GROWTH OF FISHES IN DIFFERENT SALINITIES

by

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ABSTRACT

Juvenile sockeye, coho, and chum salmon and adult goldfish were studied for a period of ten weeks to determine whether varying degrees of salinity influenced their growth. The possible influences of such factors as temperature and food were rigidly controlled. Coho and chum salmon showed higher percent weight increase in the saline media. Coho grew best in 12‰ salinity and chum had a higher percent increase in weight in 30‰ salinity. The growth of sockeye in the saline medium was retarded for the first eight weeks, but during the last two weeks it surpassed that of the corresponding group of sockeye in fresh water. The early retardation in growth of sockeye, in the saline medium, is attributed to its longer fresh water life. The adult goldfish did not show any significant difference in weight increase. The records of the sizes attained by several species of fish inhabiting both sea and fresh waters show that salinity enhances growth. The evidence from experimental study, by other workers, on the influence of different environmental factors on growth of fishes, indicates that changes in meristic counts or body proportions, in early development, produces different growth rates. These changes could eventually affect the ultimate size. The physiological mechanisms of growth of fishes are not well understood, but it has been suggested that the influence of hormones on growth is probably ameliorated in the marine environment.

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INTRODUCTION

Landlocked teleosts are usually smaller than their marine counterparts (of the same species). For example, the kokanee salmon (*Oncorhynchus nerka kennerlyi* (Suckley) reaches a size of 200 mm. to 400 mm. at maturity, while the sea-going sockeye salmon, *Oncorhynchus nerka nerka* (Walbum), averages 605 mm. in length and has been reported to attain 831 mm.

Non-migratory anadromous fish sometimes show an exhaustion of the thyroid gland (Hoar, 1952) and since the hormone produced by this gland is essential for the growth of most vertebrates, it has been suggested (Hoar, 1956) that the excessive osmotic stress in fresh water could account for the smaller size. Since some species, such as the smelt (*Osmerus mordax*) and the sea-trout (*Salmo trutta*), grow equally well in fresh water and in the ocean, it is evident that this situation is not universal.

In this work an attempt is made to evaluate the effect of osmotic stress and salinity on the growth of three species of salmon and the goldfish. Two lines of research have been followed:- (a) the literature has been reviewed and an attempt made to correlate sizes of mature anadromous fish and other species with the salinity of their environment. (b) experiments have been designed to test the salinity effect when divorced from dietary and such environmental variables as temperature, aeration and volume of water.

LITERATURE SURVEY

An extensive search of the literature was made for sizes of fish of different species that occur in habitats of different salinities. Only a few records of sizes (either length or weight) of fish other than the anadromous forms have been found.

Eleven species of fish occuring in two or three different habitats are listed in Table I, together with their sizes at maturity or as otherwise indicated. In all cases but one, Osmerus mordax, the marine and brackish water inhabitants are the larger. Some show appreciable differences and warrant the conclusion that the marine environment favours growth in these species. Even among marine species, such as the Pacific herring, Clupea harengus, or the giant perch, Lates calcarifer, the larger sizes occur in higher salinities.

Salinities of brackish or estuarine waters, and also those of "purer" sea water, vary considerably in the different parts of the world. The Atlantic herring, Clupea harengus, measures from 240 mm. to 350 mm. while the same species occuring in the Baltic measures 160 mm. to 200 mm. The salinity of the Baltic varies from 20‰ in the south to 1‰ in some of the northern regions. Hodgson (1934) states that the salinity in the regions which the herring frequents is roughly one-seventh that of the Atlantic (35‰). Similarly the giant perch, Lates calcarifer, of the Indo-Pacific varies in size in the different regions (Roughley, 1953), but no records of the salinities, temperatures, or the productivities of the waters is given.

Anadromous forms, that mature in the sea, and their related forms that mature in lakes present some vivid contrasts. Some of the forms, for which measurement data were available, have been included in Table I. The sockeye

TABLE I - Sizes at maturity of marine, brackish and freshwater fishes.

SPECIES	MARINE	BRACKISH WATER	FRESHWATER	AUTHORITY
Chanos chanos (milk fish)			600 mm. - 1500 mm. (Hawaian fresh water ponds)	Jordan and Evermann, 1903
	1800 mm. (Gulf of Mannar, Indian Ocean)			Munro, 1955
	Over 1500 mm. (Indian Ocean)			Weber and Beaufort, 1913
	1500 mm. (Australian estuarine waters)			Roughley, 1953
	257 mm.[1] (Krusadai, India)	403 mm.[1] (Mandapam Camp, India)	604 mm.[1] (Rameswaram, India)	Chidambaram and Unny, 1943
Clupea harengus (Atlantic herring)	240 mm.-350 mm. (Atlantic)	160 mm.-200 mm. (Baltic)	------	Hodgson, 1934
Clupea pallasi (Pacific herring)	450 mm. (California to Alaska)	------	------	Jordan and Evermann, 1903 Clemens and Wilby, 1949

1 - These measurements were taken only after one year's growth of the milk fish in the various experimental ponds.

TABLE I - continued.

SPECIES	MARINE	BRACKISH WATER	FRESHWATER	AUTHORITY
Lates calcarifer (Giant perch)	263 Kg. (Bay of Bengal)	27 Kg. - 45 Kg. (Australian estuaries)	------	Roughley, 1953
		1500 mm. (Australian estuaries)		Munro, 1955
Salmo gairdneri gairdneri (Steelhead trout)	1134 mm.[2] (British Columbia)	------	------	Clemens and Wilby, 1949
Salmo gairdneri kamloops (Kamloops trout)	------	------	907 mm.[2] (British Columbia)	Carl and Clemens, 1953
Oncorhynchus nerka nerka (Sockeye)	830 mm. (British Columbia)	------	------	Carl and Clemens, 1953
Oncorhynchus nerka kennerlyi (Kokanee)	------	------	200 mm. - 402 mm.	Carl and Clemens, 1953
			160 mm. - 380 mm.	Ricker, 1940
			220 mm. - 410 mm. (Cultus Lake, British Columbia)	

2 - The maximum sizes on record.

TABLE I - continued.

SPECIES	MARINE	BRACKISH WATER	FRESHWATER	AUTHORITY
Salmo salar (Atlantic salmon)	480 mm. (Nova Scotia)	------	350 mm. (Grand Lake, Nova Scotia)	Wilder, 1947
Pomolobus pseudoharengus (Alewife)	258 mm.	------	145 mm. (Lake Ontario)	Pritchard, 1929
Osmerus mordax (Smelt)	150 mm. - 250 mm. (New Brunswick)	------	------	McKenzie, 1941
			150 mm. - 250 mm.	Dymond, 1944
Salvelinus fontinalis (Eastern brook trout)	334 mm. (New Brunswick)	------	274 mm. (New Brunswick)	Wilder, 1952
Coregonus clupeaformis (Whitefish)	------	403 mm. - 466 mm. 1359 gm. - 1812 gm.	------	Rawson, 1946
		479 mm. 2038 gm. (Redberry Lake, Saskatchewan)		Rawson, 1946
	------	------	1132 gm. - 1585 gm. (Lake Winnipeg, Manitoba)	Hinks, 1943

salmon of the Pacific coast Oncorhynchus nerka nerka and its non-migratory relative, given a subspecific status (Oncorhynchus nerka kennerlyi) form an interesting comparison. Ricker (1940) states that the only known morphological difference between these two forms is the smaller average size, at maturity, of the non-migratory salmon. Non-migratory sockeye consist of two types - the residents or kokanee, the progeny of the lacustrine form and the "residual", the progeny of the migratory forms (Ricker, 1938). Both forms are distinctly smaller than the migratory sockeye, as will be seen from the figures given in Table I. The alewife, Pomolobus pseudoharengus and the Eastern brook trout, Salvelinus fontinalis, are also smaller in the fresh water environment. The two forms of trout, Salmo gairdneri, in the two environs also show differences in size. These two forms of trout have been regarded as subspecies for convenience, but they do not have any real morphological difference (Lindsey, 1956).

The data on size of Spring salmon in New Zealand is summarized in Table II. These data have been very kindly supplied by Dr. E. Percival (1956). The difference between the average lengths of the sea-run Quinnat salmon and of the "land-locked" form ranges from 170 mm. to 400 mm. The sea-run form is comparable to that of the west coast of Canada.

Johnsen (1944) mentions several species that vary in size in the different North European waters - the 15-spined stickleback, Spinachia spinachia, two-spotted goby, Gobius flavescens, lanternfish, Myctophum glaciale, and plaice Pleuronectes platessa, to mention a few, are some of the species that show great variation in the size at maturity. He states that when a species varies in size within its habitat, it usually finds the optimum conditions in places where it reaches the largest size. Temperature and food are mentioned as the chief controlling factors but there is no statement regarding the salinity in the different areas. For instance, Myctophum glaciale in the Mediterranean is half the size of that found

TABLE II - Length and weight of spring salmon (*Oncorhynchus tschawytscha*) from New Zealand (data obtained from Dr. E. Percival) and British Columbia.

"Type", Place	Date	Average length mm.	Average weight gm.
Freshwater habitat			
"Landlocked", Quinnat salmon, Macdonald creek, Westland	May, 1955	569	------
	May, 1956	546	------
Sea-run fish			
Quinnat salmon - Waimakariri	1944	746	4800
" " - Opihi	1944	900	6000
Spring salmon - British Columbia		907[1]	------

1 - Carl and Clemens, 1953. These salmon attain 1450 mm. and weights from 4500 gm. to 22,500 gm. on record.

in the Norwegian waters. The difference in the salinity in the two areas ranges from 5‰ to 10‰ (Sverdrup et al, 1942). Pleuronectes platessa in its fifth year of growth ranges from 210 mm. to 400 mm. in Iceland, but only from 170 mm. to 280 mm. in the West Baltic. In this species ~~in~~ the West Baltic, the size range is generally smaller for all the groups beyond the third year. The salinity in the West Baltic never exceeds 16‰ while in Iceland it is about 35‰ . Johnsen stresses only the variations in the temperature and the nutrients in these waters but never mentions the variations in the salinities. Hodgson (1934) on the other hand states definitely that the size variation in the Atlantic herring in the Baltic may be due to both temperature and salinity.

EXPERIMENTAL METHODS

Details of the fish used in this experimental study are given in Table III.

TABLE III - Fish used in experimental study.

SPECIES	SOURCE	INITIAL SIZE (average)	PREVIOUS HISTORY
Oncorhynchus nerka (Sockeye)	University hatchery. Eggs from Cultus lake.	2.78 cm. 0.207 gm.	Eggs received 25th November, 1955.
Oncorhynchus keta (Chum)	Nanaimo Biological station. Eggs from Jones creek.	6.7 cm. 2.42 gm.	Eggs received 12th November, 1955. Hatched January 2, 1956. Alevin began feeding February 18, 1956 - liver four times a day. Were raised in 20‰ salinity.
Oncorhynchus kisutch (Coho) 1st Series	University hatchery. Eggs from Capilano river.	3.6 cm. 0.469 gm.	Eggs received 25th November, 1955.
Oncorhynchus kisutch 2nd Series	"	4.2 cm. 1.007 gm.	"
Carassius auratus (Goldfish)	Stouffville, Ontario.	8.4 cm. 12.07 gm.	Received as adults and held at University hatchery for about two months.

Procedures

The first series of coho and the sockeye were kept in five glass tanks (50.4 cm. x 27.7 cm. x 30.3 cm.). Two long tanks (181.5 cm. x 18.9 cm. x 26.5 cm.) were used for the second series of coho and the chums occupied two tanks (45.5 cm. x 24 cm. x 20 cm.). The goldfish were kept in two glass tanks (60.5 cm. x 45.5 cm. x 40 cm.).

The three tanks of the first series of coho and the two tanks containing sockeye were placed in a large metal trough, through which tap water was continuously circulated. This maintained the temperature of the tanks at that of the tap water. All these tanks were subjected to the same variation in temperature. Temperature was thus maintained within a range of 2 C°. The second series of coho tanks and chum tanks were similarly placed in water baths so that each group compared was subject to the same variation. Goldfish tanks were kept in a room in the laboratory and although the variation in temperature was greater (5 C°) it was the same for both tanks.

Salinities of 6‰, 12‰, 18‰, and 30‰ were used in the experiment. These were prepared from sea water (taken from Burrard Inlet) supplied weekly in large carboys. Each week a sample of the fresh sea water was titrated by the modified Mohr method. At the beginning of the experiment the salinity of the sea water ranged from 20‰ to 22‰ and during the last few weeks it was in the neighbourhood of 28‰ . Proportionate quantities of dechlorinated water were added to make up the various salinity strengths 18‰ and below, and sea salt was added to make up the 30‰ strength. Samples from each tank were titrated to verify the salinity.

All tanks were cleaned daily by siphoning the faecal deposits and decomposing food from the bottom. Water in all tanks was completely changed twice a week.

There was no provision for the recirculation of water. A steady flow of air was maintained in each tank. The long tanks had two air breakers placed at equal distances from the ends.

Diets

The daily amount of food necessary for proper growth of fish was taken as 10% of the body weight (Barrett and Hurn, 1954). Several ingredients listed below were mixed in the proportions indicated to produce an acceptable and convenient diet.

Canned salmon	60 gm.
Ground liver (beef)	25 gm.
Clark's trout food	12 gm.
Pablum (mixed cereal)..............	2 gm.
Brewers yeast......................	1 gm.
Few drops of cod liver oil	
	100 gm.

Clark's trout food is said to contain all the necessary ingredients for trout growth, but the salmon were unaccustomed to it and did not take it readily. The importance of vitamin B complex (Phillips, 1946) and vitamin A (Davis, 1927; Gutsell, 1939; Phillips, 1940) in trout diet, has been stressed. Davis and Gutsell (1939) believe that cod liver oil in the diet was a successful method of including vitamin A but Phillip et al (1940) maintain that the best source is beef liver. The mixture, as given above, contained the essentials and since the fish fed well it was used throughout the experiment. During the first week of the experiment the proportions varied somewhat while the best formula was being developed. Since food was principally canned salmon it was called "salmon paste".

The ingredients listed above were mixed well and ground into a fine paste. Usually about two weeks supply was prepared at one time. The paste was spread in thin even layers and placed in the cooler part of a refrigerator to harden and desiccate quickly. The hardened paste may be broken up into fine particles or powdered depending on the size of fish to be fed. Small fish feed well only on finely ground particles.

There are several advantages in using dried food. In an experiment of this type the amount of food fed is an important factor and dried food can be weighed accurately. The size of the food particles can be selected to suit the size of the fish being fed. Young salmon and even goldfish show a preference for feeding on food particles floating on the surface and dried food particles float for sometime. Since very little food sinks to the bottom the loss of food value due to leaching is insignificant, and pollution of the tank due to decomposing food is at a minimum.

Feeding

The total weight of each group of fish was recorded at the beginning and weekly thereafter. The quantity of dried salmon paste fed per day was equal to 10% of the body weight of the fish. The food for each group was weighed separately daily and fed in approximately equal amounts three times a day (8 a.m., 11 a.m., and 2 p.m.). During the first week much of the food was not consumed because the fish were frightened when the investigator approached the tanks. From the second week onwards they came to the surface and swam about actively until fed.

Coates and Schwab (1956) report that fish tend to be healthier when given their natural food and that young salmon grew well on brine shrimp nauplii. It was decided, therefore, to add living brine shrimp nauplii to the salmon paste diet.

Brine shrimp eggs were hatched in three-gallon glass jars under heavy aeration. Two and a-half gallons of water were added to each jar. About one third of the volume was sea water and the salinity made up to about 28‰ by adding sea salt. One teaspoon of dried shrimp eggs was added to each jar and the temperature was kept at about 29 C° until hatching was completed. Each jar was heated separately by placing a 75 watt flood light at a suitable distance from the jar such that the temperature in the jar never exceeded 29 C° or dropped below 26 C°. Under these conditions it took about two days for complete hatching and about 75% of nauplii production was obtained. The nauplii were separated by filtering through a piece of No. 9 bolting silk

(6.5 cm. diameter) stitched and sealed over a plastic jar.

The brine shrimp nauplii were fed to fish daily at about 5 or 6 p.m. Since it was summer there was ample light for feeding. The chum tanks were in a dark room and an automatic lighting system was operated so that all had an equal amount of light. The amount of this feed was proportional (by volume) to the weight of the groups of fish. The filtered shrimps were washed with fresh water into a 250 ml. graduated cylinder. This was then shaken well and the proportionate volumes were quickly decanted into beakers and rechecked before introduction into the tanks. For instance, if there were four tanks containing 10, 15, 10 and 15 grams of fish in each, then they would receive 50, 75, 50 and 75 ml. of the brine shrimp nauplii respectively. This was not considered a very accurate method, but the most convenient when it is remembered that the tiny shrimp nauplii had to be alive. According to Coates and Schwab (1956) the shrimp nauplii live for about twelve hours in fresh water. An examination of the water each morning showed complete absence of nauplii - dead or alive.

Weighing the Fish

Fish were weighed at the start, and weekly thereafter until the termination of the experiment. Dip nets that fitted the tanks were used to scoop out the fish. In order to prevent them from unnecessary strain and exhaustion when out of water, a small canvas bag was fitted in the middle of the net. The fish were thus collected in the bag which was full of water, and transferred into a large beaker which was lined with a plastic coated bag-net. The beaker with fish, water and the bag-net was weighed on a balance which had a sensitivity of 0.1 gm. The bag-net was then lifted up to the edge of the beaker and held there for about five seconds so that nearly all the water, except that adhering to the fish or held between fish, drained into the beaker. The fish were then quickly transferred from the bag-net into their tank. The beaker, water and the bag-net were then weighed. The difference gave the weight of the fish.

This method of weighing was checked with a group of fifty coho taken from the same stock as the one used in the experiment. An error of only 0.5% was found in the mean, when the highest or lowest weights were taken in twenty five attempts. With fewer fish it was found that the error diminished, but did not drop below 0.2%. When chums were weighed singly an error up to 5% could be anticipated.

EXPERIMENTAL RESULTS

All fish used in the experiments were transferred directly from fresh water into the different salinities up to 12‰. Coho transferred to 18‰ were first kept in lower concentrations for two days. The chums were not acclimatized since they were originally raised in sea water of 20‰ salinity. The detailed measurements of weight will be found in Appendices II - XIII. Results are summarized in Figures 1 - 6.

Sockeye in fresh water and 6‰ salinity, (Appendices II and III, and Figures 1 and 6).

These groups of fish showed a high mortality. The results, however, show a marked weight increase in the ten week period. In fresh water the mean weight at the beginning was 0.192 gm. for 69 fish, and at the end of five weeks the average reached 0.560 gm. for the ten surviving fish. This gave a 192% increase on the initial average. At the end of the tenth week there were only 8 left and the average weight was 0.806 gm., an increase of 320%.

There was a better survival (35%) of sockeye fry in 6‰ salinity, although, during the first week the mortality was also high. The 138 available fry were initially divided equally by numbers and then weighed before being introduced into the tanks. The average initial weight of fish in 6‰ salinity was slightly higher than that of the fish used in the fresh water tank. It will be seen from Appendix III, that after five weeks there was only a 117% increase in weight for the 24 fry left in the 6‰ salinity tank which was much lower than the 192% increase of sockeye in fresh water for the same period. At the end of the ten weeks the percentage increase (336%) was slightly higher than the 320% increase of the fresh water ones (Fig. 6). The number of sockeye in this tank, after the first week, remained constant throughout the experimental period.

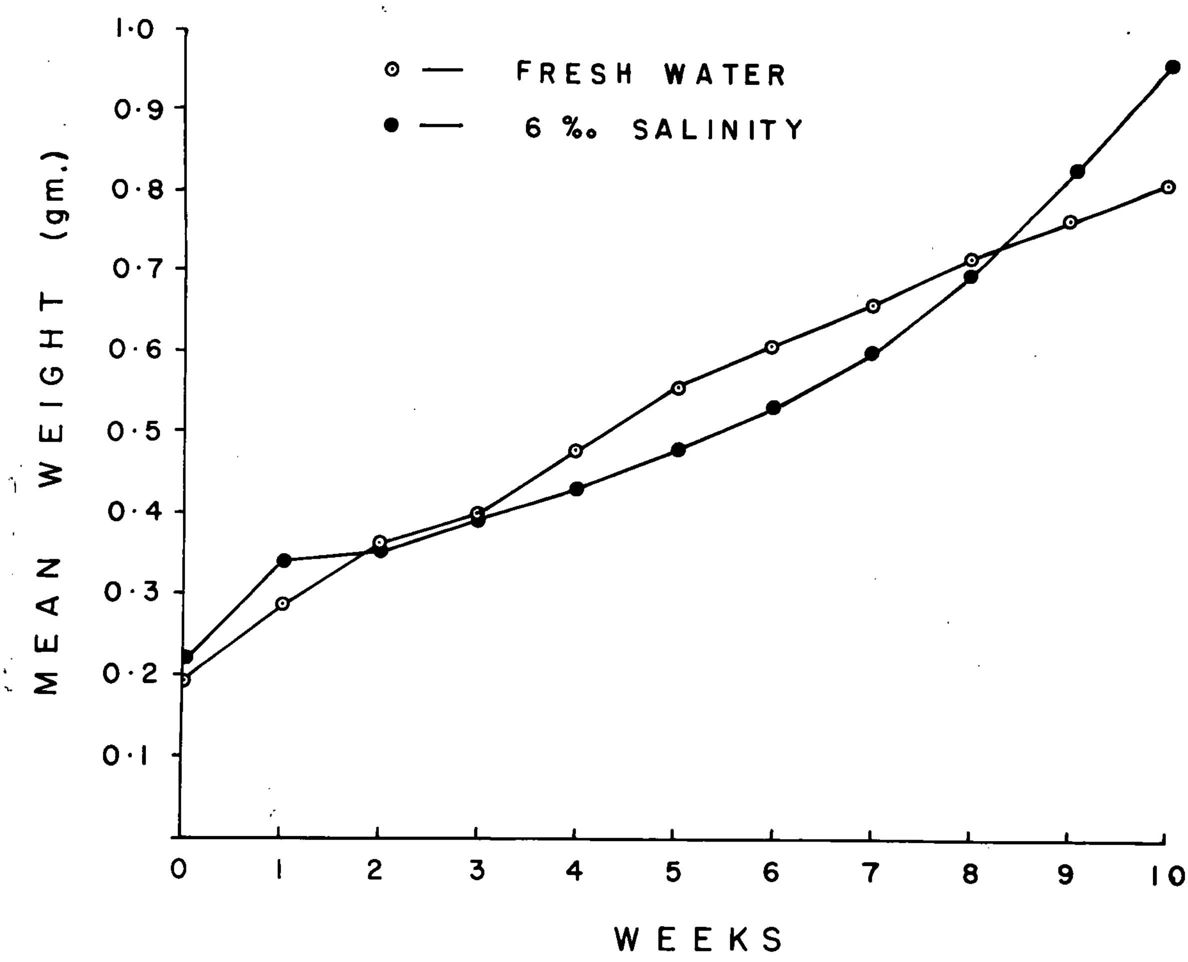

Figure 1. Mean weekly weight of sockeye in fresh water and 6‰ salinity.

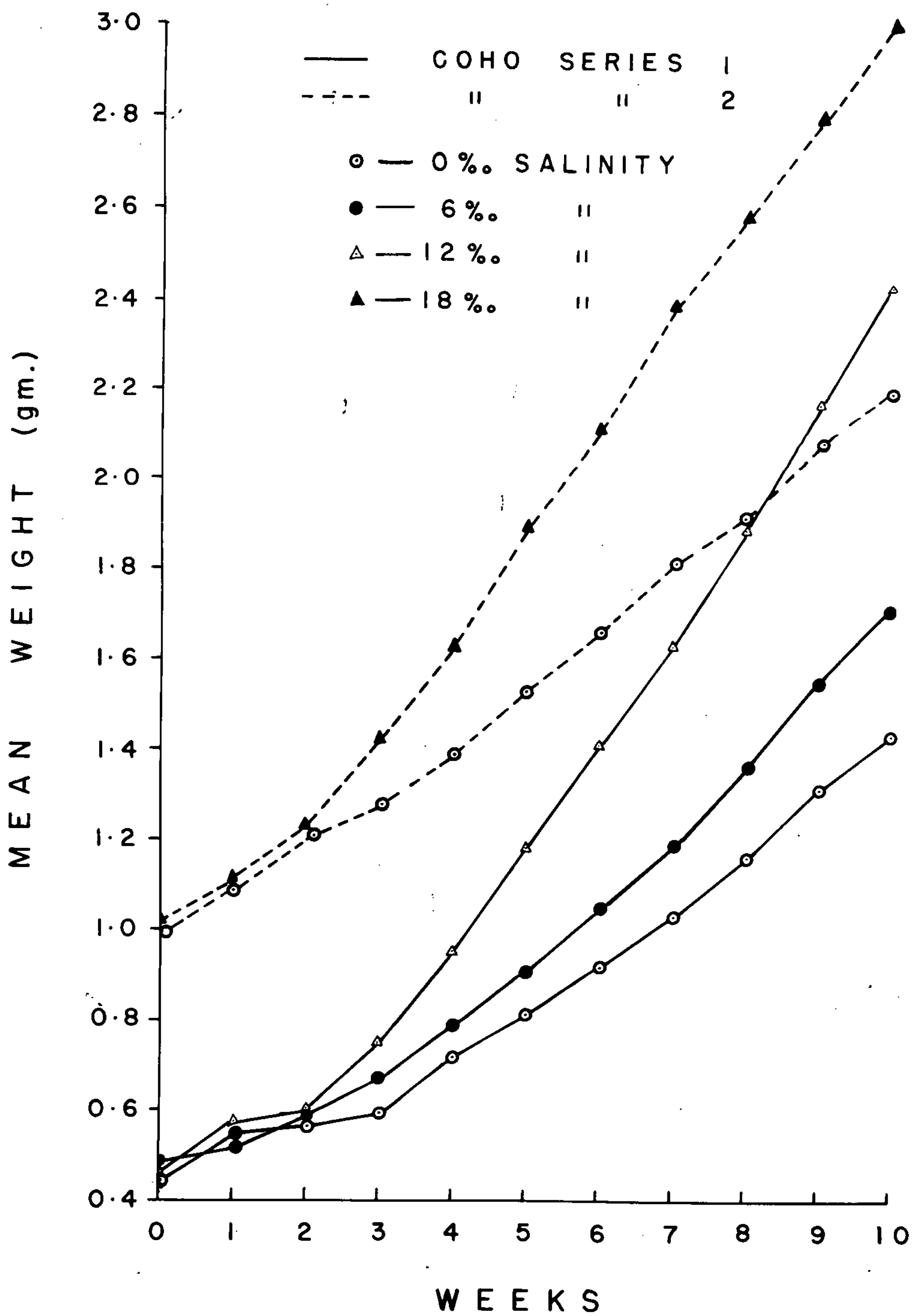

Figure 2. Mean weekly weight of coho series 1 and 2 in fresh water and in the various salinities.

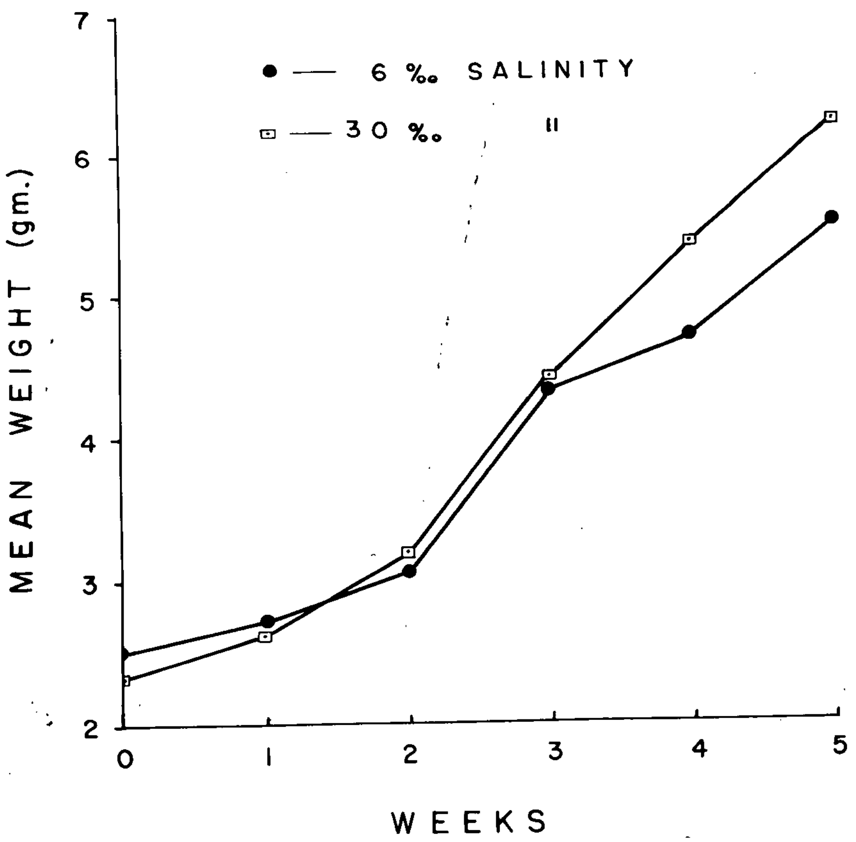

Figure 3. Mean weekly weight of chum in 6‰ and 30‰ salinity.

<u>Coho - Series 1</u>, (Appendices IV - VI, and Figures 2 and 6).

Survival of coho in the three tanks with 0‰ , 6‰ , and 12‰ salinities, was good, and the numbers remained constant after the second week. The initial average weights of the 50 fish in each tank were similar. The percentage increase was highest in the 12‰ salinity tank at both stages (end of the fifth and the tenth weeks). The percentage increase on the initial average weights in the 0‰ , 6‰ , and 12‰ salinities at the end of the fifth and tenth weeks were 77.2, 88.1, 155.8, and 215.1, 251.2, 421.5 respectively.

<u>Coho - Series 2</u>, (Appendices VII and VIII, and Figures 2 and 6).

The second series of coho was used, mainly, to observe the effect of a higher concentration (18‰) of salinity. Since these coho had a higher initial average weight their weight increase was compared with another group, from the same stock, in fresh water.

Again the coho survived well. The average initial weight in each tank (0‰ and 18‰ salinity) was a little over twice that of the average initial weight of series 1. The percentage increase was again greater in the 18‰ salinity. Fish were not kept in salinities higher than 18‰ owing to the reported high mortalities in fry and fingerlings experienced by other workers (Black, 1951).

<u>Chum</u>, (Appendices IX - XI, and Figures 3, 4, and 6).

In this experiment the fish in 30‰ salinity failed to survive after the fifth week. This is not attributed to the salinity since the experimental conditions for this group of fish were far from ideal (because of the small size of the tanks). The percentage increase at the end of this period was 166 for 11 fish, as compared with 120 for eight fish in 6‰ . salinity. These fish were active and fed well throughout the experiment. The precise cause of death of the chum in 30‰ salinity tank was not known.

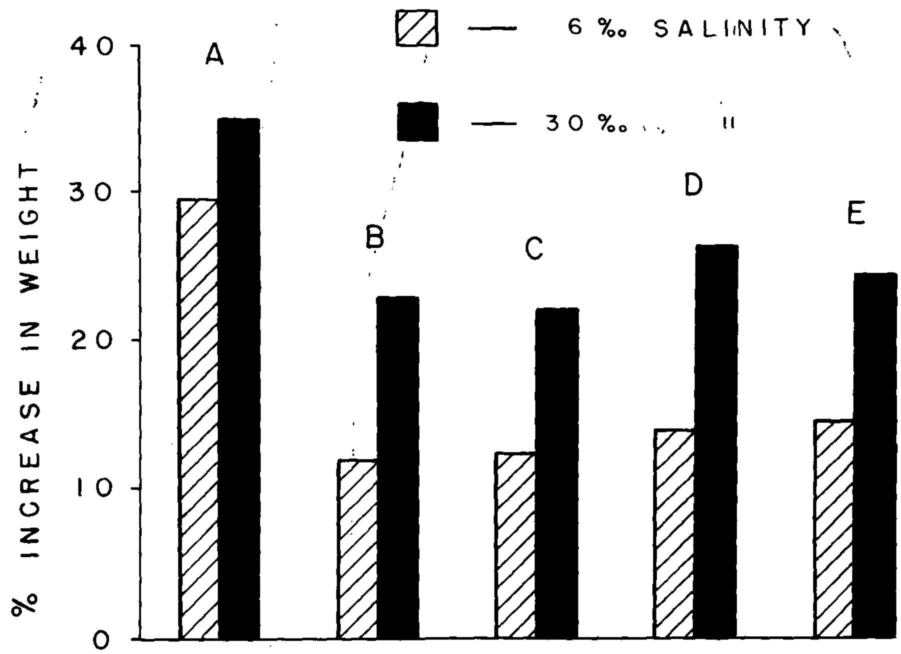

Figure 4. Percentage increase in weight of individual chum in 6‰ and 30‰ salinity. Groups A to E represent pairs of chum of approximately similar weights at beginning of experiment.

With the remaining chum (2 in 30‰ salinity and 8 in 6‰ salinity) in the two tanks, another experiment was begun, where individual weights were recorded and fish identified by clipping the fins. Three fish were taken from the lower salinity tank and acclimatized in salinities of 10‰, 18‰, and 25‰, (two days each) before being introduced into 30‰ salinity. The fish were selected so that their weights in each pair (the one in the 6‰ salinity and the corresponding one in the 30‰ salinity) were similar. For the second time the fish in 30‰ salinity died after the third week, three fish died in the fourth week in the 6‰ salinity tank. This experiment was discontinued after the third week. Even during this short period each of the five fish in 30‰ salinity showed an increase in weight over that of each of the corresponding five fish in 6‰ salinity (Fig. 4).

Goldfish, (Appendices XII and XIII, and Figures 5 and 6).

Goldfish were used primarily to test the effect of salinity on a purely fresh water type. Comparison of growth was made only in fresh water and 6‰ salinity, since higher salinities are lethal. Pora (1939) observed that goldfish were able to live in half sea water (about 12‰ - 16‰) for only a week or so. The 15 fish in each of the two tanks were mature and any appreciable increase in growth was not anticipated. At the end of the fifth week the percentage increase in fresh water was slightly higher, but at the end of the tenth week the ones in 6‰ salinity showed a very small increment over that of the fresh water group.

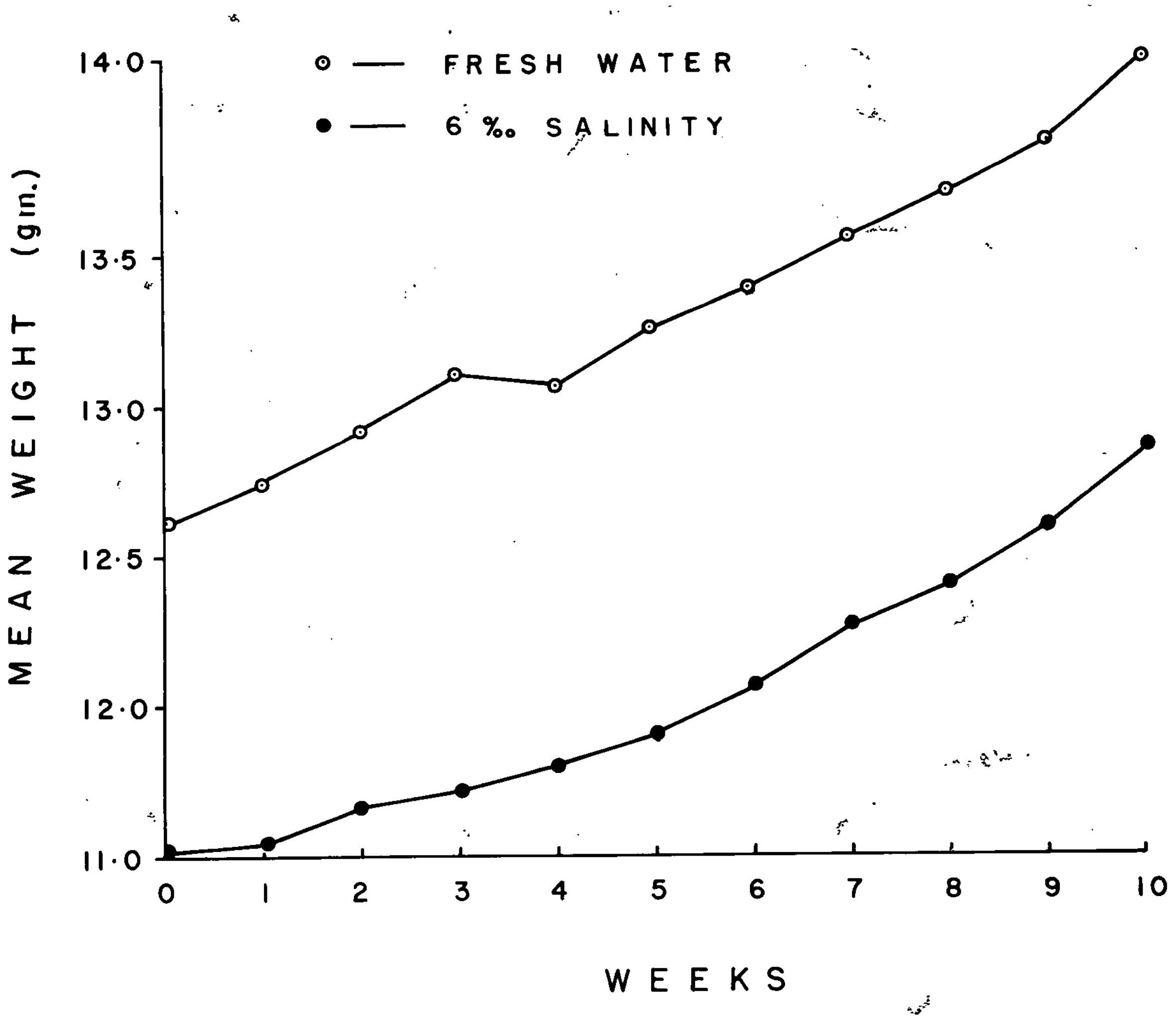

Figure 5. Mean weekly weight of adult goldfish in fresh water and 6‰ salinity.

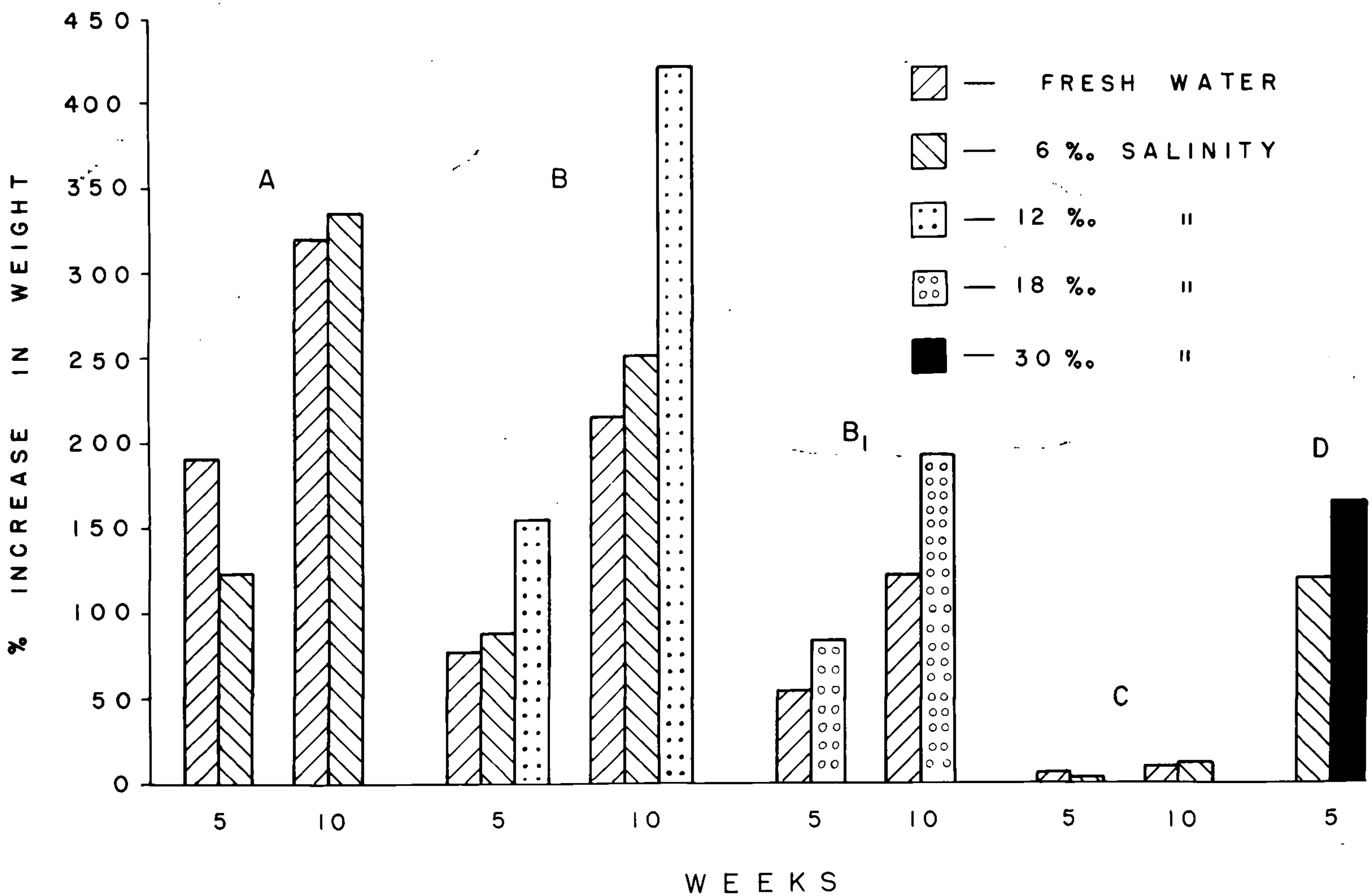

Figure 6. Percentage increase in weight of all groups in fresh water and in the various salinities, at five and ten weeks. A - Sockeye; B - Coho series 1; B_1 - Coho series 2; C - Goldfish; D - Chum.

SUMMARY OF EXPERIMENTAL RESULTS

In all the groups of fish there was an appreciable increase but those in 6‰ , 12‰ , 18‰ , or 30‰ salinity showed greater increase than the corresponding ones in fresh water. Even in the case of goldfish there was a very slight increase shown by the group in 6‰ salinity. The histogram (Fig. 6) shows the growth attained during the two periods (5 and 10 weeks) of the experiment, for all the groups. Up to five weeks sockeye and goldfish grew better in fresh water. In chum and in both series of coho, increased salinities were associated with greater percentage weight increase.

There were two instances where the fresh water groups indicated better growth at the half-time period of the experiment. In the first case, the sockeye in 6‰ salinity grew poorly at the beginning, but after the fifth week began to grow rapidly, and even surpassed that of the sockeye in fresh water. The growth increment in goldfish paralleled that of the sockeye. The final increments of these two groups in the saline medium were too small to make any statement regarding the suitability of the medium in promoting better growth.

The experiment, with the individual weights of the chum salmon, was encouraging, but unfortunately the fish did not survive after the third week. The growth increase of chum in 30‰ salinity, within this short period, seems striking (Fig. 4).

Growth curves (Figs. 1, 2, 3, and 5) for the various series show many interesting features. Only in the case of goldfish do the growth curves (Fig. 5) tend to run parallel to each other. The initial weight of the chum used in the experiments was much higher than that of the other two species and the growth curves (Fig. 3) show the greatest increase within the time period. The curves (Fig. 2) for the fresh water groups of the two series of coho run almost parallel. The curves within the series deviate markedly. In sockeye the growth curves (Fig. 1) do not deviate until after the eighth week. The increase in growth in 6‰ salinity is quite sharp in the last two weeks of the experimental period.

DISCUSSION

Environmental Effect On Growth.

The growth of fish is governed by two main factors - heredity and environment. Inherent characters are influenced to a marked extent by favourable or unfavourable environmental features, particularly in the early stages of growth. These effects may be superficial (e.g. colour) or deep seated (e.g. changes in meristic counts and size). Of the influencing environmental factors, temperature, salinity and the food supply are some of the most important.

Meristic Changes. Alteration in meristic counts in the embryo, effected by variation in environmental factors, produce variation in the size at hatching, and consequently change the rate of growth in later life. Several investigators have shown that changes in temperature and salinity may increase or decrease the number of vertebrae or fin rays in many species of fish. Schmidt (1919) studied the effect of high temperatures during development of the young of guppy, *Lebistes reticulatus*, and concluded that a higher number of fin rays were produced. Taning (1952) found, in experiments on sea-trout, *Salmo trutta*, that the number of dorsal, anal, and pectoral fin rays were greatest at intermediate temperatures. Higher or lower temperatures decreased the number.

Increase in number of vertebrae in several species of fish have been reported in many experimental results. Hubbs (1921) on cabezon, *Leptocottus armatus*, Schmidt (1930) on Atlantic cod, *Gadus callarias*, and Sund (1943) on Norwegian herring, *Clupea harengus*, to mention but a few, have all indicated that lower temperatures tend to produce higher vertebral counts. The alteration in the number of vertebrae in *Salmo trutta* is effected well before hatching as shown by Taning (1944, 1946).

Like temperature, salinity too alters the meristic characters of fishes. Heuts (1947) listed several species in which salinity probably produces higher vertebral counts. Schmidt's (1917, 1920) experimental work with viviparous blenny, Zoarces viviparous, indicated that not only low water temperatures and high salinities produce high numbers of vertebrae, but also high salinities alone bring about the same effect. Lindsey (1952) studied the effects of salinity on vertebral count in the three-spined stickleback, Gasterosteus aculeatus, and found that after making adjustments according to parental influence (hereditary), a rise in salinity at 16 C^{o} or 18 C^{o} produced an increase in vertebral count, while a rise at 12 C^{o} produced a decrease.

The overall effect of the environment on taxonomic characters of fishes has been reviewed by Vladykov (1934). He states that low temperatures, large space or area of habitat, or high degree of salinity in a given area are each correlated with a high number of segments and their components. The characters considered were vertebrae, scales, median fins, gill rakers and body proportions, and of these the least affected by temperature was vertebrae. He also states that the number of segments decrease from north to south in the Northern Hemisphere, from salt water to fresh water, from open to closed areas, from off-shore to inshore and from rivers to brooks. These changes, although small, could certainly affect the growth and size of fishes in the early stages.

Body Proportions. The relative growth of fishes is characterized by a series of stanzas and each stanza has a different growth constant. The change from one stanza to another is quite abrupt and is known as an inflection. Martin (1949) demonstrated that the differences in developmental rate in fishes, when controlled by temperature or by diet, could produce differences in body form. He also found experimentally that the length-weight relationship in trout could be altered under different temperature conditions. By increasing temperature the length of trout fry was increased, and this increased size at growth inflection altered the relative growth in weight. His experimental evidence supports the theory that differences in body form may be effected by differences in body size at growth inflection. Small differences in the early stages of development will probably produce large differences in body form in later life.

Growth and Size of Fishes of different species in different environments has been the subject of study by many investigators. In the literature, the main items considered have been temperature and food. Few workers have tried to determine the salinity effect on growth and size.

Gibson and Hirst (1955) state that an isotonic solution (physiologically saline solution) produces better growth than fresh water in the pre-adult life of guppies. In their experiments they raised guppies in fresh water for an average period of ten weeks or until mature, at various temperatures and found that the fastest growth occurred at 23 C° and 25 C°. Above and below these limits the growth was slow. Guppies in 25% sea water and at 30 C° surpassed the growth rate of the fresh water fish at 25 C° during a period of sixty to eighty days of age. The fastest growth they have on record occurred at 23 C° and 25% sea water. The fish also flourished in 50% sea water and 20 C° or 25 C°. The growth curve for the one at 20 C° and 50% sea water was steeper than that for 25% sea water and the same temperature. They state that this difference may be genetic. Since the investigators discontinued the experiments as soon as the males were mature, there is no experimental evidence to show that sea water enhances the size of adult fish or ultimate size. Nevertheless, there is the possibility of obtaining larger guppies in the optimum sea water medium.

Fish culture experiments carried out in India with the milk fish, Chanos chanos, demonstrate that food is the most important factor governing growth. Chidambaram and Unny (1946) report that their experiments with these fish, which are marine forms entering estuaries to spawn, indicated best growth in fresh water. Chanos fingerlings (7 mm. to 8.5 mm.) were raised in three tanks, one with fresh water, one with brackish water and the third with sea water. The growth of these fish was observed for a period of one year. Since the growth recorded (Table I) indicated progressive decrease with increasing salinity, an analysis of the plankton in all tanks was carried out. The sea water pond was the poorest in plankton, and especially in algae which is the main diet of these fish. From all this evidence they concluded that the best growth in Chanos fingerlings was produced by fresh water. It is rather difficult to accept such a statement, unless it could be proved that the sea water does not support a good growth of the algae, the most essential constituent of the diet of the fish.

Chanos spawns in estuaries or lagoons and the fry enter mouths of rivers or streams. Fry are often trapped by high tides in stagnant pools, where they may grow to a moderate size, depending largely on the size of the pool, the amount of water and the food available. They never mature sexually in fresh water. In Hawaii and some South East Asian countries where an extensive programme for fish culture is in progress, these fry are raised in fresh water ponds. The lengths attained vary, but never equal those captured in the sea (Table I).

Introduction of fresh water whitefish - Coregonus clupeaformis - in 1940 into a saline lake of Saskatchewan (which contained no fish), resulted in a small commercial fishery in 1945 (Rawson, 1946). The salinity of the lake was 15‰. The potential fish food supply was of the same order as that in larger fresh water lakes where whitefish are produced in large quantities. Whitefish were introduced as fry, and after four years measured from 403 mm. - 466 mm. and weighed 1359 gm. - 1812 gm. (Table I). This shows a rate of growth twice that of the same species in fresh water, as in Lake Winnipeg or the Great Lakes (Rawson, 1946). Hinks (1943) states that in Manitoba commercial catches, the average weight of whitefish is within the range 1130 gm. - 1585 gm. and the bulk of the fish so caught are 6 - 8 years old.

Alm (1934) states that those Atlantic salmon which never enter the sea do not show the same growth as those that go to sea, although they have equally good feeding conditions. Salmon in the Baltic precincts show a preference for the southern waters. Alm (1934) assumes that the warmer waters and higher salinities of the southern Baltic are beneficial and hence the smolts from the northern rivers concentrate in this region. The salinity here ranges from 8‰ to 10‰ in the surface and from 15‰ to 20‰ in the deeper parts, whereas the northern part of the Baltic never exceeds 3.5‰ . The temperature too increases southwards. The records of the sizes of salmon in the various parts of the Baltic show considerable differences (Dixon, 1934).

Fish retained in fresh water were smaller than those normally migrating to sea. Fraser (1918) reared sockeye salmon in fresh water and compared them with sea-run fish of the Fraser river. The fresh water forms reached an average length of 250 mm. while the sea-run averaged 566 mm. The growth in the first year in both cases was very nearly the same, but in the second, third, and fourth years there was almost a three-fold difference in the sea-run form.

Foerster (1947) showed experimentally that offspring of non-migratory sockeye or kokanee in Cultus lake, British Columbia, would grow to the same size as that of the sea-run fish from the same lake, if they had the opportunity of going to sea as smolts. He liberated 63,874 yearlings of kokanee, after clipping the pelvics, along with the normal sockeye seaward migrants. In the fifth year 25 individuals, with the pelvics off, were taken in the commercial fishery (34% of which was sampled). The lengths of those recovered were larger than the normal four year old Cultus sockeye but well within the range of the five year olds. This experiment demonstrated that the size difference in the sockeye and kokanee could not be hereditary, but probably environmental.

Salinity and Size. Changes in salinity not only affects the growth and size of fishes but also that of other organisms. Ekman (1935) states that the Baltic was formerly 5‰ more saline than at present. This was supported by a study of the then inner limits of distribution of certain molluscs, especially Littorina. It was during the littorina stage of the Baltic that the sizes of the molluscs Cardium edule and Mytilus edulis were larger than at present and in the same locality.

Sverdrup et al (1942) state that among the euryhaline animals, those living in reduced salinities have a smaller maximum size than those of the same species inhabiting higher salinities. Reduced size may result from the scarcity of food organisms, which must be adapted to live in or near the same biotope. These authors state "whatever the cause may be, it should be noted here that it is a strange and unexplained fact that with few exceptions marine animals from groups with fresh water representatives are larger than the fresh water relatives and usually the size difference is enormous".

Physiological Mechanisms Responsible For Growth.

The present experimental results show a tendency for better growth in juvenile salmon species in the salinities used. Factors such as food, temperature, volume of water and aeration were controlled carefully, so that the only variable was the salinity of the medium. Although the causes for the differences in size were not investigated in this project, some speculation is perhaps permissible.

Osmotic Stress. It has been suggested that the fresh water fish must expend energy in combating the effects of the hypotonic medium in order to maintain an osmotic equilibrium. Experimental evidence to date is circumstantial but the passage of large amounts of water through tissues might create extra demands either on kidney or salt absorbing mechanism. Extensive experimental work has been conducted to ascertain the specific biological effect or function of the various ions in sea water. The function of the salts in sea water cannot be entirely related to osmotic pressure control, since in many instances and particularly in fishes, they are not isotonic with sea water (Baldwin, 1949). Many inland lakes have sufficient concentrations of various salts to maintain suitable osmotic pressure for marine organisms, but lack certain essential salts and are, therefore, not conducive to supporting marine life.

Endocrine Function. Hormonal control of the metabolic activities may be one explanation of the influence of salinity on growth. Rate of respiration, maintainance of osmotic equilibrium, or water balance, changes in external appearance before migration and maturity, are all, in one way or another, related to changes in activity of the endocrine system.

The pituitary and thyroid glands are important endocrines in controlling growth or metabolism. Their role in mammals and amphibians is well known and icthyologists have speculated on the possibility of explaining the changes in metabolism in fish through the activity of the thyroid.

The first contribution to our knowledge of the pituitary growth hormone in relation to the growth of fish was made by Pickford and Thompson (1948). They observed that the growth of mimmichog, Fundulus heteroclitus, was accelerated after purified mammalian growth hormone was administered intraperitoneally. Hoar (1951) suggests that this treatment could have produced stimulation of the thyroid gland which may have been responsible for the observed effect. Growth stimulation in fish was observed as a result either of feeding powdered pituitary gland (Regnier, 1938), or injecting the extract (Nixo-Nicoscio, 1940). However, these results are not necessarily attributable to the isolated effect of the growth promoting hormone, since in the first case the effect may be dietary, and in the second the extract may have included several hormones.

Indirect tests for the function of the thyroid and its part in the growth of fishes has been attempted by many investigators. Thiourea, an anti-thyroid chemical, was used to assess the difficiences that develop in fish. Goldsmith et al (1944) and Nigrelli et al (1946), have both reported that thiourea inhibits the formation of thyroid hormone as well as producing reduced growth in the hybrid Platypoecilus-Xiphorphorus. This observation was also made in the Pacific salmon (Hoar and Bell, 1950). Thyroid hormone administration has been used to study changes in growth rate, sexual maturation, oxygen consumption in respiration, and in migration behaviour. Smith and Everett (1943) pointed out after experimenting on Lebistes reticulatus that thyroxine does not always produce growth acceleration in fish. They also concluded that it is not possible to consider thyroxine as a specific growth promoting factor in fish as is the pituitary growth hormone for the mammals.

Hoar (1951), in an exhaustive review of the hormones in fish, lays emphasis on the fact that, although pituitary growth hormone has not been conclusively demonstrated, there is much evidence to support the belief that the thyroid gland is related to growth of fish, and that a thyrotropic hormone is produced by the pituitary.

<u>Salinity and Thyroid Activity</u>. There is some evidence suggesting that thyroid hormone is related to osmoregulation and growth of fish. Olivereau (1948) found that when a marine fish is placed in dilute sea water there is an increase in thyroid activity. Hoar and Bell (1950), showed that if anadromous fish were retained in fresh water after their natural seaward migration time, they developed hyperplastic thyroids. The importance of iodine for thyroid activity is well known and it may be that those forms that could live in sea water had the added advantage of having a copious supply of this element to build up sufficient supplies of the hormone for growth.

In fresh water, osmoregulation is more difficult and it has been shown to be related to the supply of thyroid hormone (Black, 1951b). Smith's (1956) study on trout indicated a fall in thyroid activity with increase in salinity and injection of thyroxine raised the salinity tolerance. When thiourea and thiouracil were administered the salinity tolerance was reduced in trout. Hoar (1952) suggests that when both osmoregulation and growth are dependent on the availability of thyroid hormone, and when the supply is inadequate, growth is probably reduced. Fontaine (1956) states that much of the work done in this field is still inconclusive and that the suggestions made by Hoar (1952) are very attractive in not only attempting to explain this altogether hazy phenomenon, but also indicating some lines of research that may be fruitful.

Another observation made in the present experiment is worth mentioning. The growth increase in sea water was delayed in the case of the sockeye. This species spends one, two or three years in fresh water before its seaward migration. The growth difference of the experimental fish reared in fresh and sea water was insignificant. Coho go to sea after a year in fresh water (Carl and Clemens, 1953) and in the case of the chum almost immediately after emerging from the gravel. These two species survived better and grew better in the various concentrations of sea water.

Since sockeye spend a longer period in fresh water, the physiological adjustments necessary for life in sea water are delayed. The retarded growth of sockeye observed in the saline medium (6‰ salinity) during the first eight weeks of the experiment, was probably due to the failure of the physiological mechanisms to respond to the hypertonic medium. However, these sockeye fry, in 6‰ salinity, showed a marked increase in growth during the last two weeks.

The results of this experiment show that salinity alone may bring about a difference in growth rate and size. Data taken from records of sizes of some fishes also show that those in sea water grow to a greater size. These indicate that there must be some factor or combination of factors in sea water that contributes to this enhanced growth. Several environmental factors and their influence on the growth of fishes either on the whole animal or on some parts have been discussed. It is yet to be seen whether the thyroid controls fully the metabolism of fish and to what extent it may do so in the fresh water and marine environments. Study of hormonal control of growth should be a productive field of investigation that may throw light on this phenomenon of salinity and growth of fish.

SUMMARY

1. In the literature, records of the sizes attained at maturity by several species of fish, inhabiting both sea and fresh waters, indicate that the marine environment promotes better growth.

2. The experiments on growth of juvenile salmon indicate better growth in sea water and particularly in the higher salinities used.

3. Sockeye in 6‰ salinity showed only a very slight increase in weight, over that of the fresh water group. Growth in this saline medium was retarded during the first eight weeks of the experiment and this is probably due to the longer fresh water life of this species.

4. The best increase in weight of the coho was obtained in 12‰ salinity.

5. Chum showed good growth in both 6‰ and 30‰ salinities, but the percentage weight increase in the latter medium was better.

6. Goldfish did not show any significant difference in weight increase in the two media.

7. The effect of different environmental factors on growth of fish has been studied experimentally by several investigators, and their evidence shows that the alteration in meristic counts or body proportions, in early development, produces different growth rates in the successive stages of later life, and consequently affects the ultimate size.

8. The physiological mechanisms of growth of fishes are not well known. The influence of hormones on growth is probably ameliorated in sea water.

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APPENDIX - I

C
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P
Y

P. O. Box 1471

Canterbury University College

Christchurch, C. 1

New Zealand

September IX, '56

Professor W. S. Hoar
Zool. Dept.
University
Vancouver, B. C.

Dear Professor Hoar,

First, let me thank you for kindly sending some reprints of your work on fish behaviour and physiology which reached me some short time ago. Meanwhile, I have obtained details of spring salmon runs from the Marine Department and sent you them along with my material from Lake Coleridge. MacDonald's Creek, Westland, runs into a lagoon which, I think, is brackish and resembles Lake Ellesmere on the east side of Canterbury from which I obtained a male and a female mature at 16" and 1 lb. 1 oz, this last May. It does look as if your proposition carries a lot of weight, viz. that there is "evidence of osmotic stress in their relatively reduced growth rate" (Biol. Rev., p. 444, Vol. 28, 1953).

Presumably, the fish running in from the sea resemble those going into Western Canadian rivers during the spawning runs.

Yours very truly,

"E. Percival."

APPENDIX - I - continued

Oncorhynchus tschawytscha in New Zealand

Spawning run from a fresh water lake, Lake Coleridge, May, 1954 some freshly run and clean, some worn to varying extents.

LENGTH"	WEIGHT (lb.oz.)	SEX	LENGTH"	WEIGHT (lb.oz.)	SEX
18	2.0	M	19½	2.6	F
19	2.0		19	2.6	F
18	2.0	M	18½	2.4	F
17¼	2.0	F	19¼	2.8	M
17¼	2.0	M	19¼	2.10	F
17 3/4	2.0	M	19	2.6	F
17	1.8	M	18½	2.4	F
15	1.2	M	19¼	2.8	M
19½	2.0	M	19¼	2.10	F
20¼	2.4	M	19½	3.0	F
18½	2.4	M	18 3/4	2.10	F
18¼	2.4	M	19½	2.8	M
19	2.4	F	18½	2.4	F
19	2.4	M	20¼	3.8	F
18¼	2.0	M	20¼	2.8	F
18½	2.0	M	18 3/4	2.10	F
18 3/4	2.0	F	17 3/4	2.2	F
19 3/4	2.4	F	17 3/4	1.12	F
18¼	2.0	F	18	1.12	F
18½	1.8	M	20¼	2.4	M
18 3/4	1.14	M	19¼	2.0	F
19	1.14	F	18¼	2.0	F
18½	2.0	M	19¼	2.12	F
21	2.8	F	18 3/4	2.4	F
17	1.3	M	18 3/4	2.6	M
21¼	2.0	M	19½	2.4	M
18 3/4	2.0	M	18 3/4	2.4	F
17¼	1.9	M	18 3/4	2.0	F
19¼	2.7	M	19¼	2.10	F
17½	1.5	M	17½	2.0	F
19 3/4	2.2	F	18¼	2.4	?
18¼	2.0	M	19 3/4	2.6	F
18	1.15	M	18½	2.0	F
17¼	1.11	M	19½	2.8	F
18 3/4	2.1	M	18	2.6	M
18	1.9	M	18 3/4	2.12	F
18 3/4	1.13	M	18½	2.4	M
20 3/4	2.1	M	18 3/4	2.10	M
18	1.12	M	17 3/4	1.12	?
19½	2.6	F			
19 3/4	2.6	F			
19 3/4	2.8	M			
19	1.14	M			

APPENDIX - I - continued

QUINNAT SALMON "LANDLOCKED" - MACDONALD'S CREEK, WESTLAND

May, 1955

23½"	F
18"	F
24½"	F
23"	M
24½"	F
25½"	F
24½"	M
19½"	M
24"	F
23"	M
19½"	M
21½"	M

May, 1956

25"	M
24"	M
21½"	F
20"	F
19"	F
21"	F
21"	F
22"	F

QUINNAT SALMON TAKEN - RANGITATA - 1944

Weight	Length
16 lbs	30 inches
15	29
19	32
15	29
15	35
11	32
20	37
8	29
11½	33
10	30
7	28½
11½	28
12	27

QUINNAT SALMON TAKEN - WAIMAKARIRI - 1944

Weight	Length
15 lbs	33 inches
8	28
8	29
11	31
12	31
8½	27
9	30
15	33
16	34
13	32
14	34
12	31
9	28
8	27
9	28
9½	29
10	30
9½	28

APPENDIX - I - continued

QUINNAT SALMON TAKEN - continued — WAIMAKARIRI - 1944

Weight	Length
10 lbs	29 inches
12	31
11	30
14	32
11	28
9	28
9½	29
9	28
9½	25
10	30
11	30
11	27
10½	29
13	37
8	29

QUINNAT SALMON TAKEN — OPIHI - 1944

Weight		Length
12 lbs		32 inches
17		32
19		36
21		36
16		36
18		35
18)	Estimated Length and Weight	38
10)		36
12)		36
7)		33
16)		36
11)		34
21)		38
20)		38
8)		33
17)		38
16)	Estimated Length and Weight	39
23)		40
17)		37
16)		37
10)		36
21)		38
8)		34
14)		36
12)		35
18)		37
12)		36
17)		36
11)		34

APPENDIX - I - continued

QUINNAT SALMON TAKEN - RAKAIA - 1944

Weight	Length	
4 lbs	20 inches	Estimated Length and Weight
14	32	
11½	30	
12	32	
11	30	
11	30	
8	28	
12	31	
13	33	
10	27	
12	31	
12	30	
10	28	
10	31	
13	34	

APPENDIX - II

Sockeye: Weekly record of weight increase.

No. of Weeks	No. of Fish	Weight in gm.	Mean weight in gm.	% Increase	Temperature C°
	SOCKEYE - Fresh water. 0‰ SALINITY				
Initial	69	13.3	0.192		13
1	17	4.8	0.283		11.8
2	16	5.8	0.363		12
3	16	6.4	0.400		12
4	10	4.8	0.480		12.5
5	10	5.6	0.560	191.7	12.5
6	8	4.9	0.613		13
7	8	5.3	0.663		13.5
8	8	5.8	0.730		13.5
9	8	6.1	0.763		13
10	8	6.5	0.810	319.8	13

<u>APPENDIX - III</u>

Sockeye: Weekly record of weight increase.

No. of Weeks	No. of Fish	Weight in gm.	Mean weight in gm.	% Increase	Temperature C°
		SOCKEYE - 6‰ SALINITY			
Initial	69	15.3	0.221		13
1	25	8.5	0.339		11.8
2	24	8.6	0.358		12
3	24	9.4	0.392		12
4	24	10.4	0.433		12.5
5	24	11.6	0.481	117.6	12.5
6	24	12.8	0.533		13
7	24	14.4	0.600		13.5
8	24	16.8	0.700		13.5
9	24	20.0	0.832		13
10	24	23.1	0.963	335.7	13

APPENDIX - IV

Coho: Series 1. Weekly record of weight increase.

COHO - Fresh water. 0‰ SALINITY					
No. of Weeks	No. of Fish	Weight in gm.	Mean weight in gm.	% Increase	Temperature C°
Initial	50	22.8	0.456		13
1	39	21.7	0.556		11.8
2	38	21.8	0.574		12
3	38	22.6	0.595		12
4	38	27.5	0.724		12.5
5	38	30.7	0.808	77.2	12.5
6	38	35.1	0.924		13
7	38	39.2	1.032		13.5
8	38	44.1	1.161		13.5
9	38	49.8	1.311		13
10	38	54.6	1.437	215.1	13

APPENDIX - V

Coho: Series 1. Weekly record of weight increase.

COHO - 6‰ SALINITY

No. of Weeks	No. of Fish	Weight in gm.	Mean weight in gm.	% Increase	Temperature C°
Initial	50	24.3	0.486		13
1	44	23.0	0.523		11.8
2	44	26.1	0.593		12
3	44	29.8	0.677		12
4	44	34.9	0.795		12.5
5	44	40.2	0.914	88.1	12.5
6	44	46.4	1.055		13
7	44	52.3	1.189		13.5
8	44	59.9	1.361		13.5
9	44	68.1	1.548		13
10	44	75.1	1.707	251.2	13

APPENDIX - VI

Coho: Series 1. Weekly record of weight increase.

No. of Weeks	No. of Fish	COHO - 12‰ SALINITY Weight in gm.	Mean weight in gm.	% Increase	Temperature C°
Initial	50	23.3	0.466		13
1	38	21.8	0.574		11.8
2	38	22.7	0.597		12
3	37	27.8	0.751		12
4	37	35.2	0.951		12.5
5	37	44.1	1.192	155.8	12.5
6	37	52.0	1.405		13
7	37	60.4	1.632		13.5
8	37	69.7	1.884		13.5
9	37	80.1	2.165		13
10	37	89.9	2.430	421.5	13

APPENDIX - VII

Coho: Series 2. Weekly record of weight increase.

No. of Weeks	No. of Fish	Weight in gm.	Mean weight in gm.	% Increase	Temperature C°
		COHO - Fresh water. 0‰ SALINITY			
Initial	50	49.6	0.992		13.5
1	48	52.7	1.098		14.4
2	27	56.8	1.209		13
3	47	60.7	1.278		13
4	47	65.4	1.391		13
5	47	72.2	1.536	53.2	13
6	47	78.1	1.662		12.8
7	47	85.0	1.809		12.5
8	47	90.1	1.917		11.5
9	46	95.5	2.080		11
10	46	101.1	2.200	121.8	10.5

APPENDIX - VIII

Coho: Series 2. Weekly record of weight increase.

	COHO - 18‰ SALINITY				
No. of Weeks	No. of Fish	Weight in gm.	Mean weight in gm.	% Increase	Temperature C°
Initial	50	51.1	1.022		13.5
1	50	55.3	1.106		14.4
2	50	61.1	1.222		13
3	49	69.7	1.422		13
4	49	80.0	1.632		13
5	49	92.4	1.886	84.5	13
6	49	103.6	2.114		12.8
7	49	117.2	2.392		12.5
8	49	126.8	2.589		11.5
9	49	137.1	2.797		11
10	49	146.9	2.998	193.5	10.5

APPENDIX - IX

Chum: Weekly record of weight increase.

No. of Weeks	No. of Fish	Weight in gm.	Mean weight in gm.	% Increase	Temperature C°
	CHUM - 6‰ SALINITY				
Initial	11	27.6	2.509		12.6
1	11	30.0	2.727		13
2	11	33.8	3.073		12.8
3	9	39.1	4.344		13.5
4	9	42.4	4.710		12.8
5	8	44.2	5.530	120.4	13

APPENDIX - X

Chum: Weekly record of weight increase.

No. of Weeks	No. of Fish	Weight in gm.	Mean weight in gm.	% Increase	Temperature C°
		CHUM - 30‰ SALINITY			
Initial	12	28.1	2.342		12.6
1	12	31.6	2.633		13
2	12	38.4	3.200		12.8
3	11	48.6	4.420		13.5
4	11	59.1	5.373		12.8
5	11	68.4	6.220	165.6	13
6	2	Experiment discontinued.			

APPENDIX - XI

Chum: Data on individual weights in gm.

	6‰ SALINITY					30‰ SALINITY					
Time in weeks	Normal fish	Left Pelvic	Adipose	Upper Caudal	Lower Caudal	Normal fish	Left Pelvic	Adipose	Upper Caudal	Lower Caudal	Temperature C°
Initial	6.1	6.7	5.6	7.1	6.8	5.8	7.1	5.4	6.8	6.9	13
1	6.6	6.9	5.7	7.4	7.0	6.3	7.5	5.6	7.1	7.3	12.8
2	7.2	7.2	5.9	7.7	7.3	7.0	7.9	6.0	7.7	7.8	13
3	7.9	7.5	6.3	8.1	7.8	7.8	8.7	6.6	8.6	8.6	13
4	DEAD	8.0	DEAD	8.6	DEAD	DEAD	DEAD	DEAD	DEAD	DEAD	13
% increase up to 3rd wk.	29.5	12.0	12.5	14.1	14.7	34.5	23.0	22.2	26.5	24.6	

APPENDIX - XII

Goldfish: Weekly record of weight increase.

No. of Weeks	GOLDFISH - Fresh water. 0‰ SALINITY				Temperature
	No. of Fish	Weight in gm.	Mean weight in gm.	% Increase	C°
Initial	15	189.5	12.63		17.5
1	15	191.2	12.75		17
2	15	193.8	12.92		17.5
3	15	196.4	13.10		17.8
4	15	196.0	13.06		17
5	15	199.0	13.27	5.1	16.8
6	15	201.00	13.40		16.5
7	15	203.6	13.57		16.5
8	15	205.8	13.72		15
9	15	208.0	13.87		13
10	15	209.8	13.99	10.77	12.5

APPENDIX - XIII

Goldfish: Weekly record of weight increase.

		GOLDFISH - 6‰ SALINITY			
No. of Weeks	No. of Fish	Weight in gm.	Mean weight in gm.	% Increase	Temperature C°
Initial	15	172.8	11.52		17.5
1	15	173.1	11.54		17
2	15	175.0	11.67		17.5
3	15	176.6	11.77		17.8
4	15	177.0	11.80		17
5	15	178.6	11.91	3.4	16.8
6	15	181.2	12.08		16.5
7	15	184.1	12.27		16.5
8	15	186.2	12.41		15
9	15	189.1	12.60		13
10	15	192.8	12.85	11.5	12.5