Nutrition and Marine Survival of Chinook Salmon *(Oncorhynchus tshawytscha)*

II. Further Investigation of the Potential Role of Smolt Body Composition (Robertson Creek Hatchery 1980 Brood)

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by

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ABSTRACT

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Two studies were conducted at Robertson Creek Hatchery to investigate the influence of dietary lipid level or protein to lipid ratio on chinook salmon growth, body proximate and lipid composition and marine survival. The findings of the first study have been reported (Plotnikoff et al. 1983). In the second study, triplicate groups of approximately 7,000 chinook swim-up fry were assigned to each of three dietary treatments. Two of these were an experimental dry diet with 9.9 or 19.5% lipid on a dry matter basis and with protein to lipid ratios of 5.3 and 2.4, respectively. The other treatment was Oregon Moist Pellets (OMP), the usual hatchery diet composed of 17.2% lipid on a dry matter basis and a protein to lipid ratio of 3.0. All groups were differentially tagged and simultaneously released to the ocean after 63 days of freshwater culture. Wild chinook were collected to compare their body proximate and lipid compositions to those of hatchery-reared fish.

Results from this and the previous study showed that dietary lipid levels or protein to lipid ratios had pronounced effects on growth, food, protein and energy utilization, and on body proximate and lipid composition. Growth and food, protein and energy utilization were best for fish fed diets with highest lipid (metabolizable energy) content. In hatchery-reared fish, body protein and lipid contents were respectively directly and inversely related to dietary protein to lipid ratio. Wild counterparts had higher percentages of moisture, protein and ash but a much lower percentage of body lipid. In cultured fish, differences in the fatty acid composition of body lipid were confined mainly to neutral lipid with few changes occurring in the polar lipid fraction. Wild fish had the highest percentage of ω3 fatty acids and the lowest percentage of ω9 fatty acids in both neutral and polar lipid. Return information has not been evaluated yet due to the long marine residency of chinook salmon.

Key words: diet, body composition, marine survival, salmon.

RÉSUMÉ

Plotnikoff, M. D., D. A. Higgs, J. R. Markert, B. S. Dosanjh, J. R. McBride, and J. T. Buckley. 1984. Nutrition and marine survival of chinook salmon (*Oncorhynchus tshawytscha*). II. Further investigation of the potential role of smolt body composition (Robertson Creek Hatchery 1980 brood). Can. Tech. Rep. Fish. Aquat. Sci. 1235: iv + 17 p.

Au cours de deux études menées à la piscifacture du ruisseau Robertson, les auteurs ont examiné l'influence du niveau de lipides dans le régime ou le rapport protéine-lipide sur la croissance du saumon quinnat, sur la composition corporelle immédiate et lipidique et sur la survie en mer. Les résultats de la première étude ont déjà été présentés (Plotnikoff et al. 1983). La deuxième étude portait sur trois groupes d'environ 7 000 alevins quinnats à vésicule résorbée, nourris selon trois diètes différentes. Dans deux cas, il s'agissait d'une nourriture sèche expérimentale composée de 9,9 parties de lipide ou 19,5% (poids sec) et ayant des rapports protéine-lipide s'élevant à 5,3 et à 2,4 respectivement. L'autre source alimentaire était constituée d'Oregon Moist Pellets (OMP), source alimentaire habituellement utilisée dans les piscifactures et composée de 17,2% de lipides (poids sec) et d'un rapport protéine-lipide de 3,0. Tous les groupes ont été étiquetés de façon différente et relâchés simultanément dans l'océan après 63 jours de pisciculture d'eau douce. On a capturé des quinnats sauvages afin de comparer leurs compositions corporelles immédiate et lipidique à celles des poissons d'élevage.

Selon les résultats des deux études, les niveaux de lipides dans le régime ou les rapports protéine-lipide ont une incidence prononcée sur la croissance, sur l'utilisation de la nourriture, des protéines et de l'énergie ainsi que sur la composition corporelle lipidique et immédiate. La croisasance et l'utilisation des différentes composantes étaient plus élevées chez les poissons nourris selon un régime à haute teneur lipidique (énergie métabolisable). Chez les quinnats d'élevage, les niveaux corporels de lipides et de protéines étaient, dans chaque cas respectivement, directement et inversement reliés au rapport protéine-lipide. Les quinnats sauvages contenaient un pourcentage plus élevé d'humidité, de protéines et de cendre; par contre, leur niveau de lipides était moindre. Chez les saumons d'élevage, la variation du contenu en acide gras des lipides corporels était restreinte principalement aux lipides neutres, en plus de quelques changements dans la fraction des lipides polaires. Les poissons sauvages possédaient le plus fort pourcentage d'acides gras de type w3 et le plus faible pourcentage d'acide gras de type w9 dans les lipides neutres et polaires. Les données sur les saumons de remonte n'ont pas encore été évaluées à cause du long séjour en mer du saumon quinnat.

Mots-clés: régime, composition corporelle, survie en mer, saumon.

INTRODUCTION

Increasing the return rate or marine survival of hatchery released chinook salmon (Oncorhynchus tshawytsha) can result in a significant monetary benefit. For example, even a 1% increase in chinook survival would result in a monetary gain of almost 4 million dollars annually to the fishery (D.A. Higgs, unpublished). As outlined in the 1980 study (Plotnikoff et al. 1983), the returns of cultured chinook are considerably less than their wild counterparts. Moreover, of the differences that exist between wild and cultured salmonids, we postulated that body composition, and specifically body lipid content, might influence ocean survival and thus rate of return of chinook salmon.

To test the hypothesis, we simultaneously released differentially tagged smolts of similar size but of different body compositions from Robertson Creek Hatchery. Dissimilar body compositions were created by manipulating dietary protein to lipid ratios. For a more accurate assessment of the possible role of body composition on marine survival, we conducted the study in two successive years. The first report (Plotnikoff et al. 1983) summarized the findings for brood year 1979 and this report on 1980 brood year fish concludes the investigation. Evaluation of the effect of dietary treatment on adult returns is not included in this report because chinook salmon have a long marine residency of up to 6 years.

MATERIALS AND METHODS

The 1981 study was conducted as previously reported (Plotnikoff et al. 1983) for the 1980 study except for minor changes. These included an earlier time of ponding and release, 3 rather than 4 treatment groups and a different dry basal diet.

Approximately 7,000 fish of 0.60 g mean size were taken from incubators and distributed into each of 9 three-meter diameter fibreglas tanks on March 19, 1981. Three groups were randomly assigned the Oregon Moist Pellets (OMP) diet (see Higgs et al. 1982, for formulation) or the West Vancouver Laboratory dry diet No. 32 (WV32; Table 1) with either a low (WV32-LL) or high (WV32-HL) lipid level. Differences in the lipid content of WV32 were created by supplementation of the diet with marine oil using previously described procedures (Higgs et al. 1979). Total dietary lipid and protein contents expressed as a percentage of dry matter ranged from 9.9 to 19.5 and 46 to 53, respectively (Table 2). Diets were prepared and administered as reported previously (Plotnikoff et. al. 1983). Water temperature during the study ranged from 8.0-13.9°C. and all groups were maintained on a natural photoperiod.

Representative samples of fish were removed from each treatment group for measurement of growth (60 fish/replicate every 21 days), initial and final body proximate composition, fatty acid composition, state of health (n = 45), histopathological examination (n = 10) and ability to transfer to seawater (Tables 3, 5, 6, 7, and Fig. 1.) using previously described methods (Higgs et al. 1979, 1982: Plotnikoff et al. 1983). Data were analyzed according to procedures described by Plotnikoff et al. (1983).

To determine whether cultured and wild chinook smolts differed in body composition, samples of wild chinook smolts were collected in the mouth of the Somass River approximately 200 yards upstream from the MacMillan Bloedel Pulp and Paper plant (Fig. 2). Fish were collected using a 50 ft. beach seine on the evening of May 11, 1981. Most fish were found close to the banks of the river rather than in midstream. About 120 fish were collected from 3 seine sets. Fish were transported live to shore after which they were anaesthesized, dipped in liquid nitrogen and stored on dry ice for transport to the laboratory. At the laboratory, samples were stored in bags which were flushed with nitrogen and then sealed. Four samples of 30 fish each were analyzed for proximate composition and 6 fish were pooled and analyzed in duplicate for percent fatty acids in neutral and polar lipid by methods previously described (Plotnikoff et al. 1983).

RESULTS AND DISCUSSION

I. INFLUENCE OF DIET ON GROWTH, FOOD, PROTEIN AND ENERGY UTILIZATION, STATE OF HEALTH AND OSMOREGULATORY ABILITY.

Level of lipid in the diet or dietary protein to lipid ratio had a pronounced effect on the final size of fish at release (Table 3). Final mean weight was directly related to the amount of lipid in the diet and negatively correlated with dietary protein to lipid ratio. While the final sizes of groups fed OMP and WV32-LL did not differ significantly on a wet weight basis, this was not true on a dry matter basis. In this case fish fed WV32-HL or OMP were significantly larger at release than fish fed WV32-LL. This was due to improved food, protein and energy utilization (Table 4). These findings are consistent with results observed in 1980. Best growth, food and protein utilization, however, were noted for fish fed WV32-HL (Tables 3 and 4). The final mean weights of all treatment groups at release were larger than observed in the first study. This may reflect differences between studies in basal diet formulation, cultural conditions or both. Terminal condition factors of the fish were directly related to dietary lipid content and consequently to final size at release.

Overall mortalities during the study were low (Table 3). Histological examination showed no pathology in the liver, thyroid, kidney or alimentary tract in fish from any treatment group. Also, no incidence of infectious disease was found in the fish at release. Hematocrits were high in all treatment groups indicating a good state of health (Table 3).

Plasma sodium titres of fish from each treatment group after seawater challenge tests ranged from 174.2 - 183.2 meq/l (Table 5). These values were lower than those found for fish in the previous year and thus indicated improved osmoregulatory ability. This may have been the result of the increased size of the fish in this study relative to those in the previous one. No differences were found between treatment groups in their ability to transfer to the marine environment.

II. EFFECT OF DIETARY LIPID CONTENT ON BODY PROXIMATE AND FATTY ACID COMPOSITION.

The level of lipid in the WV diet significantly influenced final body proximate composition (Fig. 1). Body lipid content was directly related whereas body moisture, protein and ash contents were inversely related to dietary lipid level. These results support those of 1980. Furthermore, there were significant differences in all body proximate constituents between fish fed OMP and WV32-LL but between fish fed OMP and WV32-HL there were significant differences noted only for percent moisture and protein. Relative to hatchery-reared chinook, wild counterparts had higher percentages of moisture, protein and ash but a much lower percentage of body lipid (Fig. 1). These differences can most likely be attributed to the dissimilar composition of natural and artificial food, level of dietary intake and physical activity and to the larger size of cultured fish in comparison to wild fish. Mean wet weight of chinook caught in the wild was 0.97 g. By contrast, hatchery-reared chinook sampled 10 days after the wild fish ranged in mean weight from 4.5 - 5.2 g.

Level of dietary lipid also influenced the fatty acid composition of the fish neutral and polar lipids. In the neutral lipid fraction, increased lipid content in WV32 resulted in elevated levels of 20:1 ω9, 20:5 ω3, 22:1 ω9 and 22:6 ω3, and a concomitant decrease in levels of 18:1 ω9, 18:2 ω6 and 22:5 ω6 (Table 6). Percentages of ω3, ω6 and ω9 fatty acids in neutral lipid of fish fed WV32 with high lipid content respectively increased, decreased or showed no change relative to those of fish fed WV32 with low lipid content (Table 7). Fish fed OMP had increased percentages of most saturated fatty acids, 20:4 ω6, 20:5 ω3, and 22:6 ω3 and decreased percentages of 20:1 ω9 and 22:1 ω9 in neutral lipid relative to fish fed the dry diets (Table 6). Moreover, the ratio of saturated to unsaturated (s/u) fatty acids in neutral lipid was higher in OMP-fed-fish than in fish fed the dry diets (Table 7). Levels of ω3 and ω6 fatty acids were greater and those of ω9 fatty acids were lower in OMP-fed fish than in dry diet-fed fish (Table 7).

The fatty acid composition of the body lipid and especially the neutral lipid fraction is directly related to the character of the dietary lipid (Buckley & Groves 1979; Mugrditchian et al. 1981; Reinitz & Yu 1981). Since the composition of the diet of wild and cultured fish is markedly different, differences in body lipid composition would be expected. In our study, we found that wild chinook had higher levels of 16:1 ω7, 18:1 ω9, 18:3 ω6, 20:4 ω6, 20:5 ω3 and 22:5 ω3 and much lower levels of 20:1 ω9 and 22:1 ω9 than in cultured counterparts (Table 6). Further, wild fish had the highest percentage of ω3 fatty acids and the lowest amount of ω9 fatty acids in neutral lipid. Levels of ω6 fatty acids were intermediate to fish fed dry diets and OMP. The foregoing differences were clearly reflected in the ratios of ω6 to ω3 fatty acids which ranged from 0.47 in fish fed WV-HL to 0.89 for fish fed WV-LL. Ratios in OMP-fed fish and in wild fish were 0.58 and 0.55, respectively (Table 7).

Differences between treatment groups in the composition of the polar lipid fraction were not as distinct. There were few major changes in individual fatty acids between fish fed the dry diets and OMP. But levels of ω3 and ω6 fatty acids in W.V.-fed groups were respectively higher and lower than noted in OMP-fed fish (Table 7). Wild fish, however, had the highest levels of ω3 and ω6 fatty acids but the lowest amount of ω9 fatty acids in the polar lipid fraction. Ratios of ω6 to ω3 fatty acids were lowest in WV groups.

Successful seawater transfer and adaptation to increased salinity or cold water temperature are facilitated by increased levels of ω3 fatty acids in body and membrane lipids (Cowey and Sargent 1977, Castell 1979). Therefore, the fatty acid composition of chinook smolts at time of seawater entry as determined by the amount and composition of dietary lipid may have a pronounced influence on marine survival quite apart from size and time of release and level of energy reserves. If chinook smolts require similar levels of body protein and lipid to those of wild fish for maximum survival, then fish fed WV32 with low lipid content would be anticipated to have improved survival. On the other hand, if enhanced body energy levels in smolts promote increased survival during transition from artificial food to natural prey, then groups fed WV32 with high lipid content or OMP would likely demonstrate increased adult returns. Hopefully, clear cut trends will emerge from the survival data which will then permit development of strategies for improving chinook return rates.

SUMMARY

The findings from both studies investigating the influence of dietary lipid level or protein to lipid ratio on fish performance, body proximate and lipid composition and marine survival indicated the following:

1. Optimum dietary levels of protein and energy were necessary to promote good growth. Fish fed diets with protein to lipid ratios of 2.78 - 2.99 had enhanced growth due to better food conversion and more effective utilization of protein.

2. Dietary moisture content did not influence chinook performance while in freshwater. In this study the performance of fish when fed a dry diet of less than 10% moisture was superior to that of fish fed OMP, a high moisture content diet.

3. Dietary lipid level or protein to lipid ratio had a significant and predictable influence on body composition.

4. Fatty acid profiles in the diets were influenced by level of lipid

supplementation. Dietary fatty acid composition had most effect on the whole body neutral lipid composition.

5. Any definite conclusions regarding the influence of smolt body composition on ocean survival were not possible at this time. Return information is incomplete due to the long marine residence of chinook salmon. If returns of 3, 4, 5, and 6-year old fish imply that body composition is important for marine survival, then cultured chinook of similar proximate and fatty acid composition to that of wild counterparts can be produced by diet manipulation. Additionally, considerable improvement in the cost effectiveness of chinook culture would result.

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TABLE 1. Composition of WV32 diet fed to juvenile chinook salmon at Robertson Creek Hatchery.

Ingredients	WV32 g/kg dry diet
Herring meal (crude protein = 70.0%)	594.8
Blood flour (crude protein = 93.2%)	49.9
Shrimp meal (crude protein = 43.1%)	49.4
Wheat millrun	217.9
Vitamin supplement[1]	40.0
Mineral supplement[2]	20.0
Permapell	20.0
Ascorbic acid	2.0
Choline chloride (50%)	6.0

[1] The vitamin supplement supplied the following levels of nutrients/kg of dry diet: D-calcium pantothenate 96.1 mg; pyridoxine HCl 53.5 mg; riboflavin 64.2 mg; niacin 666.5 mg; folic acid 20.5 mg; thiamine mononitrate 53.5 mg: biotin 1.11 mg; vitamin B_{12} 0.03 mg; menadione (as hetrazeen) 27.9 mg; vitamin E 852 IU: vitamin D_3 535 IU: vitamin A 8012 IU: inositol 480 mg;

[2] The mineral supplement provided the following levels of minerals (mg/kg dry diet): Mn (as $MnSO_4.H_2O$) 34.5; Zn (as $ZnSO_4.7H_2O$) 20.1: Co (as $CoCl_2.6H_2O$) 0.95; Cu (as $CuSO_4.5H_2O$) 9.2; I (as KI) 5.4; Na (as NaCl) 2073.

TABLE 2. Proximate composition of WV32 with low (WV32-LL) or high (WV32-HL) lipid content and OMP. The basal WV32 formulation was supplemented with 11% marine oil to reduce the dietary protein to lipid ratio.

	Diet		
	WV32-LL	WV32-HL	OMP
Protein (% N x 6.25)	52.62	46.36	51.1
Crude lipid (Bligh-Dyer)	9.90	19.46	17.17
Crude fiber[1]	3.06	3.06	3.64
Nitrogen-free extract	22.56	20.54	14.33
Ash	11.86	10.58	13.76
Moisture (as fed)	7.79	7.33	27.04
Metabolizable energy (kcal/g)[2]	3.36	3.84	3.75
Digestible protein (mg/dig. kcal)[3]	140.9	108.7	122.6
Protein/lipid	5.3	2.38	2.98

[1] Crude fiber contents of the diets were estimated.

[2] Brett and Groves (1979) coefficients used for estimating caloric value of the diets, i.e. 4.2 kcal/g crude protein, 8.0 kcal/g crude lipid and 1.6 kcal/g carbohydrate.

[3] Calculated assuming protein 90% digestible.

TABLE 3. Wet weights, dry weights and condition factors at 21 days and at release (63 days), specific growth rates, overall mortalities and percent hematocrits of juvenile chinook salmon fed WV32 with a low (LL) or high (HL) level of lipid or OMP. Values are means ± 2 SEM. Numbers of fish sampled for hematocrit are shown in parentheses.

	Diet		
	WV32-LL	WV32-HL	OMP
Parameter			
Wet wt at 21 days[1],[2]	$1.06^{a} \pm 0.02$	$1.13^{a} \pm 0.02$	$1.14^{a} \pm 0.02$
Dry wt at 21 days[2]	$0.23^{a} \pm 0.005$	$0.26^{b} \pm 0.005$	$0.26^{b} \pm 0.005$
Wet wt at release (63 days)[2]	$4.52^{a} \pm 0.12$	$5.16^{b} \pm 0.12$	$4.68^{a} \pm 0.12$
Dry wt at release (63 days)[2]	$0.99^{a} \pm 0.02$	$1.26^{c} \pm 0.02$	$1.08^{b} \pm 0.02$
Condition factor (21 days)[2] $\left(\frac{\text{wet wt (g)} \times 1000}{\text{fork length (cm)}^{3.25}}\right)$	$7.32^{a} \pm 0.08$	$7.43^{a} \pm 0.08$	$7.53^{a} \pm 0.08$
Condition factor (release)[2]	$6.66^{a} \pm 0.06$	$6.99^{b} \pm 0.06$	$6.86^{ab} \pm 0.06$
Specific growth rate (%)[3] (% dry wt/day)	$3.50^{a} \pm 0.09$	$3.68^{b} \pm 0.09$	$3.42^{a} \pm 0.09$
Overall mortality (%)	2.7	1.8	2.0
Hematocrit (%)[2]	$45.2^{b} \pm 1.1$ (45)	$42.8^{b} \pm 1.1$ (45)	$38.1^{a} \pm 1.1$ (45)

[1] Common initial wet weight of fish for all groups was 0.59 g.

[2] Hierarchical analysis of variance with a random replication factor nested in diet indicated $P < 0.05$ for wet weight, dry weight and condition factor at release, dry weight at 21 days and hematocrits and $P > 0.05$ for wet weight and condition factor at 21 days.

[3] Hierarchical analysis of covariance with replicate nested in diet with time as a covariate and including a test for equality of slopes indicated $P < 0.001$. Groups with the same superscript form a homogeneous subset.

TABLE 4. Food conversion efficiency, protein efficiency ratio, protein utilization, and gross energy utilization of juvenile chinook salmon fed WV32 with a low (LL) or high (HL) level of lipid or OMP. Values given are means ± 2SEM[1]

	Diet		
Parameter	WV32-LL	WV32-HL	OMP
Food conversion efficiency			
$\frac{\text{dry wt gain (g)}}{\text{dry food intake (g)}} \times 100$	$25.9^{a} \pm 0.99$	$31.6^{b} \pm 0.99$	$30.1^{b} \pm 0.99$
Protein efficiency ratio			
$\frac{\text{gain in dry fish wt (g)}}{\text{wt of protein consumed (g)}}$	$0.49^{a} \pm 0.095$	$0.68^{c} \pm 0.095$	$0.59^{b} \pm 0.95$
Protein utilization (%)			
$\frac{\text{wt of fish protein retained (g)}}{\text{wt of protein consumed (g)}} \times 100$	$34.0^{a} \pm 1.3$	$42.7^{b} \pm 1.3$	$37.5^{a} \pm 1.30$
Gross energy utilization (%)			
$\frac{\text{gross energy gain}}{\text{gross energy intake}} \times 100$	$29.8^{a} \pm 1.2$	$35.3^{a} \pm 1.2$	$35.2^{a} \pm 1.2$

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[1] Analysis of variance (mixed model) with a random factor nested in diet crossed with time indicated $P < 0.05$ for food conversion efficiency, protein efficiency ratio and protein utilization. Groups with the same superscript form a homogeneous subset.

TABLE 5. Mortality and plasma sodium titres for representative samples of fish taken from each dietary treatment before ocean release. Fish were transferred to seawater (10°C, 30%) for 24 hr and then a blood sample was withdrawn from the caudal vessels of each fish for sodium determination. Values are means ± 2SEM.

Diet	N	Mortality	Length (cm)	Weight (g)	Sodium (meq/l)
WV32-LL	18	0/22	7.5 ± 0.3	4.09 ± 0.49	183.2 ± 6.3
WV32-HL	18	0/23	7.9 ± 0.2	4.91 ± 0.44	174.2 ± 3.0
OMP	18	0/23	7.6 ± 0.1	4.12 ± 0.23	181.3 ± 3.2

TABLE 6. Percent fatty acid composition of neutral and polar lipid in cultured and wild juvenile chinook salmon. Lipid was extracted from 3 fish pooled one from each dietary replicate in hatchery samples and from 6 fish in the wild sample. Analyses were conducted in duplicate. Refer to Table 2 for additional information.

	Neutral lipid Fraction				Polar Lipid Fraction			
	Diet				Diet			
	WV32-LL	WV32-HL	OMP	Wild chinook	WV32-LL	WV32-HL	OMP	Wild chinook
Fatty acid								
14:0	4.4	5.1	5.6	5.4	2.3	2.2	3.9	1.7
15:0	0.9	0.7	1.4	1.5	1.3	1.3	1.9	0.7
16:0	15.3	13.7	13.9	11.0	11.3	13.2	14.0	12.8
16:1ω7	7.3	8.3	8.3	10.7	9.6	7.6	6.5	7.5
17:0	1.0	0.7	1.6	1.9	5.5	5.6	6.3	6.2
18:0	4.8	4.0	5.8	6.5	12.1	12.6	10.8	14.6
18:1ω9	20.6	17.0	16.0	22.0	2.4	2.6	2.5	3.0
18:2ω6	8.8	6.0	8.1	6.7	0.7	0.8	0.9	1.4
18:3ω6	1.2	1.3	1.5	2.7	0.6	0.6	0.8	0.6
18:3ω3	1.1	1.7	1.8	1.8	-	-	-	0.2
20:1ω9	8.7	10.0	5.5	2.8	3.0	3.2	2.5	1.0
20:3ω9	0.3	0.4	0.7	0.9	0.5	0.6	0.7	0.5
20:4ω6	0.6	0.8	1.5	1.9	2.0	2.1	2.4	3.2
20:5ω3	3.4	5.1	6.2	7.5	5.5	5.3	4.5	9.2
22:1ω9	8.5	10.8	5.0	1.0	0.9	1.1	1.0	-
22:5ω6	0.5	0.2	0.7	0.7	0.6	0.6	0.9	0.5
22:5ω3	1.1	1.5	1.7	3.1	1.8	1.8	1.7	3.1
22:6ω3	7.1	9.1	10.5	8.7	34.7	35.2	32.3	31.3

TABLE 7. Percentages of ω3 and ω6 fatty acids, ω6/ω3 fatty acid ratios and saturated/unsaturated (S/U) fatty acid ratios in neutral and polar lipid of cultured and wild chinook salmon. Refer to Table 2 for additional information.

	Neutral lipid				Phospholipid			
	Diet				Diet			
	WV32-LL	WV32-HL	OMP	Wild	WV32-LL	WV32-HL	OMP	Wild
Total ω3	12.5	17.3	20.2	21.0	42.0	42.3	38.4	43.8
Total ω6	11.1	8.2	11.7	11.6	3.8	4.0	5.0	5.6
Total ω9	38.1	38.1	27.1	26.7	6.8	7.5	6.6	4.4
ω6/ω3	0.89	0.47	0.58	0.55	0.09	0.09	0.13	0.13
S/U	0.38	0.34	0.42	0.37	0.52	0.56	0.65	0.59

Fig. 1 - Body composition of chinook salmon at Robertson Creek Hatchery before release to ocean. Two samples of 5 fish each were taken from every tank (6 samples/dietary treatment) for determination of proximate composition. A hierarchical analysis of variance with a random replication factor nested in diet indicated $P < 0.05$ for moisture and lipid and $P < 0.001$ for ash and protein. Six samples of 30 fish each were analyzed before the start of test feeding and mean percentages for moisture, and for protein, lipid and ash on a dry matter basis were 77.9, 67.5, 22.9 and 6.3, respectively.

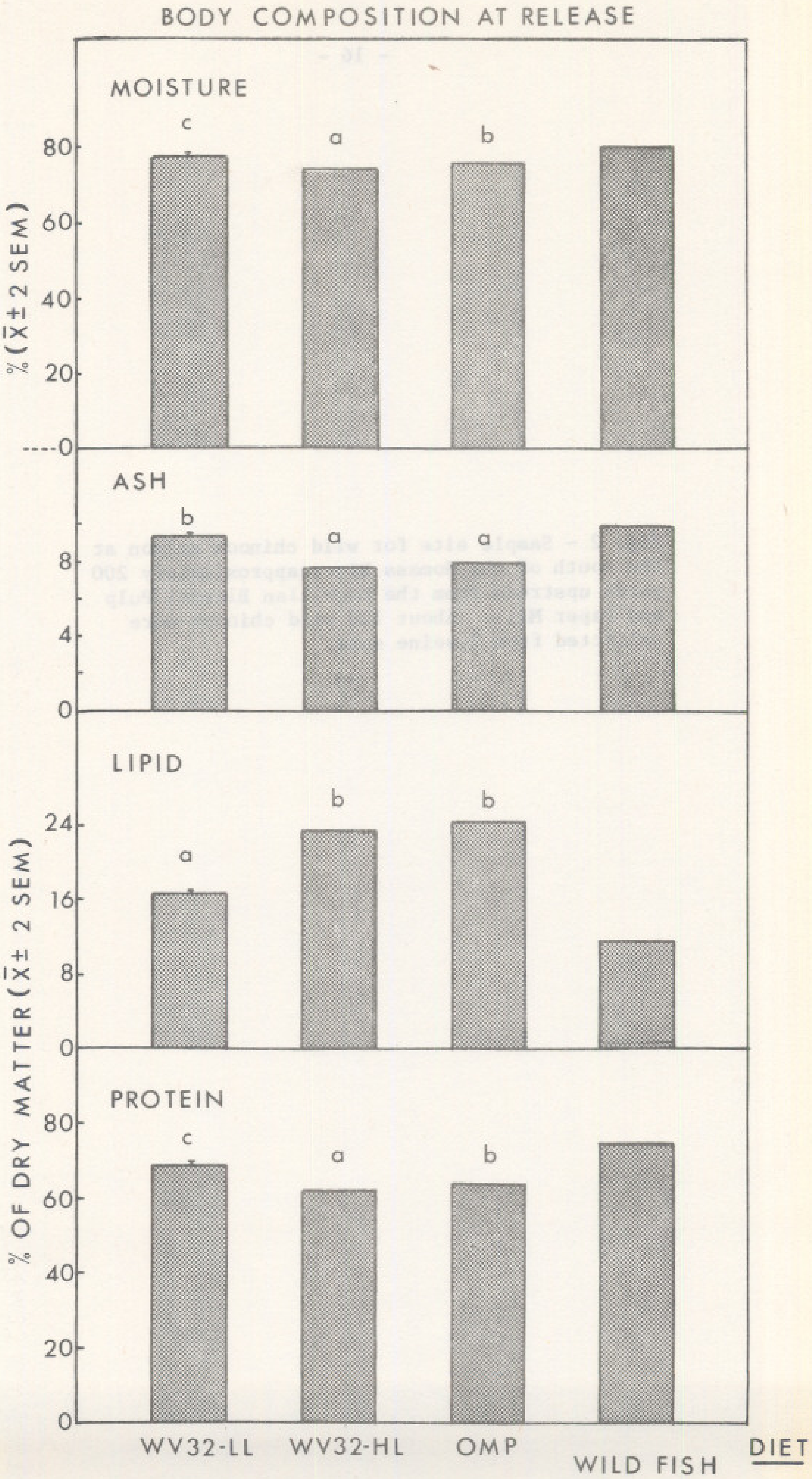
BODY COMPOSITION AT RELEASE
MOISTURE
% ($\bar{X}$ ± 2 SEM)
0
20
40
60
80
c
a
b
ASH
0
4
8
b
a
a
LIPID
% OF DRY MATTER ($\bar{X}$ ± 2 SEM)
0
8
16
24
a
b
b
PROTEIN
0
20
40
60
80
c
a
b
WV32-LL
WV32-HL
OMP
WILD FISH
DIET

FIG. 1

Fig. 2 - Sample site for wild chinook salmon at the mouth of the Somass River approximately 200 yards upstream from the MacMillan Bloedel Pulp and Paper Mill. About 120 wild chinook were collected from 3 seine sets.

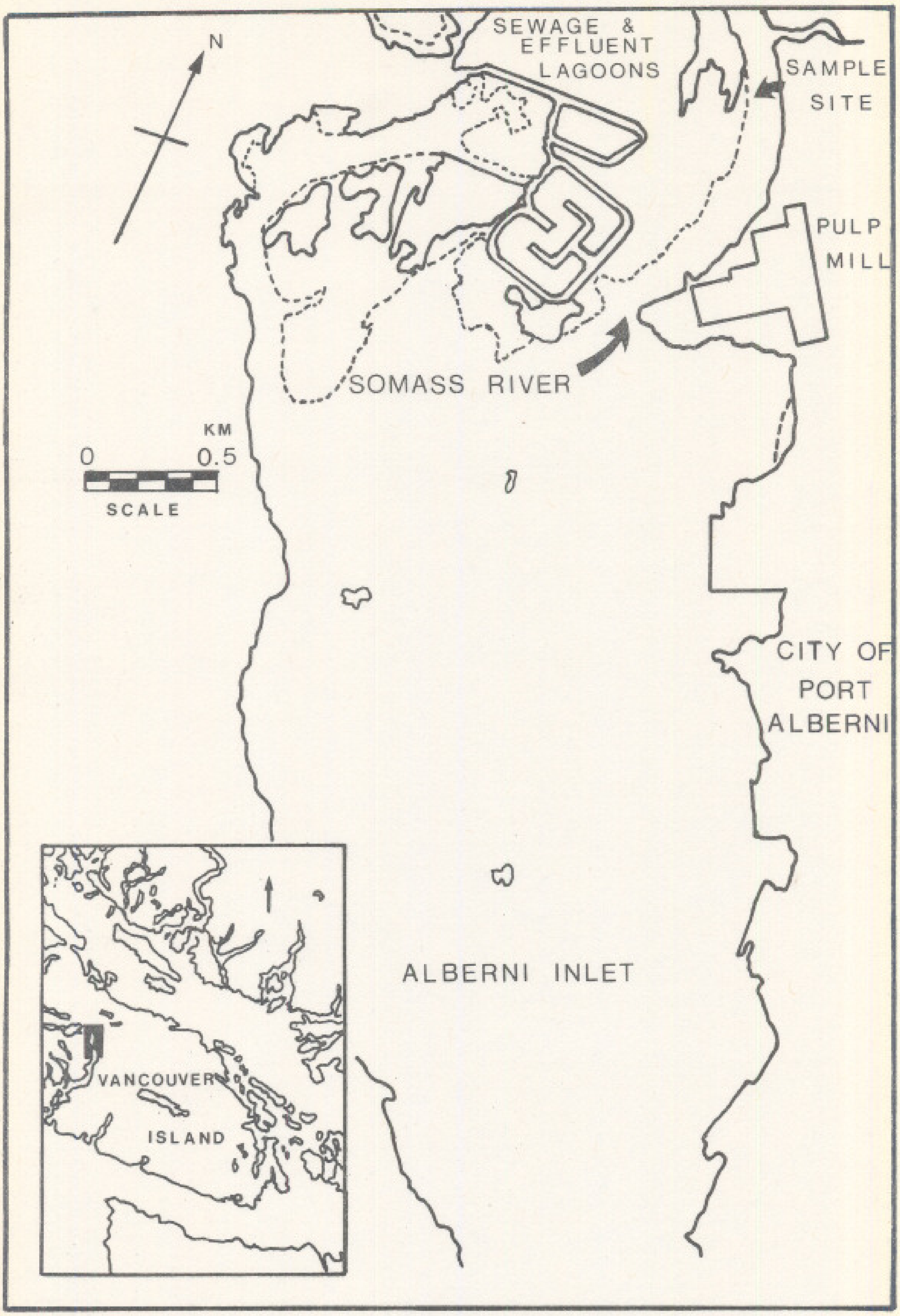
SEWAGE &
EFFLUENT
LAGOONS
SAMPLE
SITE
N
PULP
MILL
SOMASS RIVER
KM
0
0.5
SCALE
CITY OF
PORT
ALBERNI
ALBERNI INLET
VANCOUVER
ISLAND

FIG. 2