	2.85	0.91	59	240	16	39	458	56	89	492	48	107	2.59	580	82
	Medium	0.326	0.06	36	2.58	1.10	42	3.00	0.97	40	239	15	65	464	48	94	501	44	86	2.78	601	90
	Large	0.356	0.05	49	2.31	1.04	42	3.22	0.69	32	247	16	105	456	56	56	502	39	73	2.81	590	82
Pond mean		0.345			2.41			3.02			243			460			498			2.71	590	
Medium density mean		0.345			2.30			2.98			243			456			495			2.67	590	
98,756	Small	0.321	0.06	7	2.12	0.89	34	2.90	0.88	32	241	13	17	446	54	79	492	50	64	2.47	584	65
	Medium	0.324	0.06	12	2.55	1.11	31	3.11	1.00	19	238	14	20	467	56	55	500	48	57	2.84	596	66
	Large	0.330	0.05	29	2.40	0.91	33	3.02	0.87	33	253	75	66	455	61	62	504	42	62	2.71	599	74
Pond mean		0.326			2.35			3.01			247			456			499			2.66	593	
101,738	Small	0.317	0.07	7	1.85	0.67	30	2.74	0.64	36	232	19	11	436	48	64	494	43	68	2.30	591	63
	Medium	0.309	0.06	13	2.12	0.83	44	2.88	0.93	33	234	14	20	450	49	79	501	46	63	2.45	582	61
	Large	0.338	0.06	36	2.49	0.98	27	3.02	0.71	16	241	15	66	458	60	59	502	38	54	2.75	592	66
Pond mean		0.330			2.14			2.87			239			447			498			2.48	588	
High density mean		0.326			2.24			2.94			242			451			498			2.57	590	
Overall mean		0.343			2.31			2.94			244			455			497			2.63	588	

Fig. 1. Total number of returning adults per 10,000 smolts released in 1983 versus initial number of fish in a pond. Individual regression lines are shown for "small", "medium" and "large" size-groups. Groups in the medium-low-density pond are represented by three replicates.

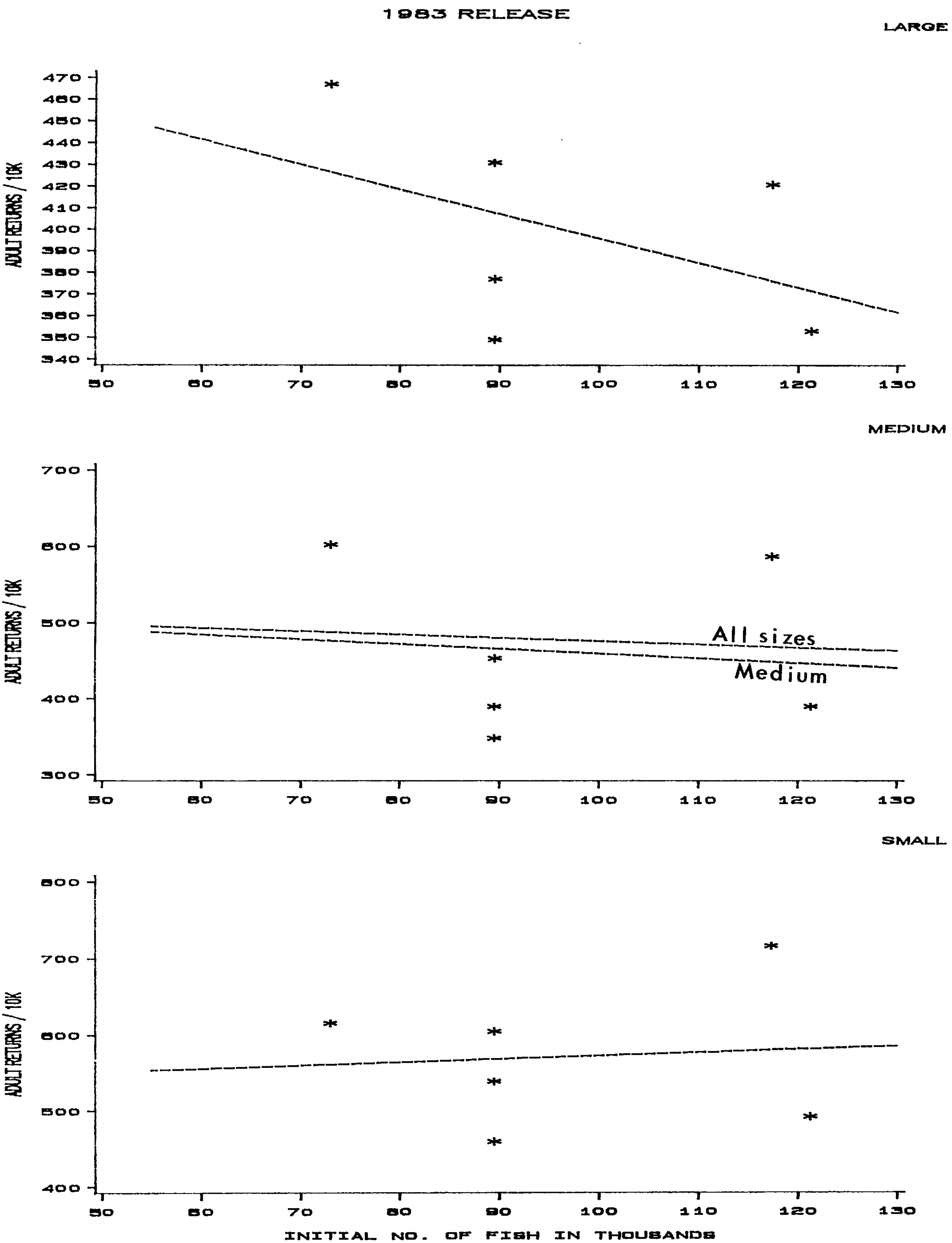
1983 RELEASE
LARGE
ADULT RETURNS / 10K
470
460
450
440
430
420
410
400
390
380
370
360
350
340
50
60
70
80
90
100
110
120
130
MEDIUM
ADULT RETURNS / 10K
700
600
500
400
300
All sizes
Medium
50
60
70
80
90
100
110
120
130
SMALL
ADULT RETURNS / 10K
800
700
600
500
400
50
60
70
80
90
100
110
120
130
INITIAL NO. OF FISH IN THOUSANDS

Fig. I

Fig. 2. Total number of returning adults per 10,000 smolts released in 1983 versus weight of smolts (solid lines). Points for "small", "medium" and "large" size-groups are connected by solid lines. Individual points for the three replicates of medium-low-density groups are marked by ◇, X, △, respectively. Broken lines show linear regression for each size-group. Ponds are numbered in order of increasing density (see Table 12).

1983 RELEASE

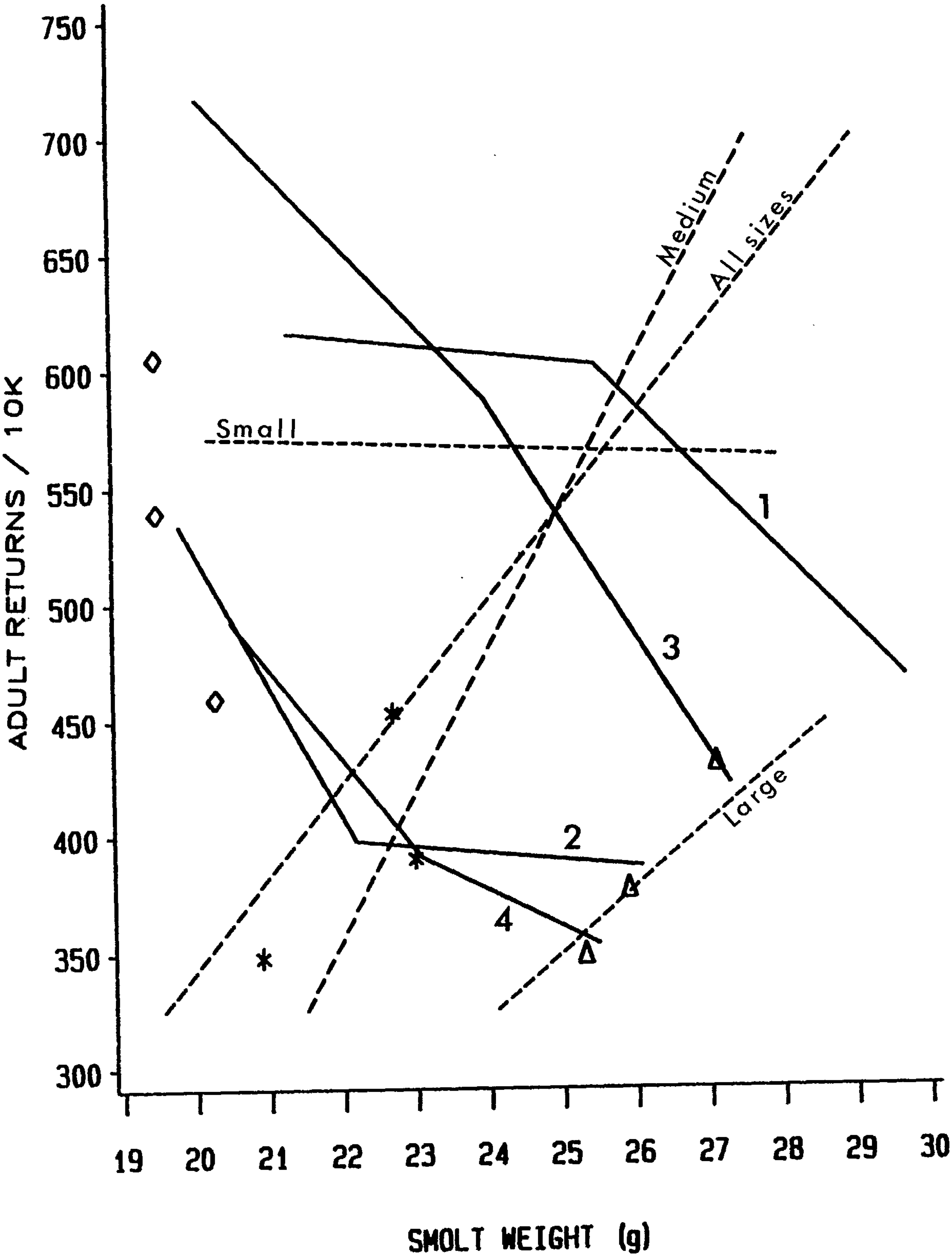

Fig. 2

Fig. 3. Total number of returning adults per 10,000 smolts released in 1984 versus initial number of fish in a pond. Individual regression lines are shown for "small", "medium" and "large" size-groups.

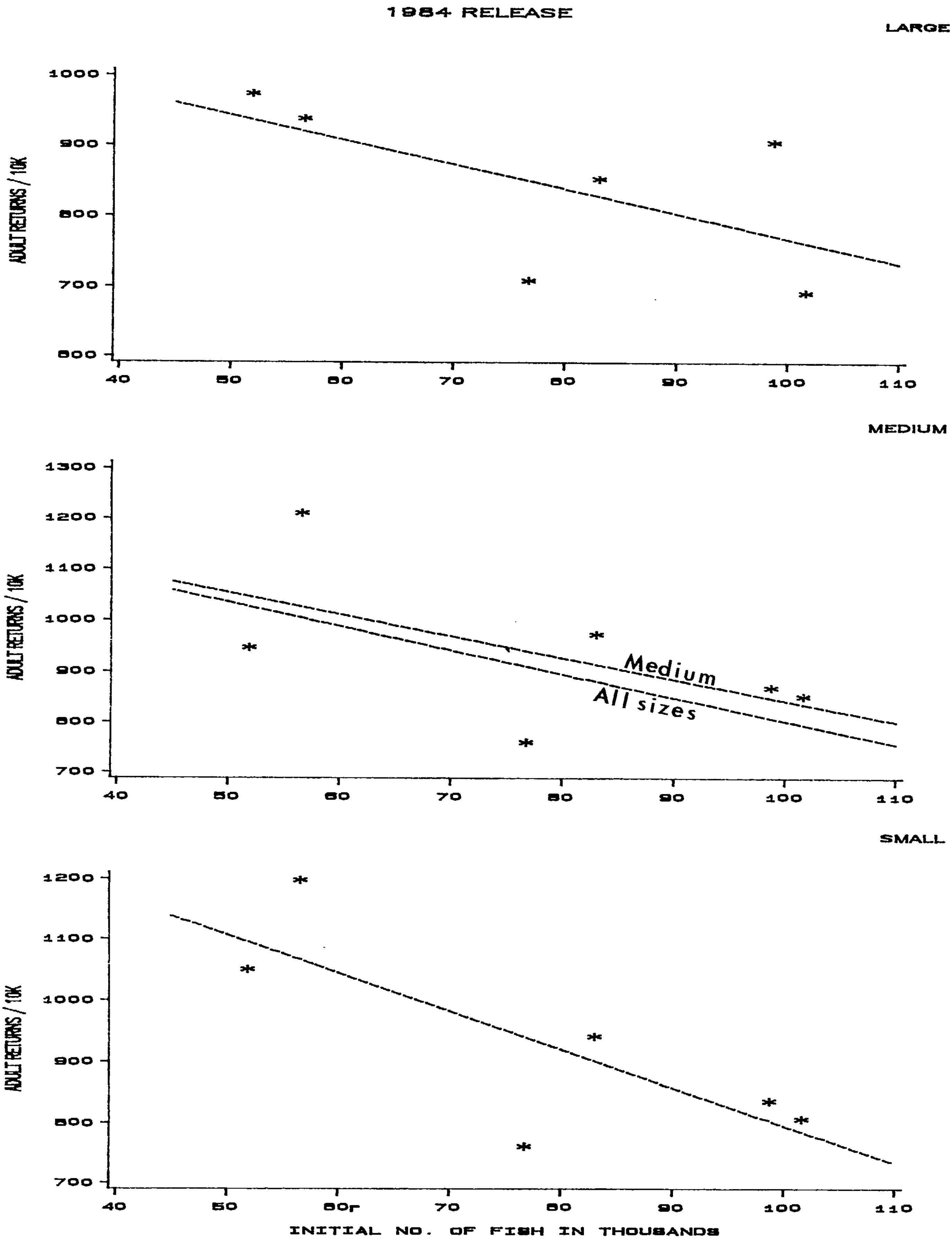
1984 RELEASE
LARGE
ADULT RETURNS / 10K
1000
900
800
700
600
40
50
60
70
80
90
100
110
MEDIUM
1300
1200
1100
1000
900
800
700
Medium
All sizes
SMALL
1200
1100
1000
900
800
700
INITIAL NO. OF FISH IN THOUSANDS

Fig. 3

Fig. 4. Total number of returning adults per 10,000 smolts released in 1984 versus weight of smolts. Points for "small", "medium" and "large" size-groups are connected by solid lines. Broken lines show linear regression for each size-group. Ponds are numbered in order of increasing density (see Table 1).

1984 RELEASE

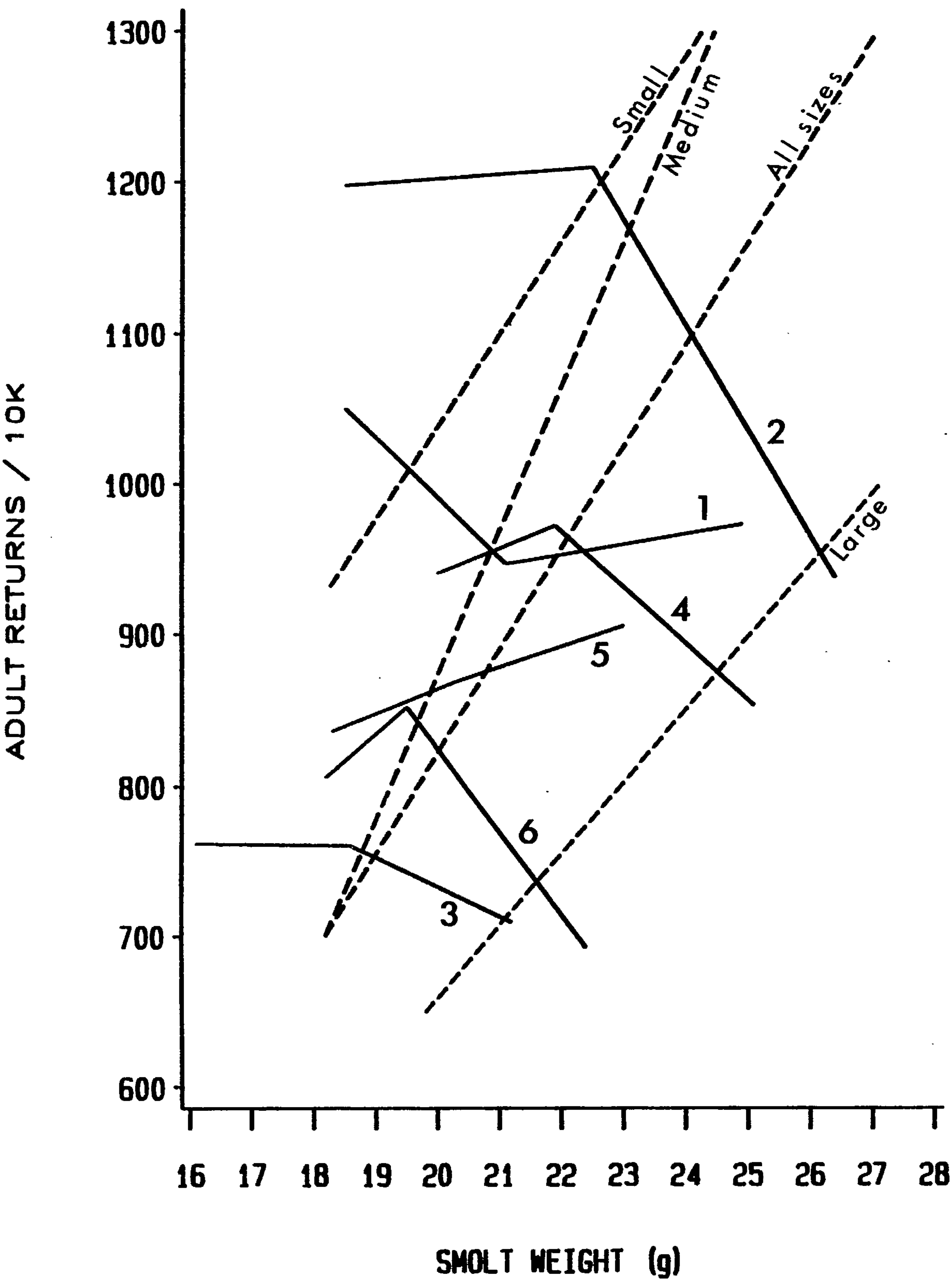

Fig. 4