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OSTEOLOGY AND MORPHOLOGY OF THE GENERA CRISTIVOMER AND SALVELINUS AND THEIR RELATIONSHIPS WITH OTHER SALMONIDAE

by

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A Thesis
submitted to the
University of Ottawa
in partial fulfillment of the requirements for the degree of
Doctor of Philosophy

September, 1964

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ACKNOWLEDGMENTS

I am especially grateful to Dr. V.D. Vladykov, Professor of Biology at the University of Ottawa, for his guidance and criticism throughout the course of this study. I am also greatly indebted to Dr. A.L. Pritchard, Director, Conservation and Development Service of the Department of Fisheries, Ottawa, who guided the research in the absence of Dr. Vladykov when the latter was posted to Iran on an F A O mission. Dr. A. DesMarais, Chairman, Department of Biology of the University of Ottawa, provided laboratory facilities and generously helped in the statistical analysis of the data. I wish to express my sincere appreciation to Dr. J.R. Dymond and Dr. W.B. Scott, both of the Royal Ontario Museum, Dr. C.C. Lindsey of the University of British Columbia, and Dr. D.E. McAllister of the National Museum of Canada, for discussion of the problem. Dr. R. Legault, O.M.I., of the University of Ottawa, brought the eggs from St. Faustin Hatchery, Quebec, and helped me in rearing them.

Many people have assisted me by providing live or preserved fish for this study, and it is a pleasure to acknowledge my debt to them.

In Canada the following persons provided research material: Mr. F.M. Atton of the Department of Natural Resources, Saskatoon, Sask.; Mr. J. Cuerrier of the Department of Northern Affairs and National Resources, Ottawa; Mr. J.D. Hughes, District Forester, Swastika, Ont.; Mr. J.G. Hunter of the Fisheries Research Board of Canada; Mr. N.V. Martin of the Department of Lands and Forests,

Maple, Ont.; Mr. Camille Paré of the Department of Fish and Game, Quebec; Mr. L.A. Sunde of the Department of Mines and Natural Resources, The Pas, Man.; Mr. J.C. Ward of the Department of Northern Affairs and National Resources, Jasper, Alta.

In the U. S. A. the following sent material: Dr. R.M. Bailey of the University of Michigan; Mr. R. Behnke of the University of California; Dr. D.E. Rosen of the American Museum of Natural History, New York; Dr. L.P. Schultz of the Smithsonian Institution, Washington. Dr. W.H. Everhart, Mr. K. Warner, and Mr. K. Havey, all of the Department of Inland Fisheries and Game, Maine, made possible the collection of blueback and Sunapee chars.

Mr. G. Ben-Tchavtchavadze of the University of Ottawa expertly took the photographs. Miss P. MacKinnon assisted me in different aspects of this work. Miss Florence Kwan and Mr. Marcel Laperle helped me in the preparation of skeletons and analysis of data.

To all these persons and many others the author expresses his sincere gratitude.

ABSTRACT

The aim of this study, which is mainly osteological, is to clarify the status of the genera *Cristivomer* and *Salvelinus*. A morphometric and meristic study in conjunction with osteology was used to assess their phylogenetic relationships with other genera of Salmonidae.

About 390 specimens of adult and adolescent fish and 268 eggs and fry were examined.

Presently, seven genera are recognized in Salmonidae. The genus *Cristivomer* is separated from *Salvelinus* because of the shape of the supraethmoid, supramaxilla, subopercle, vomer, lingual plate, and caudal fin, and also the high number of pyloric caeca, presence of pearl organs, and breeding behaviour of the former.

In the genus *Salvelinus*, *S. alpinus* (including various forms), *S. malma*, and *S. fontinalis* are distinguished. *S. alpinus oquassa*, previously known as *S. marstoni*, is considered a subspecies of *S. alpinus*. The two previously designated species *S. oquassa* and *S. aureolus* are synonymized with *S. a. oquassa*. *S. timagamiensis* is reduced to a subspecies of *S. fontinalis*.

The genus *Salmothymus* is maintained.

The genus *Cristivomer* is more generalized than *Salvelinus*. The species *S. malma* is intermediate between *S. alpinus* and *S. fontinalis*.

For the first time a detailed osteological study of *C. namaycush* and several forms of *Salvelinus* is undertaken, and their relationships assessed.

INTRODUCTION

The family Salmonidae includes salmon, trout, and char. They are coldwater fishes of the Northern Hemisphere and stay throughout their lives in fresh water or grow in the sea but return into streams to spawn. The fishes of this family are of greatest importance to the commercial fisherman and to the angler.

The systematics of the genera and species in the family Salmonidae is complex and controversial. It has received considerable attention from morphologists, osteologists, ecologists, behaviourists, and more recently, geneticists and biochemists. Different criteria have been used to separate various taxa. Frequently, species, rarely genera, have been created or deleted. This unstable situation is possibly the result of the paucity of organized studies.

The aim of the present study, which is mainly osteological and morphological in nature, is to clarify the status of the genus <u>Cristivomer</u>. An attempt is also made to assess the status of the North American species of the genus <u>Salvelinus</u>.

The order Isospondyli (Regan, 1909; Jordan, 1923) was renamed as Clupeiformes (Berg, 1940). Goodrich (1930) preferred the ending, -formes for the suborders. A few important characteristics of the order are: the Weberian apparatus is absent, the upper jaw is bordered by the premaxilla and the maxilla, the scales are cycloid, and the caudal fin is homocercal. This order is divided into several suborders. The suborder Salmonoidei (Gosline, 1960) concerns us here. The fishes of the suborder Salmonoidei are soft-eyed teleosts and are usually defined by the presence of an adipose fin, parapophyses not co-ossified with the centra, the neural and haemal arches of the caudal fin skeleton laterally compressed, and oviducts absent or incomplete (Regan, 1913; Gosline, 1960). The Salmonoidei includes the salmons, trouts, chars, whitefishes, graylings, smelts, and other related fishes. Berg (1940) has listed twelve families in the suborder Salmonoidei, but revisions by Chapman (1941a, 1941b, 1942, 1948) and Hubbs (1953) have reduced this number to 7: Salmonidae, Argentinidae, Osmeridae, Salangidae, Retropinnatidae, Aplochitonidae, and Plecoglossidae.

Some important characteristics of the family Salmonidae are the presence of the 3 upturned caudal vertebrae, orbitosphenoid (rarely absent), suprapreopercle, basibranchial plate, developed teeth on the jaws and a few other bones, separation of the parietals, usually large ova, and the young almost invariably with parr marks. The hypethmoid and epipleurals usually, and the dermosphenotics essentially, are absent in this family.

Regan (1913) distinguished trouts and chars, whitefishes and graylings from all the other members of the suborder by the presence of 3 upturned caudal vertebrae. The salmonines (salmons, trout, and chars), coregonines (whitefishes), and thymallines (graylings) are variously placed in 1, 2 or 3 families. Boulenger (1895) included salmonines, coregonines, and thymallines in a single family Salmonidae. Among recent authors Norden (1961) included the 3 subfamilies Salmoninae, Coregoninae, and Thymallinae in the family Salmonidae. Regan (1914) divided Salmonidae into 2 subfamilies. Salmoninae with separated parietals, smaller scales, and stronger dentition, and

Coregoninae, which included graylings, with parietals meeting at the midline, larger scales, and very weak dentition. Jordan and Everman (1896), Tchernavin (1923), and Berg (1940) included coregonines within the family Salmonidae, but established a separate family Thymallidae for graylings on the basis of the absence of the orbitosphenoid bone, and a long dorsal fin. Hubbs and Lagler (1958), Carl, Clemens, and Lindsey (1959), Needham and Gard (1959), and Vladykov (1963), kept Pacific salmons, trouts and chars, whitefishes, and graylings well separated and assigned them to 3 distinct families, Salmonidae, Coregonidae, and Thymallidae, respectively. The family Salmonidae is used here in this restricted sense.

In the family Salmonidae, 5 genera are usually recognized: *Brachymystax*, *Hucho*, *Salvelinus* (including *Cristivomer*), *Salmo*, and *Oncorhynchus*. Rounsefell (1962) and Vladykov (1954 and 1963) kept the genera *Cristivomer* and *Salvelinus* separate. The genus *Salmothymus* was recognized by Berg (1908) but Regan (1920) amalgamated it with *Salmo*. Tentatively, we recognize the above 5 genera, as well as the genera *Cristivomer* and *Salmothymus*. The genera *Cristivomer* and *Salvelinus* (North American species only) are of primary importance to this study and are discussed in some detail. Some distinguishing characteristics for the genus *Salmothymus* are included here. Brief diagnosis and distribution for the remaining genera are provided by Vladykov (1963).

Cristivomer Gill and Jordan, 1878. The generic status is controversial. This genus has a large mouth. The jaw articulation is behind the orbit. Teeth on the shaft of the vomer are absent. Some authors include the genus *Cristivomer* with the genus *Salvelinus*.

Others distinguish it from the genus Salvelinus by the raised and posteriorly prolongated crest of the vomer, the shape of the supraethmoid bone (Kendall, 1919), and the presence of the pearl organs (Vladykov, 1954). The flanks of the fish in the genera Cristivomer and Salvelinus have light spots on a dark background. Cristivomer namaycush (Walbaum), the only species in the genus, is almost always restricted to the fresh waters of northern North America (Vladykov, 1963).

In 1792 Walbaum described Salmo namaycush from the Hudson Bay area, based on the Namaycush salmon Pennant (1792). In subsequent years the fish was variously named as Salmo pallidus Rafinesque (1817), Salmo amethystinus Mitchell (1818), Salmo confinis De Kay (1842), Salmo siscowet Agassiz (1850). In 1878 Gill and Jordan created a monotypic genus Cristivomer. The fish then acquired a new name Cristivomer namaycush (Walbaum). Kendall (1919), Stokell (1951), Rounsefell (1962), Vladykov (1954; 1963) and Dymond (1964), are some of the more recent proponents of the genus Cristivomer. Jordan and Gilbert (1883), Regan (1914), Kendall (1914), Pfaff (1937), and Morton and Miller (1954) consider Cristivomer synonymous with Salvelinus.

Salvelinus Richardson, 1836. Before the establishment of the genus Salvelinus most of the species which are presently included in Salvelinus were described in the genus Salmo. For earlier nomenclature of the genus Salvelinus, Jordan, Evermann, and Clark (1930) may be consulted. At present American and Russian ichthyologists consider Salvelinus a distinct genus. Some authors in Europe, (Haär, 1949; Fabricius and Gustafson, 1954) still consider it synonymous with *Salmo*. The genus *Salvelinus* has a large mouth. The jaw articulation is well behind the orbit. The teeth on the shaft of the vomer are absent, and the vomerine and palatine teeth are usually narrowly separated. It is widely distributed across northern Europe, Asia, and North America and extends into the temperate zones in these continents (Dymond and Vladykov, 1934; Vladykov, 1963). It is freshwater and anadromous.

Jordan, Evermann, and Clark (1930) have listed 12 species of the genus *Salvelinus* from North America including the Canadian Arctic and Greenland. McPhail (1961) feels that most are synonymous with *S. alpinus*. Contemporary authors deal with 7 forms which represent either species or subspecies.

Salvelinus alpinus group. The status of the chars from the North American Arctic and Greenland is uncertain. Some workers (Hilderbrand, 1948; Walters, 1953; McPhail, 1961) prefer to call this assemblage of Arctic chars the *S. alpinus* complex. Others (Vladykov, 1954; Rounsefell, 1962) suggest the use of the single name *S. alpinus* for the whole group of fishes until more material is available. The latter trend of thought is preferred here. McPhail (1961) separated *S. alpinus* from *S. malma* because of a higher gill raker count on the lower limb of the first gill arch in *S. alpinus*; the ranges for *S. alpinus* and *S. malma* were 12 - 19 and 8 - 14, respectively. The colour on the dorsal surface of *S. alpinus* is blue, olive-green, or brown; the sides are often bright orange or red. In sea-run individuals the sides are silvery. This species group occurs from Alaska, along the Arctic coast, to the New England states. It is optionally anadromous or adfluvial.

Salvelinus oquassa (Girard). The species status of the blueback char is disputed. It was described by Girard in 1854. For its synonomy Kendall (1914) may be consulted. The earlier workers differentiated it from the other chars by its small, conical, and coregonine type of head. The mouth is smaller than in S. fontinalis. A bluish tint extends all along the back. For further differentiating characteristics Kendall (1914), Everhart (1950; 1950a), and Waters (1960) may be referred to. These authors feel that S. oquassa is a valid species. Vladykov (1954) believes that S. oquassa may be conspecific with S. marstoni, and Backus (1957) considers it a relict population of S. alpinus. It is found in freshwater lakes of northwestern Maine.

Salvelinus aureolus Bean, 1887. The Sunapee char is a controversial species. Its synonymy may be obtained from Kendall (1914). It was distinguished by earlier workers from the blueback char, its closest relative, by longer maxilla and small to large orange or yellowish spots on the flanks of the body (Rounsefell, 1962). Between the Sunapee char and the blueback char, Waters (1960) found differences in the number of caudal vertebrae, haemal and neural spines, and some morphological and serological characteristics. Sisson (1950), Vladykov (1954), and Waters (1960) considered S. aureolus a distinct species, whereas Bailey et al. (1960), Backus (1957), and McPhail (1961) thought it synonymous with S. alpinus. It occurs in freshwater lakes of New Hampshire and Maine.

Salvelinus marstoni Garman, 1893. For its synonymy Jordan et al. (1930) may be consulted. Its specific status is questionable. Vladykov (1954) distinguished it from the other chars on the basis of the skeleton of the head and tail, and colouration. He considered it a valid species. However, Backus (1957) and McPhail (1961) regarded it synonymous with S. alpinus. It is distributed in the freshwater lakes of the province of Quebec.

Salvelinus malma (Walbaum). Walbaum described this species in 1792. Jordan et al. (1930) may be consulted for its synonymy. An acknowledged species, it is differentiated from the other chars because of its morphology (Delacy and Morton, 1943; Morton and Miller, 1954), the low number of gill rakers (McPhail, 1961) and colour differences (Rounsefell, 1962). Dymond (1936, 1947), Carl and Clemens (1953), and Lindsey (1956) gave it subspecific rank, S. alpinus malma, and considered it a part of the S. alpinus complex. In North America it ranges from northern California to southern Alaska (McPhail, 1961). It is optionally anadromous or fluvial.

Salvelinus fontinalis (Mitchell). In 1814, Mitchill described this species. Jordan et al. (1930) have given its synonymy. A distinct species, it can be recognized by the truncate tail fin, precaudal vertebrae fewer than 37, the vomer without a long, raised crest, and lower fins with a black stripe near the leading edge (Hubbs and Lagler, 1958). It is native to eastern and central North America (Hubbs and Lagler, 1958) and is optionally anadromous, fluvial, or adfluvial.

Salvelinus timagamiensis Henn and Rinkenback, 1925. The specific status of this fish is not yet definitely determined. Initially it was separated from the other chars on the basis of the extremely long maxilla, slight differences in colour, and the shape of the head. Martin (1940) and Dymond (1947) considered it a subspecies of *S. fontinalis*. Vladykov (1954) regarded it a colour variety of *S. fontinalis*. It occurs in the waters of the Timigami forest in Ontario and is a fresh-water dweller.

Salvelinus agassizii Garman, 1885. For its synonomy refer to Kendall (1914). It was separated from *S. fontinalis* on the basis of a shorter head, lower dorsal fin, shorter ventral fin, forked tail, and some colour differences. Kendall (1914) considered it a distinct species whereas Vladykov (1954) thought it a colour variety of *S. fontinalis*. It was described from a freshwater lake in New Hampshire. This species is now extinct. Unfortunately, we could not get specimens of this species for our study.

Salmothymus Berg, 1908. The fish in this genus are characterized by a small to large mouth. The eyes are large as compared to the genus *Salmo*. The jaw articulation is located below the posterior margin of the orbit. The maxilla reaches to the middle of the orbit of the eye and has a distinctive shape. Teeth on the lingual plate are in a series of 4 - 5 rows in *S. ohridanus* (Hadžišče, 1960). The vomerine and palatine teeth form a continuous or sometimes interrupted series on the roof of the mouth. There are at least 3 distinct species in this genus. The fish in this genus occur in Dalmatia and Lake Ohrid (Vladykov, 1963).

The osteology of *Salmo* (Kölliker, 1860; Bruch, 1861; Gregory, 1933; de Beer, 1937; and Tchernavin, 1937, 1938b) and *Oncorhynchus* (Tchernavin, 1937, 1938a; Nomura, 1954; Vladykov, 1962; Hikita, 1962) has been worked out in sufficient detail. Morton and Miller (1954), Vladykov (1954), and Norden (1961) have done some work on the osteology, morphology, and meristic features of the genera *Cristivomer* and

Salvelinus but their account is by no means complete. For this reason detailed osteological studies of the adult and of the developmental stages of the genera *Cristivomer* and *Salvelinus* are undertaken. For comparative purposes the osteology of the genera *Salmo* (*S. gairdnerii* only) and *Brachymystax* (1 of the foreign genera) is also studied. The morphometric and meristic features of the adult as well as of the young of several species of the family Salmonidae are considered as well.

The present study furthers our existing knowledge of the ontogeny and morphology, particularly the osteology, of the salmonoid fishes. In addition, this investigation helps to assess the systematics of the genus *Cristivomer* and the North American species of the genus *Salvelinus*.

MATERIALS, METHODS, AND TERMINOLOGY

Materials

For the fish used in the present study, the number of eggs, fry, adolescents and adults are shown in Table 1. Table 2 shows the localities and sizes of adolescent and adult salmonids studied. Table 52 lists the skeletal structures photographed. The sources and sizes of the egg and fry samples are presented, respectively, in Tables 3 and 4. All the study material is deposited in the Department of Biology of the University of Ottawa.

Methods

Different techniques have been used for the preparation of skeletal material and for measuring the adult fish and fry. Therefore the methods are discussed under the separate sections on adult fish and fry.

For uniform comparisons, skeletal structures of mature (but not spawning) males were photographed. However we did not lose sight of the structural differences, if any, found between the males and females.

All morphometric measurements and meristic counts were made on the left side of a fish. The paired cranial bones, as for instance premaxillae, are usually discussed in singular form.

The generic names which are referred to rather sparingly, such as Salmo and Salmothymus, are written in full, whereas, abbreviated "S" is used for Salvelinus only.

Table 5 lists vernacular and scientific names extensively used in text and tables.

TABLE 1. The number of eggs, fry, adolescents, and adults of several species of Salmonidae studied.[1]

Species	Ripe eggs (4.0-7.3 mm)	Fry (12.2-49.3 mm)	Sub-total	Adolescents (87-129 mm)	Adults (130-835 mm)	Sub-total	Total
Cristivomer namaycush	19	56	75	-	88	88	163
Salvelinus alpinus alpinus	36	44	80	-	21	21	101
Salvelinus alpinus oquassa - Quebec[2]	-	-	-	-	48	48	48
Salvelinus alpinus oquassa - Pushineer Lake, Maine[3]	5	-	5	-	25	25	30
Salvelinus alpinus oquassa - Floods Pond Maine[4]	5	-	5	-	23	23	28
Salvelinus malma	-	-	-	17	34	51	51
Salvelinus fontinalis fontinalis	15	42	57	-	27	27	84
Salvelinus fontinalis timagamiensis	10	20	30	-	20	20	50
Salmo gairdnerii	14	-	14	9	36	45	59
Salmo clarkii	-	16	16	-	-	-	16
Salmothymus ohridanus[5]	-	-	-	-	2	2	2
Hucho hucho	-	-	-	2	3	5	5
Hucho perryi	-	-	-	-	7	7	7
Brachmystax lenok	-	-	-	1	5	6	6
GRAND TOTAL	104	178	282	29	339	368	650

[1] Actual numbers of fishes used for the osteological, morphometric, and meristic characters are shown in other tables in the pertinent sections of this paper.

[2] Preferred common name Quebec red char. This common name is followed in all the subsequent tables.

[3] Preferred common name blueback char. This common name is followed in all the subsequent tables.

[4] Preferred common name Sunapee char. This common name is followed in all the subsequent tables.

[5] Six additional specimens of Salmothymus ohridanus, three specimens of Salmothymus obtusirostris, and three specimens of Salmothymus letnica were also examined less intensively.

TABLE 2. Sizes of the adolescent and adult Salmonidae studied, according to the locality. In this and many other tables the minimum, maximum, and mean (in parantheses) values are given.

Species	Abbreviation	Locality		Adolescents (87-129 mm)				Adults (130-835 mm)			
		Place	Area			Total				Total	
				No.	Fork length mm	No.	Fork length mm	No.	Fork length mm	No.	Fork length mm
Cristivomer namaycush	A_1	Little Bear Lake	Saskatchewan	-	-	-	-	11	188 - 376 (316.1)	88	184 - 614 (429.7)
	A_2	Atikaneg Lake	Manitoba	-	-	-	-	17	421 - 550 (484.4)		
	A_3	Athapapuska Lake	Manitoba	-	-	-	-	12	448 - 565 (502.9)		
	A_4	Lavielle Lake	Ontario	-	-	-	-	30	371 - 614 (473.7)		
	A_5	Louisa Lake	Ontario	-	-	-	-	18	276 - 374 (325.1)		
Salvelinus alpinus alpinus	B_1	Ferguson Lake, Victoria Is.	Northwest Territories	-	-	-	-	21	420 - 722 (588.3)	21	420 - 722 (588.3)
Salvelinus a.oquassa - Quebec	C_1	York Lake	Quebec	-	-	-	-	18	170 - 290 (238.9)	48	135 - 473 (247.5)
	C_2	Harriman Lake	Quebec	-	-	-	-	10	270 - 296 (283.4)		
	C_3	Laurentide Park	Quebec	-	-	-	-	10	135 - 188 (161.5)		
	C_4	St. Germaine Lake	Quebec	-	-	-	-	5	224 - 253 (233.6)		
	C_5	Battle Lake	Quebec	-	-	-	-	5	291 - 473 (394.0)		
S.a.oquassa - Pushineer Lake, Maine	D_1	Pushineer Lake	Maine, U.S.A.	-	-	-	-	25	136 - 296 (212.5)	25	136 - 296 (212.5)
S.a.oquassa - Floods Pond, Maine	E_1	Floods Pond	Maine, U.S.A.	-	-	-	-	23	184 - 302 (244.4)	23	184 - 302 (244.4)
S.malma	F_1	Martin River, Ocean Falls	British Columbia	3	92 - 110 (102.7)	-	-	23	130 - 218 (171.4)	34	130 - 663 (215.9)
	F_2	Sumalko River, east of Hope	British Columbia	3	84 - 108 (92.7)	17	92 - 123 (108.2)	2	135 - 160 (147.5)		
	F_3	Hardisty Creek (52°41'N, 118°05'W)	Alberta	11	99 - 123 (114.0)			4	136 - 175 (159.8)		
	F_4	Athabaska River (52°55'N, 118°05'W)	Alberta	-	-	-	-	5	387 - 663 (492.8)		
S.fontinalis fontinalis	G_1	Lavielle Lake	Ontario	-	-	-	-	13	178 - 432 (292.0)	27	150 - 432 (259.0)
	G_2	Laurentide Park	Quebec	-	-	-	-	6	201 - 270 (241.7)		
	G_3	St. Germain Lake	Quebec	-	-	-	-	1	181		
	G_4	Pushineer Lake	Maine, U.S.A.	-	-	-	-	7	150 - 276 (223.7)		

Table 2 cont.

Species	Locality			Adolescents (87 - 129 mm)				Adults (130-835 mm)			
	Abbre-viation	Place	Area	No.	Fork length mm	Total No.	Total Fork length mm	No.	Fork length mm	Total No.	Total Fork length mm
<u>S.f.timagamiensis</u>	H_1	Whirligig Lake	Ontario	-	-	-	-	12	275 - 418 (329.2)		
	H_2	Seashore Lake	Ontario	-	-	-	-	3	354 - 375 (367.3)	20	146 - 418 (295.9)
	H_3	Hill Lake Hatchery, Charlton	Ontario	-	-	-	-	5	146 - 193 (173.2)		
<u>Salmo gairdnerii</u>	I_1	Gold River, Vancouver Is.	British Columbia	-	-	-	-	16	532 - 835 (711.2)		
	I_2	Lakelse Lake Hatchery	British Columbia	2	110 - 117 (113.5)	9	91 - 129 (113.0)	7	136 - 175 (155.4)	36	136 - 835 (408.4)
	I_3	Salmo River east Kootenay	British Columbia	7	91 - 129 (112.9)			13	136 - 210 (171.9)		
<u>Salmothymus ohridanus</u>	J_1	Ohrida Lake	Yugoslavia	-	-	-	-	2	154 - 250 (197.0)	2	154 - 250 (197.0)
<u>Hucho hucho</u>	K_1	Traun River, Danube system	Austria - upper	-	-	-	-	1	378		
	K_2	Danube River system	Austria - upper	2	87 - 88 (87.5)	2	87 - 88 (87.5)			3	365 - 528 (423.6)
	K_3	Zeltweg on the Mur River, Styria	Austria - south	-	-	-	-	1	365		
	K_4	-	Yugoslavia	-	-	-	-	1	528		
<u>H.perryi</u>	K_5	Iturup Is.	Japan	-	-	-	-	1	264		
	K_6	Nbshi, Betsu River, Hokkaido	Japan	-	-	-	-	5	226 - 277 (258.6)	7	226 - 430 (283.9)
	K_7	Otaki	Japan	-	-	-	-	1	430		
<u>Brachymystax lenok</u>	L_1	Irkutsk, Siberia	Russia	-	-	-	-	3	232 - 372 (294.6)		
	L_2	Anibabora River, Japan Sea	Russia	1	122	1	122	1	178	5	178 - 372 (270.0)
	L_3	Tola River at Urga, Mongolia	Russia	-	-	-	-	1	288		

TABLE 3. Localities with their code letters from which eggs and fry of different Salmonidae were obtained. In this, and also in Table 4, the following abbreviations are used: Fer. - fertilized eggs; Un. - unfertilized eggs; -. indicates absence; +. indicates presence.

Locality			Stage		Remarks	
Abbreviations	Place	Area	Eggs	Fry	Eggs reared at Ottawa University	Received preserved
		C.namaycush				
A	Atikaneg Lake	Manitoba	Un.	-	-	+
B	Tremblant Lake[1]	Quebec	Fer.	-	+	-
C	West Buxton Hatchery	Maine, U.S.A.	-	+	-	+
		S.a.alpinus				
D	Ferguson Lake, Victoria Is.	Northwest Territories	Un.	-	-	+
E	Sakeska Lake[2]	Quebec	Fer.	-	+	-
F	Travers Lake	Quebec	Un.	-	-	+
		S.a.oquassa - Pushineer Lake				
G	Pushineer Lake	Maine, U.S.A.	Un.	-	-	+
		S.a.oquassa - Floods Pond				
H	Floods Pond	Maine, U.S.A.	Un.	-	-	+
		S.f.fontinalis				
I	Assinica Lake[2]	Quebec	Fer.	-	+	-
		S.f.timagamiensis				
J	Hill Lake Hatchery, Charlton	Ontario	-	+	-	+
K	Whirligig Lake	Ontario	Un.	-	-	+
		Salmo gairdnerii				
L	Gold River, Vancouver Is.	British Columbia	Un.	-	-	+
		Salmo clarkii				
M	Cultus Lake Hatchery	British Columbia	-	+	-	+

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[1] Eggs from the parent stock were fertilized on November 20, 1961, at the lake and reared up to the eyed stage at St. Faustin Hatchery, before they were sent to the University of Ottawa.

[2] Eggs were procured from the hatchery stock at St. Faustin on November 10, 1961, and were reared there up to the eyed stage, before shipping to Ottawa.

TABLE 4. Measurements of eggs and fry of several species of Salmonidae. TL = Total length; H = Head length.

Species	Locality	Ripe eggs			Sac fry			Fry up to 29.9 mm			Fry 30 mm and over 30 mm		
		No.	Stage	Diameter mm	No.	TL mm	H mm	No.	TL mm	H mm	No.	TL mm	H mm
<u>C.namaycush</u>	A	8	Un.	6.0 - 6.5 (6.3)	-	-	-	-	-	-	-	-	-
	B	11	Fer.	6.0 - 6.8 (6.4)	33	16.7 - 24.1[1] (21.1)	1.3 - 2.9 (2.2)	19	24.5 - 29.8[2] (26.2)	3.1 - 4.1 (3.5)	-	-	-
	C		-	-	-	-	-	-	-	-	4	45.0 - 49.3 (46.6)	6.0 - 6.9 (6.4)
<u>S.a.alpinus</u>	D	17	Un.	4.0 - 5.5 (4.7)	-	-	-	-	-	-	-	-	-
	E	8	Fer.	4.7 - 5.3 (5.0)	32	12.8 - 18.8 (16.8)	0.9 - 1.8 (1.4)	12	19.1 - 22.2 (20.5)	1.9 - 2.7 (2.2)	-	-	-
	F	11	Un.	4.6 - 5.3 (5.0)	-	-	-	-	-	-	-	-	-
<u>S.a.oquassa</u> - Pushineer Lake, Maine	G	5	Un.	4.2 - 4.6 (4.4)	-	-	-	-	-	-	-	-	-
<u>S.a.oquassa</u> - Floods Pond, Maine	H	5	Un.	4.3 - 4.8 (4.5)	-	-	-	-	-	-	-	-	-
<u>S.f.fontinalis</u>	I	15	Fer.	4.3 - 5.2 (4.6)	19	12.2 - 20.2 (17.3)	0.9 - 2.3 (1.7)	23	22.8 - 27.7 (24.8)	3.3 - 5.3 (4.1)	-	-	-
<u>S.f.timagamiensis</u>	J	-	-	-	-	-	-	20	23.5 - 25.8 (24.4)	2.5 - 3.3 (3.0)	-	-	-
	K	10	Un.	4.5 - 5.2 (4.9)	-	-	-	-	-	-		-	-
<u>Salmo gairdnerii</u>	L	14	Un.	6.2 - 7.3 (6.8)	-	-	-	-	-	-	-	-	-
<u>Salmo clarkii</u>	M		-	-	5	17.0 - 22.3 (19.5)	1.7 - 3.1 (2.4)	7	23.1 - 30.0 (26.1)	3.3 - 5.2 (3.6)	4	32.9 - 49.2 (42.9)	5.9 - 9.1 (7.5)

[1] Fry up to 29.9 mm in TL were reared in the aquarium of the University of Ottawa. These fry are extensively used in the present study.

[2] There is a little overlap in the sizes of the sac fry and fry. Three sac fry had maximum lengths up to 25.3 and two fry had shorter lengths of 22.9 and 23.2 mm.

TABLE 5. List of vernacular names for Salmonidae of three genera with their scientific equivalents extensively employed in text and tables. The common names, the usage of which is preferred by the author, are underlined.

NAMAYCUSH:	CRISTIVOMER
Namaycush, mascamacush, lake char, lake trout, togue, silver laker, laker, lounge, salmon trout, trout, Mackinaw trout, gray trout, red trout, black salmon, touladi.	C. namaycush
CHARS:	SALVELINUS
Arctic char, alpine char, red lake char.	S. alpinus alpinus
Quebec red char, lac de Marbre trout, Marston trout, Canadian red trout.	S. alpinus oquassa - Quebec population
Blueback char, blueback trout, blueback, quasky, red-spotted trout.	S. alpinus oquassa - Pushineer Lake, Maine population
Sunapee char, Sunapee trout, Sunapee-lake trout, golden trout, white trout,American saibling	S. alpinus oquassa - Floods Pond, Maine population
Dolly Varden char, Dolly Varden, Dolly Varden trout, malma trout, Oregon char, bull trout, red-spotted trout.	S. malma
Brook char, speckled char, eastern char, brook trout, eastern brook trout, salmon trout, red-bellied trout, red-spotted trout, squaretail trout.	S. fontinalis fontinalis
Aurora char, aurora trout, rainbow trout, salmon trout, land-locked salmon.	S. fontinalis timagamiensis
PACIFIC TROUTS:	SALMO (PARASALMO OF VLADYKOV, 1963)
Rainbow trout, steelhead, steelhead trout, brook trout, salmon trout, Kamloops trout.	Salmo gairdnerii
Cutthroat trout, cutthroat steelhead, Columbia river trout.	Salmo clarkii

Adult Fish

Preparation of skeleton. For American Salmonidae, only fresh or frozen specimens were used for the preparation of skeletons. Foreign specimens, which were received preserved in formalin or alcohol from the various museums, were dissected but left intact, and were stained by alizarine red S for study. The preparation of a salmonid skeleton is tedious and requires special care. Usually, skeletons from adult fish were prepared according to the recommended technique of Vladykov (1962). However, the following modifications were made in the procedures. Before immersing fish in hot water the branchial apparatus was removed and placed in 5% formalin for 4 - 5 hours. Then it was washed in water for 5 - 6 hours, stained overnight in 2 - 3% KOH solution with alizarine red S, and finally stored in 50 - 55% alcohol. Smaller fish, 12 - 16 cm in total length were immersed in fairly warm water, temperatures between 55°C. and 58°C., in a covered dish for about 10 minutes. The flesh was removed only from the left side of a fish before it was stained. The flesh remaining on the right side of the fish helped to keep the skeleton intact. Staining procedures of Hollister (1936), Ford (1937), and especially Vladykov (1962) were followed.

Measurements of skeletal parts. Measurements in mm were made on 17 cranial bones but only the following 9 bones are used in this study: supraethmoid, frontal, premaxilla, maxilla, supramaxilla, dentary, preopercle, vomer, and lingual plate. The caudal skeleton was also measured. Abbreviations: $L-L_3$ - represent lengths, $W-W_1$ and $w-w_1$ - widths, and H - height of bones.

Supraethmoid (Fig. 1, A(a), and 1, A(b))

L	Maximum length at the lateral side; sometimes this is the total length
L_1	Length up to fork of bone; sometimes there is no fork and this becomes the maximum length
W	Maximum width of bone

Frontal (Fig. 1, B)

L	Total length
W	Maximum width

Premaxilla (Fig. 1, C)

W	Maximum width
H	Maximum height

Maxilla (Fig. 1, D)

L	Total length
L_1	Length of body
L_2	Length of head
W	Maximum width at posterior flat region, a part of the bone without teeth

Supramaxilla (Fig. 1, E)

L	Total length
W	Maximum width

Dentary (Fig. 2A)

L	Total length
W	Maximum width at posterior end

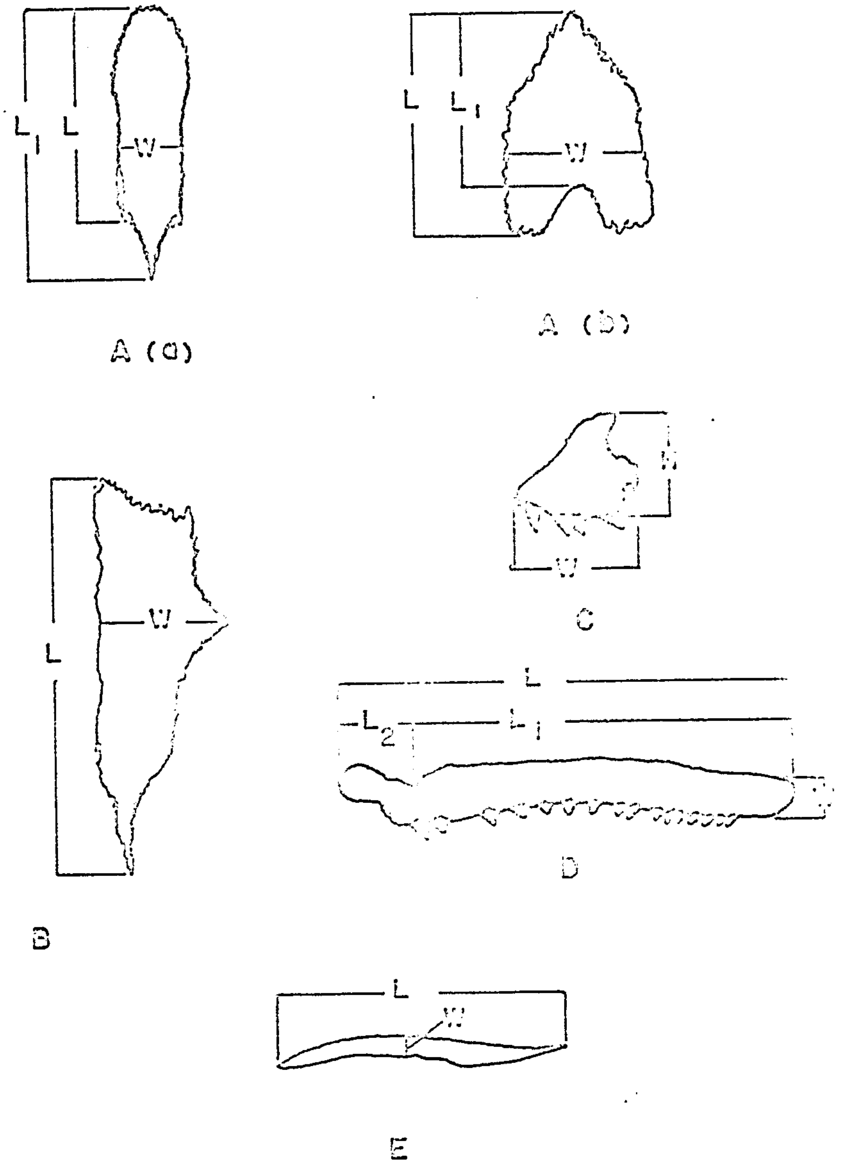

Fig. 1. Schemes of measurement [illegible] bones. A(a) and A(b)-dorsal view of the supraethmoid; B-dorsal [illegible] frontal; C-lateral view of the premaxilla; [illegible]-lateral view [illegible]; [illegible]-lateral view of the supramaxilla. For explanation of abb[illegible] the section "Methods".

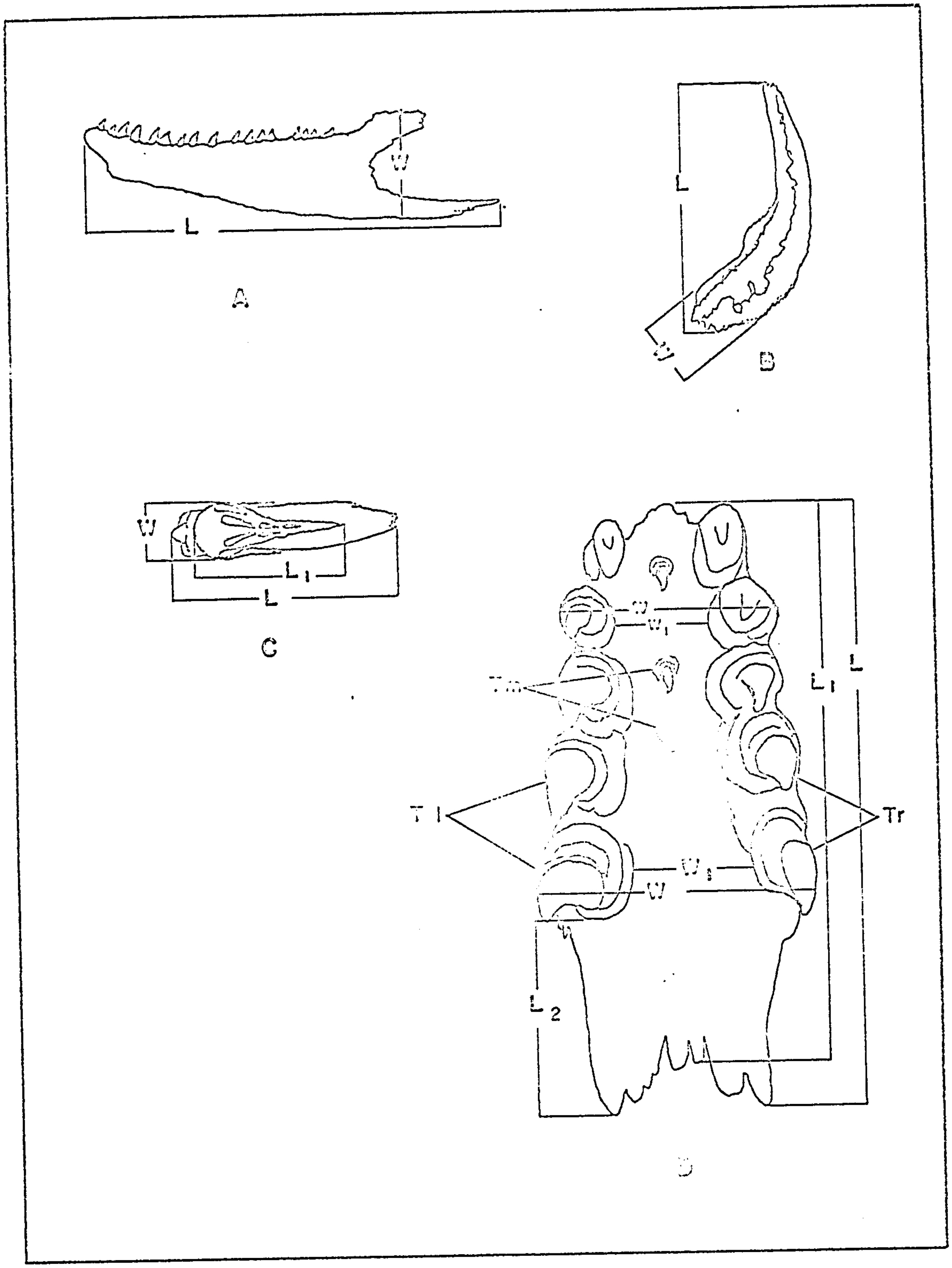

Fig. 2. Schemes of measurements of h skull bones. A-lateral view of the dentary; B-lateral view of the preopercle; C-ventral view of the vomer; D-dorsal view of the lingual plate. For explanation of abbreviations see the section on "Methods".

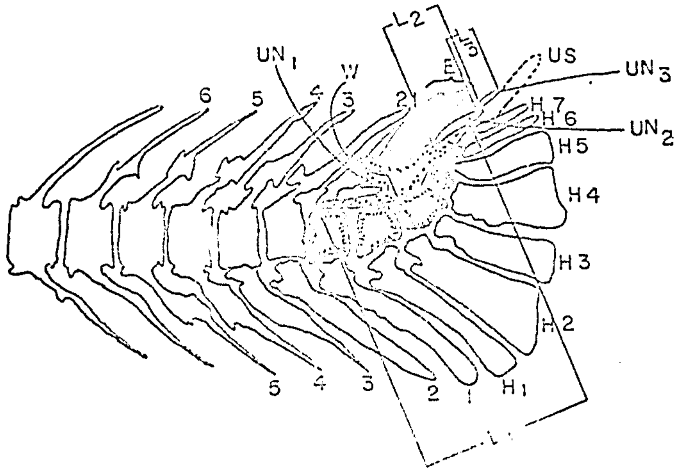

Fig. 3. Scheme of measurements of the caudal skeleton. For explanation of abbreviations see the section "Methods".

Preopercle (Fig. 2, B)

L	Total length
W	Maximum width

Vomer (Fig. 2, C)

L	Total length of bone
L_1	Combined length of crest (or dentigerous part of shaft) and head
W	Maximum width of bone in head region

Caudal skeleton (Fig. 3)

L_1	Length of first uroneural
W	Width of first uroneural
L_2	Length of second uroneural
L_3	Length of third uroneural

Lingual plate (Fig. 2, D)

L	Total length; when there is no fork, L and L_1 are the same
L_1	Length from anterior end to fork of bone
L_2	Distance between end of tooth row and posterior end of bone
w_1	Inner width between lateral tooth rows at anterior end
W_1	Inner width between lateral tooth rows at posterior end
w	Outer width between lateral tooth rows at anterior end
W	Outer width between lateral tooth rows at posterior end
Tl	Number of teeth in left lateral row
Tm	Number of teeth in middle of plate
Tr	Number of teeth in right lateral row

Measurements of body parts. Morphometric measurements on adolescent and adult fish were made in mm with the aid of vernier callipers, dividers, and a ruler graduated in mm, with or without the help of a dissecting binocular microscope. These measurements were adopted from Vladykov (1954) and Hubbs and Lagler (1958). Fifty measurements were made on each fish; however, only 18 most important ones were used for this study (Fig. 4, A).

TL	Total length
FL	Fork length
BdL_1	Body length from anterior upper end of opercle to fork of tail
BdL_2	Calculated body length, total length less head length
aD	Predorsal fin length

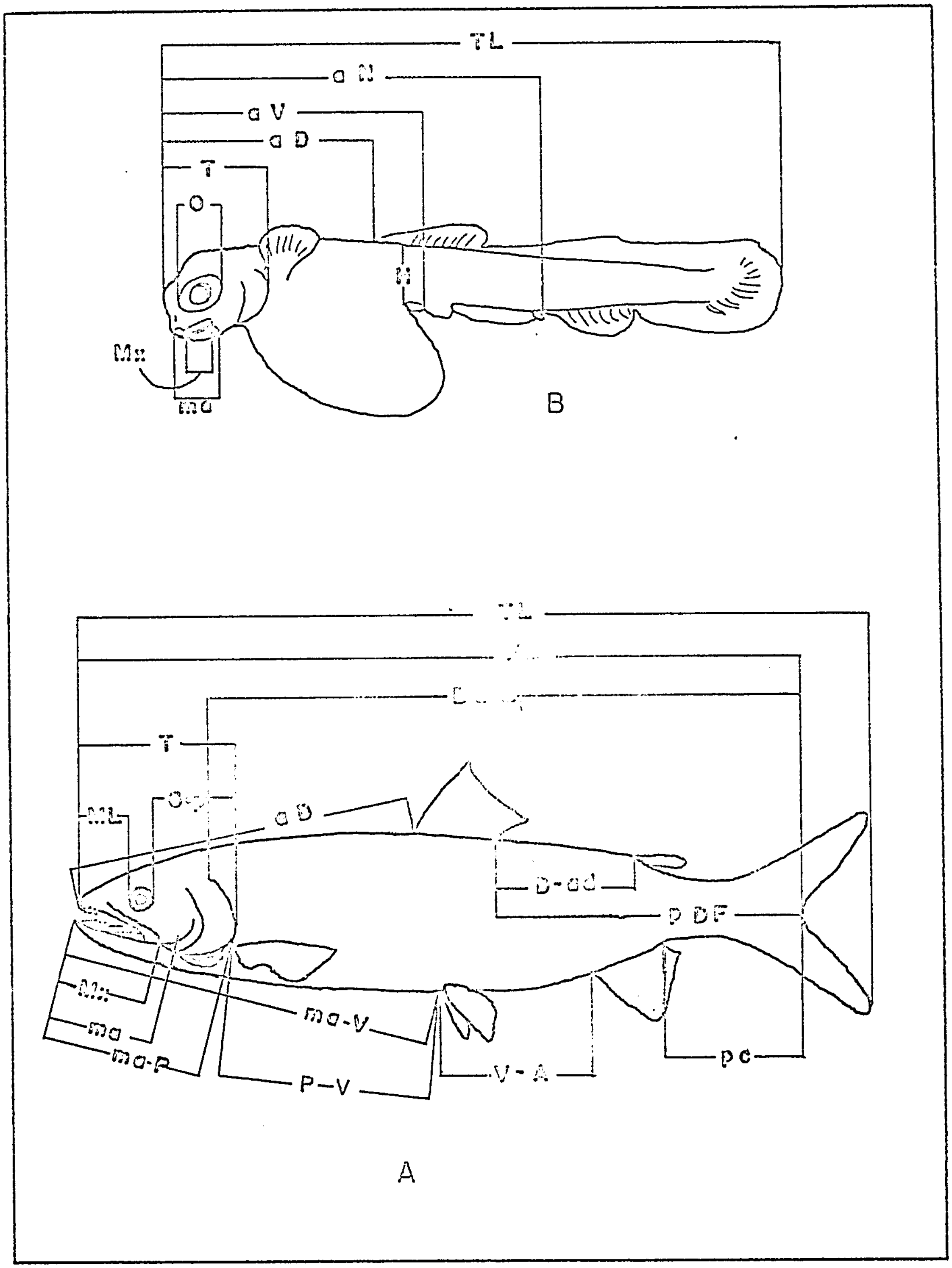

Fig. 4. Schemes of measurements of adult fish and fry. A-adult fish; B-fry. For explanation of abbreviations see the section "Methods".

pDF	-Distance from the insertion of the dorsal fin to fork of the tail
V-A	-Distance from the origin of the ventral fin to the origin of anal fin
pc	-Distance from the insertion of the anal fin to fork of the tail
D-ad	-Distance from the insertion of the dorsal fin to the origin of the adipose fin
ma-V	-Distance from the anterior tip of the lower jaw to the origin of ventral fin
P-V	-Distance from the origin of the pectoral fin to the origin of the ventral fin
T	-Head Length from anterior end of premaxilla to end of opercle (membrane excluded)
I	-Interorbital space
O-p	-Posterior margin of orbit of eye to end of opercle (membrane excluded) - postorbital distance
ML	-Length of snout from anterior end of premaxilla to the front margin of cartilaginous eyeball
Mx	-Length of upper jaw (premaxilla and maxilla combined)
ma	-Length of lower jaw
ma-P	-Distance from anterior tip of the lower jaw to the origin of the pectoral fin

Meristic characters. In most cases counts of the meristic characters were made on stained specimens, although X-ray radiographs of foreign Salmonidae were used in some instances. In counting the pyloric caeca, each caecum was cut off by a pair of scissors and counted separately. All fin rays, principal and rudimentary, were enumerated in the dorsal, anal, and paired fins. In the dorsal and anal fins the last double or single ray was counted as one. Total counts were made on the following structures: the pterygiophores in the dorsal and anal fins; the gill rakers on the first gill arch; the branchiostegal rays; the haemal spines; the completely and partially ossified ribs, epineurals, and epipleurals. Also counted were the single and paired neural spines and the number of trunk, precaudal, and caudal vertebrae. The last 3 upturned vertebrae were counted with the caudal vertebrae. The vertebrae which did not have well developed parapophyses were considered as the trunk vertebrae. The vertebrae on which the extended processes of the ventral parapophyses complete the arch are considered as the precaudal vertebrae. The urostyle a cartilaginous termination of the vertebral column, was not included in the vertebral count.

Eggs and Fry

Rearing techniques. For the osteological study of the developmental stages of different Salmonidae, the eyed eggs of namaycush, of Arctic char, and of brook char were brought from the St. Faustin Hatchery, Quebec, to the Aquarium of the University of Ottawa, Ontario, on December 16, 1961. The eggs and fry were reared for three and a half months at water temperatures between 9°C. and 9.5°C. Up to April, 1962, embryos and fry were usually collected at intervals of about 7 days, sometimes more frequently. Unfortunately, on April 5, 1962, the fry were accidentally killed by a sudden rise in the pH of the city water.

Some four month old namaycush fry were received from the West Buxton Hatchery, Maine. Fry of aurora char were sent by the Hill Lake Hatchery, Ontario, and were raised at temperatures between 4.4°C. and 7.2°C. Cutthroat trout fry were from the Cultus Lake Hatchery, British Columbia. The unfertilized eggs were collected from the ovaries of mature females of various species.

Age in days and total length in mm at the beginning of ossification of many bones were recorded. However, information is provided on only 15 skeletal elements.

Measurements of body parts. Morphometric measurements on eggs, sac fry, and advanced fry were made in tenths of a mm with the help of a cross-slide stage (Wild of Canada, Ltd.) in conjunction with the Spencer's dissecting binocular microscope. Eggs and fry were magnified 10 X for their measurements. Measurements of sac fry (prolarva of Lagler *et al.*, 1962) and advanced fry are according to the following scheme (Fig. 4, B):

TL	Total length
aD	Predorsal fin length
aV	Preventral fin length
aN	Preanus length
T	Length of head
H	Maximum depth of body, at posterior end of yolk sac where it joins the body
O	Horizontal diameter of eye
Mx	Length of maxilla
ma	Length of lower jaw

Meristic characters. Total number of rays in pectoral, ventral, dorsal, and anal fins, and also the branchiostegal rays were counted. Observations on the pigmentation of fry were also made.

Statistical Procedures

The data on morphometric and meristic features for adult salmonoid fishes were subjected to the analysis of variance by using the Px2 method of classification as adopted by Steel and Torrey (1960). By this treatment the effects of the groups (species and subspecies of fish), sex, and their interactions were considered. One per cent level of significance was preferred. Only the effect of the groups, but not the sex, showed significant differences at 1 per cent. Whenever the F values were found significantly different, the means for a particular character for various groups were compared among themselves with the help of the Duncan's (1955) new multiple F range test as modified by Kramer (1956) for unequal subclasses.

A slight modification of Duncan's method for the presentation of the data is made. The various species or subspecies are separated into groups (of varying number) according to the significance of the differences between parameter means, as for example Table 20.

The coefficient of difference values (C.D.) for several meristic characters of adult fish were calculated as prescribed by Mayr, Linsley, and Usinger (1953). If the resultant value of C.D. for a parameter between the two populations was higher than the conventional value of 1.28, only then the two populations were considered for subspecific ranking.

Terminology

Many authors such as Regan (1910), Goodrich (1930), Gregory (1933), Hollister (1936), Tchernavin (1937 and 1938a), Berg (1940), Gosline (1960), Norden (1961), and Vladykov (1954 and 1962) have worked on Salmonidae or closely related families and have used variform terminology. In this study the terminology corresponds with that of Norden (1961), who has given the definitions and synonymy for skeletal elements. The list of abbreviated designations used in drawings and photographs is as follows:

A	Angular	F	Frontal
AC	Actinost	FM	Foramen magnum
AFR	Anal fin ray	H	Hypural
BB	Basibranchial	HA	Haemal arch
BH	Basihyal	HB	Hypobranchial
BCC	Basioccipital	HE	Hypethmoid
BP	Basibranchial plate	HH	Hypohyal
BPTG	Basipterygium	HS	Haemal spine
BR	Branchiostegal rays	HY	Hyomandibular
BS	Basisphenoid	IH	Interhyal
C	Centrum of vertebra	IN	Interneural
CB	Ceratobranchial	IO	Infraorbital
CC	Coracoid	IOP	Interopercle
CH	Ceratohyal	LA	Lachrymal
CL	Cleithrum	LP	Lingual plate
CM	Coronomeckelian	LPP	Lower pharyngeal plate
D	Dentary (D' inside view)	M	Maxilla (M' inside view)
DF	Dorsal fontanelle	MC	Meckel's cartilage
DFR	Dorsal fin ray	MES	Mesopterygoid
E	Epural	MSC	Mesocoracoid
EB	Epibranchial	MET	Metapterygoid
ECT	Ectopterygoid	N	Nasal
EH	Epihyal	NA	Neural arch
EHS	Expanded haemal spine	NS	Neural spine
EN	Epineural	OP	Opercle
ENS	Expanded neural spine	OPO	Opisthotic
EOC	Exoccipital	OS	Orbitosphenoid
EP	Epipleural	P	Parasphenoid
EPO	Epiotic	PA	Parietal
ES	Extrascapular	PAL	Palatine

PAP	Parapophysis
PB	Pharyngobranchial
PCL	Postcleithrum
PEFR	Pectoral fin ray
PF	Prefrontal
PM	Premaxilla (PM' inside view)
PO	Postorbital
POP	Preopercle
POZ	Postzygapophysis
PQ	Palatoquadrate
PRO	Prootic
PRZ	Prezygapophysis
PS	Pterosphenoid
PT	Posttemporal
PTG	Pterygiophore
PTO	Pterotic
Q	Quadrate
R	Ribs
RA	Retroarticular
S	Scapula
SC	Sclerotic bone
SCL	Supracleithrum
SE	Supraethmoid
SM	Supramaxilla
SO	Supraorbital
SOC	Supraoccipital
SOP	Subopercle
SP	Suprapreopercle
SPO	Sphenotic
SY	Symplectic
U	Urohyal
UN	Uroneural, three to four plates
UPP-1 and 2	Upper pharyngeal plate
US	Urostyle
V	Vomer
VE	Vertebra
VFR	Ventral fin ray

ADULT FISH

Osteology

The osteology of the adult namaycush has been discussed under separate sections: skull, median fins and appendicular skeleton, and axial skeleton.

Skull

The Olfactory Region

In Cristivomer namaycush the olfactory region is triangular in shape. The anterior rostral part of it is covered by the supraethmoid. Laterally the rostrum bears a cartilaginous knob which articulates anteriorly with the maxilla and posteriorly with the palatine. The rostrum is a little longer in namaycush (Pl. 1, A and B) than in the genus Salvelinus (Pl. 1, F-Q). The slight expansion and depression in this region forms the olfactory capsule. The anterior tip of the rostrum is capped anteriorly and laterally by the premaxillae. The notch at the tip of the rostrum is not visible in namaycush (Pl. 1, A-C). Its presence is noticeable in the adult Arctic char, Quebec red, blueback, Sunapee, Dolly Varden (more pronounced), and brook chars (Pl. 1, F, H, J-I, J-2, L, N, and P). In the rainbow trout this notch is deep and distinctive (Pl. 1, R).

Prefrontal. In namaycush the prefrontals are paired bones. A prefrontal bone is present on each side of the posterior olfactory region and covers it dorsolaterally (Pl. 1, A and B). The bone is somewhat triangular in shape. The posterior face of the prefrontal forms the frontal surface of the orbit. The prefrontal is mainly endochondral. Below the prefrontal is a second cartilaginous process, the ethmopalatine process, with which the palatine articulates posteriorly. De Beer (1927) described this process in Salmo trutta. The olfactory nerve and the orbitonasal artery reach the olfactory capsule through the foramen olfactorium advehens of Boker (1913). The cartilage posterior to the prefrontal is pointed caudad, and covers the orbit anterodorsally. The position of the prefrontal in several species of the genus Salvelinus is shown in Pl. 1, F-Q, and in rainbow trout in Pl. 1, R and S.

Hypethmoid. The hypethmoid bone in namaycush is always absent. In the genus Salvelinus it is often found in brook and aurora chars only. About 40 per cent of the individuals of brook and aurora chars possessed it (Pl. 1, N). Its size varied from small to large. Norden (1961) stated its presence in brook char but did not comment about it in namaycush. The hypethmoid is occasionally observed in Salmo trutta, but is always present in Coregonidae.

The Orbital Region

In Cristivomer the orbital region is composed of the frontal cartilage, a cartilaginous interorbital septum, a pair of orbitosphenoid bones (may be missing), a pair of pterosphenoids, a median basisphenoid and two pairs of sclerotic bones. The frontal cartilage is flat in Cristivomer namaycush and Hucho hucho, but slightly convex in Salvelinus and Salmo, and connects the ethmoid cartilage to the taenia tecti medialis (median strip of cartilage between the dorsal fontanelles).

Orbitosphenoid. In Cristivomer the orbitosphenoids are paired endochondral bones (Pl. 1, C). The orbitosphenoid was completely absent in about 30 per cent of the specimens (Pl. 1, B). In some adults of namaycush the size of the bone was greatly reduced. Generally this bone is smaller in namaycush than in any other salmonoids studied. The bone lies in the sagittal plane, forms part of the interorbital septum, and meets the pterosphenoid posteriorly. The orbitosphenoid is surrounded by cartilage anteriorly, dorsally, and ventrally. The olfactory foramen in Cristivomer is cartilaginous and the olfactory tract passes through it to reach the nasal capsule.

In young fishes of the genera Cristivomer, Salvelinus, Salmo, and Oncorhynchus the orbitosphenoid is a paired bone. The paired condition persists in the adults of Cristivomer and Salvelinus. Only in 1 specimen (S. a. oquassa) out of the 30 examined for the two genera was the bone partly fused. In the adults of the genera Salmo and Oncorhynchus the bone is fused completely and the olfactory foramen is entirely surrounded by the orbitosphenoid. In the adults of Salmonidae, the orbitosphenoid is considered to be a single bone by Goodrich (1930), Gregory (1933), Berg (1940), and Norden (1961). Our observations show that in the genera Cristivomer and Salvelinus the bone is usually paired.

Pterosphenoid. In Cristivomer the paired pterosphenoids are rounded and endochondral in origin, and lie posterodorsally in the orbit. The pterosphenoid forms the anterodorsal rim of the dorsal fontanelle (Pl. 1, A). Posteriorly, it comes in contact with the sphenotic and prootic bones, the cartilaginous sutures separate these three bones. Ventrally, the pterosphenoid protects the anterior part of the brain. Dorsally, the two pterosphenoids are far separated by the anterior part of the taenia tecti medialis.

Basisphenoid. In Cristivomer (Pl. 1, B) and other genera of Salmonidae the median well developed basisphenoid is Y-shaped and lies ventrally to the pterosphenoid. The two oblique arms of the Y are short and articulate with the two prootic bones on each side of the skull. The median ventral arm is about twice as long as the lateral arms and is supported by an ossified projection from the dorsal surface of the parasphenoid. The basisphenoid is well developed in Thymallidae but poorly developed in Coregonidae.

Sclerotic. In Cristivomer two semilunar sclerotic bones partly surround the eyeball and are situated at the front and back of each eyeball.

The Otic Region

The chondrocranium in namaycush is best ossified in the otic region, more so ventrally and laterally. The bones are interspaced with cartilage and at times meet with jagged sutures. All except the opisthotics, and parts of the pterotics and supraoccipitals, are endochondral bones (de Beer, 1937).

Sphenotic. In namaycush the paired sphenotics are the most anterior bones (Pl. 1, A and B). Each sphenotic is subconical and strong. The conical process projects anteriorly. The sphenotic also has a small posterolateral projection. Laterally it borders the cartilage of the orbit but is preceded by the pterosphenoid. Dorsally the frontals cover the sphenotics completely. The sphenotic is bordered anteromesially by the pterosphenoid, ventrally by the prootic, and posteriorly by the pterotic. Only its posterodorsal edge is jagged. The inner surface of the sphenotic is hollowed out to receive part of the anterior semicircular canal. The strong levator arcus muscle originates from this bone. In namaycush, the distance between the anterior ends of the two sphenotics is greater than in the species of *Salvelinus* and in rainbow trout.

The position of the sphenotic in various species of *Salvelinus* is shown in Pl. 1, F-Q, and in rainbow trout in Pl. 1, R and S.

Pterotic. The pterotics are paired bones (Pl. 1, A and B) in namaycush. Anteriorly it articulates with the posterolateral face of the frontal and receives the canals of the lateral line system from the frontal and postorbital 3. Dorsally the pterotic forms the ventral margin of the lateral temporal fossa. Posteriorly it touches the lateral extrascapular bone and the suprapreopercle. Ventrally the pterotic is barely separated by thin cartilages from the exoccipital and the prootic (Pl. 1, B and D). The pterotic is fringed and has a serrated edge, particularly in the area where it touches the prootic. Its origin is partly dermal and partly cartilaginous. Its outer portion is described with the roofing bones. The deeper endochondral part of the pterotic fans out dorsally and ventrally, covering part of the otic capsule. It meets the sphenotic dorsally, and prootic, and exoccipital ventrally. Its endochondral portion is separated from the dorsal fontanelle and the supraoccipital by an expanse of cartilage. The inner surface of the pterotic is irregular and bears a deep cavity for the lateral semicircular canal.

The pterotics for several species of *Salvelinus* are presented in Pl. 1, F-Q, and for the rainbow trout in Pl. 1, R and S.

Epiotic. In *Cristivomer*, the epiotics are paired and irregularly shaped bones (Pl. 1, A, B, and E). The anterior end of the epiotic lies partly under the parietal. The fringed posterolateral part touches the parietal dorsally. Its dorsolateral side is separated from the supraoccipital by a band of cartilage. Ventrally its fringed portion touches the fringed process of the pterotic. Posteriorly its ventral surface joins the exoccipital. The anterior ends of the epiotics surround the posterior side of the lateral temporal fossa. Its strong posterior projection is fringed. The epiotics form a part of the dorsal and posterior surface of the chondrocranium. The posterior point of the epiotic serves for the attachment of a strong ligament from the inner surface of the more dorsally directed prong of the post-temporal.

The position of the epiotic on the skull in the genus *Salvelinus* is shown in Pl. 1, F-Q, and in rainbow trout in Pl. 1, R and S. The posterior projection of the epiotic is more strongly developed in *Cristivomer* than in *Salvelinus* and *Salmo*.

Opisthotic. In namaycush the opisthotic bone is cap-like and covers the junction of the pterotic, the epiotic, and the exoccipital on each side of the skull. It is an intermembranous and completely non-endochondral ossification. The opisthotic is loosely attached to the chondrocranium and is easily removed.

Supraoccipital. In namaycush the supraoccipital is a median bone and covers the caudodorsal surface of the cranial cavity (Pl. 1, A and E). It is somewhat circular in shape. Its anterior region is fringed and comes in contact with the posterior fringed regions of the frontals; laterally it barely touches the parietals (Pl. 2, N). Laterally and posteriorly it is separated by a band of cartilage from the epiotics. Posteriorly it is separated from the exoccipitals by a comparatively broader band of cartilage (Pl. 1, E). The prominent dermal crest which arises in the centre is directed posteriorly and forms a broad area of attachment for the protractor dorsalis muscle of the trunk (Green and Green, 1913).

The supraoccipital in several species of the genus Salvelinus is presented in Pl. 1, F, H, J-L, N, and P, and rainbow trout in Pl. 1, R.

Prootic. In namaycush the prootics are paired bones. The prootic bone is the largest bone of the chondrocranium and forms the floor of the cranial cavity (Pl. 1, B-D). It has 3 wings. The dorsal wing forms the anterolateral wall of the brain cavity. The second expanded flange extends ventrally and encloses the posterior myodome. The third wing extends to the midline to form the roof of the posterior myodome. Anteriorly and dorsally the prootic borders the pterosphenoid, sphenotic, and pterotic. Posteriorly it is in contact with the basioccipital and exoccipital. Anteriorly and ventrally it meets its fellow member from the opposite side as well as the lateral projections of the basisphenoid. These two prootics and the basioccipital form the roof, sides, and floor of the posterior myodome. Three foramina pierce the lateral side. Through the ventral foramen passes the blood vessel (de Beer, 1937). Immediately above this is the trigeminofacial foramen. Anteriorly is the palatine foramen for the palatine branch of the seventh cranial nerve.

In several species of the genus Salvelinus the description of the prootic is similar to that of namaycush. The location of the bone in Salvelinus is presented in Pl. 1, G, I, K-1, K-2, M, O, and Q, and in rainbow trout in Pl. 1, S.

Basioccipital. In namaycush the basioccipital bone is endochondral and wing-shaped (Pl. 1, B, C, and E). Its anterior flanges are covered by the parasphenoid ventrally. It is in contact with the prootic anteriorly and with the exoccipital dorsally. Posteriorly its circular part articulates with the centrum of the first vertebra. It forms the posterior floor of the cranial cavity.

In Salvelinus it is located as shown in Pl. 1, G, I, K, M, O, and Q, and in rainbow trout as in Pl. 1, S.

Exoccipital. In namaycush the exoccipitals are paired bones. The exoccipital is large and convoluted (Pl. 1, B, C, and E). It forms the greater part of the posterior region of the cranium. Ventrally it meets the basioccipital, surrounds the first vertebra, and meets the occipital condyle. It barely meets its fellow member from the other side; a cartilaginous strip hinders the fusion. Dorsally it meets the pterotic and the epiotic. Most of its edges are smooth. Anteriorly it meets the prootic. The side walls of the exoccipital are pierced anteriorly by the small glossopharyngeal foramen, and posteriorly by the larger jugular foramen for the vagus nerve. There is a little space between the two foramina. The two exoccipitals completely surround the foramen magnum but a small dorsally placed cartilage between them prevents their fusion.

The position of the exoccipitals on the chondrocrania of several species of Salvelinus is shown in Pl. 1, G, I, K, M, O, and Q, and of rainbow trout in Pl. 1, S.

Otoliths. The 3 otoliths in namaycush are similar in shape and location to those of chars and rainbow trout. The sagitta is the largest of the 3 otoliths. The otoliths are not discussed in detail.

Dorsal fontanelle. In namaycush a pair of oblong dorsal fontanelles are present (Pl. 1, A). The anterior end of each fontanelle is broader than the posterior end. The posterior margin of the fontanelle is overlapped by the anterior edge of the supraoccipital. The distance between the anterior inner edges of the two dorsal fontanelles is about twice the distance between the posterior inner edges. Tchernavin (1937; 1938b) considered the absence of the dorsal fontanelles in adult Oncorhynchus of taxonomic importance and thought that their absence in Oncorhynchus was helpful to separate it from Salmo where they are present. I have observed dorsal fontanelles in adults of O. keta, O. nerka, and O. kisutch, and found that the sizes of the fontanelles are greatly reduced. Norden (1961) observed the fontanelles in young specimens of O. keta, O. tshawytscha, and O. nerka. Norden also mentioned that the fontalles in namaycush, chars, trouts, and salmons, particularly in young specimens, are smaller and more circular than in either grayling or whitefishes. These fontanelles are separated by a median strip of cartilage (taenia tecti medialis) derived from a posterior extension of the tectum cranii similar to that illustrated by Saunderson (1935) in the early development of Salmo salar. Dorsally there are two lateral strips of postorbital cartilage from the auditory capsule in the otic region.

The shape of the dorsal fontanelles in several species of Salvelinus is different. Also slight variability is noticed in various populations of each species. In Arctic and Quebec red chars the fontanelles are narrow posteriorly. In blueback and Sunapee chars they are roundish. In Dolly Varden, brook, and aurora chars, and also in rainbow trout, the fontanelles are oblong.

The median and lateral strips of cartilage are narrower in namaycush than in chars (Pl. 1, A, F, H, J-1, J-2, L, N, and P). In rainbow trout the median strip is much broader anteriorly (Pl. 1, R) and the lateral strips are narrower than those of namaycush and chars.

Roofing Bones

The dermal bones which cover the cranium dorsally are: the single supraethmoid, the paired nasals, the paired frontals, the paired parietals, and the 4 - 5 pairs of small extrascapulars.

Supraethmoid. In namaycush this long, narrow, irregular bone lies anterior to the frontals on the dorsal median surface of the chondrocranium (Pl. 2, A). Anteriorly the supraethmoid is rounded but does not have a knob-like head and fits between the backward extensions of the premaxillae. Laterally it borders the nasals but does not articulate with them. Posteriorly it is conical in shape, indented, and pointed. It covers about one-fourth of the anterior part of the frontals.

The shape of the supraethmoid is quite similar in Cristivomer and Brachymystax (Pl. 4, A and K). The supraethmoid in the genera Cristivomer, Salvelinus, and Salmo is distinctive (Vladykov, 1963). In Salvelinus, the front is rounded and forms a distinct head; the part of the main body is wider than the head region. There are also some specific differences in the shape of the bone among the representatives of the genus Salvelinus; for example, see Arctic char (Pl.2, B; Pl. 4, C) and Dolly Varden char (Pl. 2, C; Pl. 4, G). In Quebec red char (Pl. 4, D), blueback char (Pl. 4, E), and Sunapee char (Pl. 4, F), the bone is similar. The supraethmoid is similar in brook char

TABLE 6. Proportional measurements, in percentages, of 3 cranial bones of different Salmonidae. Number and fork length of fish in this and Tables 7 - 11 are the same.

Species	No. of fish	Fork length of fish, mm	Supraethmoid $\frac{L}{L_1}$	Supraethmoid $\frac{W}{L_1}$	Frontal $\frac{W}{L}$	Preopercle $\frac{W}{L}$
C. namaycush	46	276-572 (466)	56.9 - 82.7 (68.2)	19.7- 37.2 (26.6)	34.8- 41.2 (37.4)	21.6- 29.7 (25.2)
S. a. alpinus	18	457-722 (578)	85.0 - 113.0 (101.1)	42.3- 77.7 (60.7)	45.7- 53.6 (49.1)	31.2-42.2 (36.3)
S. a. oquassa - Quebec	9	224-470 (300)	89.2 - 112.6 (101.5)	35.6- 63.7 (46.2)	43.7- 50.6 (47.1)	29.5- 34.0 (31.7)
S. a. oquassa - Pushineer Lake, Maine	21	198-245 (215)	70 - 100 (85.7)	36.4- 58.8 (47.8)	40.0- 46.0 (43.1)	27.8- 38.2 (33.9)
S. a. oquassa - Floods Pond, Maine	20	184-282 (242)	76 - 89.9 (81.3)	34.0- 51.9 (40.4)	35.3- 45.5 (41.1)	30.5- 38.5 (33.6)
S. malma	10	130-663 (281)	78.3 - 101.6 (100.1)	33.3- 49.6 (41.9)	38.6-45.2 (41.0)	26.3- 32.2 (29.6)
S. f. fontinalis	9	178-392 (252)	95.7 - 100.0 (99.5)	40.2- 68.3 (48.7)	38.8-52.3 (43.5)	27.6- 35.8 (31.7)
S. f. timagamiensis	15	146-418 (281)	71.3 - 91.2 (81.60)	27.3- 50.9 (41.9)	35.7-44.4 (40.7)	26.1- 33.1 (30.4)
Salmo gairdnerii	16	136-775 (495)	128.7- 179.4 (142.9)	68.0- 130.7 (93.1)	39.9-63.2 (52.5)	23.6- 39.4 (31.1)

(Pl. 2, D; Pl. 4, H) and aurora char (Pl. 4, I). The bone is massive in Dolly Varden char but in other chars it is thin.

In *Salmothymus* the bone is without a rounded front head; posteriorly it is not broad and has a slight notch. In *Salmo gairdnerii* (Pl. 4, J) the bone has a deep cut posteriorly. In *Oncorhynchus* the supraethmoid is butterfly shaped without a rounded front head, and deeply notched posteriorly (Vladykov, 1962).

Morphometric study of the bone shows that the three genera *Cristivomer*, *Salvelinus*, and *Salmo* can be separated on the basis of the supraethmoid (Table 6). The mean values for the proportion $\frac{L}{L_1}$ % show that they are minimum for namaycush (68.2), and maximum for rainbow trout (142.9). The mean values for the various species of the genus *Salvelinus* ranged between 81.3 - 101.5. The mean values for the proportion $\frac{W}{L_1}$ % are minimum in namaycush (26.6) and maximum in rainbow trout (93.1). The chars again form a separate group.

Nasal. In namaycush the pair of nasal bones are small (Pl. 4, A) and enclose the anterior parts of the supraorbital canals. The nasal bone lies lateral to the supraethmoid. No notable differences were found in the nasal bones of the various species.

Frontal. In namaycush the paired frontals are large and triangular bones covering most of the dorsal surface of the chondrocranium (Pl. 2, A). They also overhang the orbit laterally. Anteriorly the frontals are separated by the cartilaginous chondrocranium. The supraorbital canal of the lateral line system is transmitted through it directly to the pterotic. At times there is a small gap between the canals of the frontal and the pterotic bones. Anteriorly the frontal meets both the nasal and the prefrontal bones laterally, and covers only a small portion of the latter bone. It also comes in contact with the supraorbital 1. Caudolaterally a pointed posterior projection of the frontal meets the dermal crest of the pterotic. Half of the posterior margin of the frontal meets the parietal laterally (Pl. 2, A). The rest of the posterior margin meets the supraoccipital medially. The frontals are not fused at the midline but touch each other. The frontals barely touch the temporal fossa which lies between the pterotic and the parietal.

In a few species of chars (Pl. 2, B-D) and rainbow trout (Pl.6, I) the frontals are not as long as but are comparatively broader than those of namaycush. The caudolateral projection in chars is not well developed; it is absent in rainbow trout. On the basis of the general configuration of the bone, Arctic char and Quebec red char form one group (Pl. 6, B and C), blueback and Sunapee chars another (Pl. 6, D and E), and brook, aurora (still different from brook), and Dolly Varden chars a third group (Pl. 6, F-H). The frontal of Brachymystax (Pl. 6, J) is somewhat similar to that of namaycush. In Salmothymus the frontal is much longer than broad and differs from that of Salmo.

The mean values of $\frac{W}{L}$ % are minimum for namaycush (37.4) and maximum for rainbow trout (52.5). See Table 6. The values for chars fall in between these two groups. On the basis of the values of $\frac{W}{L}$ % the same grouping may be retained for the various species of chars as is shown in the previous paragraph. However, in various Salmonidae the ranges for this proportion overlap.

Parietal. In namaycush the paired parietals are rectangular in shape (Pl. 2, A; Pl. 6, A). The posterior end of each bone is fringed. Each bone forms a major part of the dorsal border of the lateral temporal fossa. Posteriorly its ventral surface covers the anterior end of the epiotic. Laterally the parietals meet the supraoccipital. The two parietals are separated by the posterior ends of the frontals and the single supraoccipital and cover a small part of the skull roof. These bones are of little importance in the separation of various chars and trouts.

Extrascapular. In namaycush the extrascapular bones consist of 4 - 5 small bones on each side of the skull (Pl. 6, A). The extrascapulars are located on the posterior region of the skull between the parietal and the posttemporal. They are tube-like and are not expanded as in grayling and whitefishes. The extrascapulars overlie and partly hide the epiotics, parietals, and supraoccipitals. The canal of the lateral line system which traverses the pterotic enters the lateral extrascapular, where it is joined by the supratemporal canal. The combined canal is transmitted to the posttemporal canal.

The extrascapulars are not important in the taxonomy of chars and are not included.

Posttemporal. In namaycush the paired posttemporal bones are seen in part in a dorsal view. These bones are discussed in detail with the pectoral girdle.

Lateral Bones

The dermal bones which cover the cranium laterally are: the bones of the upper and lower jaws, bones of the circumorbital series, and bones of the opercular series.

Premaxilla. In namaycush the premaxilla covers the anterior portion of the ethmoid region dorsolaterally, and does not come in contact with its fellow member from the other side (Pl. 2, A). This separation is more noticeable in old adult specimens. Posteriorly the premaxilla articulates with the smooth inwardly curved anterior portion of the maxilla. The backward ascending process of the premaxilla is in contact with the anterolateral margin of the supraethmoid. This process is strong and pointed caudad. The premaxilla is somewhat triangular in shape. Its lateral sides are slightly curved inward. The pair of premaxillae comprise the anterior end of the upper jaw. To the anterior flange of each bone a single series of 6 - 8 conical teeth are attached (Pl. 4, A and B). The number of alveoles are included in the count of the teeth. At times up to 7 teeth are embedded in the conjunctive tissue around the tooth-bearing flanges. These teeth are not included in the count. The anterolateral side of the premaxilla, which is in contact with the supraethmoid, is more inwardly curved than the posterolateral side which articulates with the maxilla.

The ascending process of the premaxilla is strong and extends well backward in the genera *Cristivomer* and *Salvelinus*. It is longest in *S. malma* (Pl. 4, G) and shortest in *S.a. alpinus* (Pl. 4, C). The remaining species of the genus *Salvelinus* fall in between the two extremes (Pl. 4, D-F, and H-I). In *Brachymystax*, *Salmothymus* (Pl. 3, E), and *Hucho* (Pl. 3, F) the premaxilla is triangular in shape. In *Salmo gairdnerii* the ascending process is weak and poorly developed (Pl. 4, J) and the premaxilla is band-like and teeth are strong in spawning fish. The ascending process of premaxilla is lost. Teeth on the premaxilla in *Brachymystax* are intermediate between those of chars and trouts, and whitefishes (Pl. 4, K).

Table 7 shows the mean values of $\frac{H}{W}$ % as 78.2 in namaycush and

TABLE 7. Proportional measurements, in percentages, of 4 cranial bones of different Salmonidae.

Species	Premaxilla	Maxilla			Supramaxilla	Dentary
	$\frac{H}{W}$	$\frac{L1}{L}$	$\frac{L_2}{L}$	$\frac{W}{L}$	$\frac{W}{L}$	$\frac{W}{L}$
C.namaycush	66.7-94.8 (78.2)	80.0-88.4 (84.5)	17.3-21.6 (20.9)	7.3-12.8 (8.9)	8.3-16.1 (12.3)	22.0-35.4 (31.6)
S.a.alpinus	58.9-85.0 (70.6)	85.6-89.1 (87.4)	12.8-17.8 (15.4)	6.7-10.8 (8.2)	12.9-25.0 (19.4)	18.6-31.1 (27.2)
S.a.oquassa - Quebec	53.3-76.4 (68.1)	85.7-92.6 (89.1)	15.6-17.[illegible] (17.1)	4.8-9.7 (8.0)	15.7-22.8 (19.6)	22.2-28.5 (26.5)
S.a.oquassa - Pushineer Lake, Maine	58.8-81.7 (68.7)	79.4-89.0 (85.8)	16.6-22.1 (19.0)	6.8-13.2 (10.3)	19.1-25.0 (20.5)	25.4-30.1 (27.3)
S.a.oquassa - Floods Pond, Maine	60.8-88.9 (72.9)	85.4-92.1 (88.5)	11.8-22.2 (18.5)	7.3-13.3 (9.2)	17.9-26.8 (21.9)	25.0-32.3 (27.8)
S.malma	64.0-90.9 (77.1)	81.6-86.1 (83.5)	21.1-24.4 (22.5)	8.2-15.7 (12.4)	13.8-22.3 (18.5)	30.2-33.3 (31.7)
S.f.fontinalis	56.3-75.0 (65.2)	86.5-90.8 (89.0)	13.5-17.5 (15.0)	6.5-12.7 (10.2)	9.1-13.6 (10.8)	26.8-34.9 (30.1)
S.f.timagamiensis	57.3-82.2 (64.6)	83.9-93.3 (88.3)	13.7-19.0 (16.7)	7.6-15.5 (10.9)	9.1-24.2 (15.3)	23.6-32.7 (27.9)
Salmo gairdnerii	44.4-84.8 (61.6)	79.1-95.7 (86.0)	10.1-24.2 (18.2)	8.9-25.2 (13.9)	13.6-29.8 (23.4)	25.6-37.8 (29.6)

61.6 in rainbow trout. The values for this proportion in various species of chars are between the two extremes. The values of Arctic and Sunapee chars overlap, as do those of Quebec red and blueback chars, and brook and aurora chars. The number of teeth ranged between 5 and 9 for the various species (Table 8).

Maxilla. In namaycush the maxilla is a long, massive, slightly curved bone comprising about three-quarters of the upper border of the gape of the mouth on each side of the skull and extending far beyond (about the size of the orbit of eye) the posterior margin of the eye (Pl. 3, A). The anterior end of the maxilla articulates with the premaxilla on one side and with the palatine on the other side. Dorsally and laterally it is attached by ligaments to the lachrymal, the supramaxilla, the bones of the palate, and the bones of the lower jaw. Ventrally the bone itself bears a single series of 22 - 30 conical teeth (Pl. 4, A and B). The teeth are strong but not as sharp in namaycush as in Salvelinus. There are up to 7 teeth embedded in the conjunctive tissue lateral to the first series; these are not included in the count. Teeth on the maxilla are comparatively smaller than teeth on the premaxilla. About one-seventh of both the anterior and the posterior parts of the bone are toothless.

The shape of the maxilla in Cristivomer resembles that in Salvelinus (Pl. 3, B-D; Pl. 4, C-H), except S.f. timagamiensis (Pl. 4, I) in which the body of the maxilla is curved dorsally. In Cristivomer and Salvelinus the head of the maxilla (Fig. 1, D, L_2) is long and slightly curved and not in line with the body of the maxilla.

Various proportions for this bone overlap considerably (Table 7) and do not seem to be of much use in characterizing the

TABLE 8. Total number of teeth (including alveoles) on 5 cranial bones of different Salmonidae. Tl.teeth on left lateral row of the lingual plate; Tm.teeth in the middle of the plate; Tr.teeth on right lateral row of the plate.

Species	Premaxilla	Maxilla	Dentary	Vomer	Lingual plate		
					Tl	Tm	Tr
C.namaycush	6 - 8 (6.9)	20 - 30 (25.2)	15 - 20 (18.2)	6 -12 (8.6)	5 -10 (8.3)	1 -10 (2.4)	7 - 9 (8.9)
S.a.alpinus	5 - 9 (7.4)	21 - 32 (24.8)	16 - 25 (19.6)	6 -12 (8.2)	7 -14 (9.8)	2 - 9 (5.6)	7 -13 (9.3)
S.a.oquassa - Quebec	6 - 8 (6.9)	18 - 25 (21.7)	14 - 22 (17.3)	6 - 8 (7.3)	5 -10 (7.1)	1 - 6 (2.4)	6 - 8 (6.9)
S.a.oquassa - Pushineer Lake, Maine	6 - 9 (7.1)	13 - 24 (18.5)	15 - 18 (16.6)	5 - 8 (6.1)	5 - 8 (6.1)	0 - 1 (0.2)	4 - 7 (5.9)
S.a.oquassa - Floods Pond, Maine	6 - 9 (7.6)	19 - 28 (23.3)	13 - 21 (17.5)	4 - 8 (6.2)	5 - 7 (6.0)	1 - 2 (1.2)	5 - 7 (6.0)
S.malma	6 - 9 (8.0)	17 - 22 (19.9)	14 - 17 (15.4)	7 - 9 (8.2)	5 - 7 (5.4)	0 - 3 (0.8)	4 - 6 (5.2)
S.f.fontinalis	7 - 9 (8.3)	18 - 24 (21.7)	12 - 24 (17.2)	5 - 8 (7.0)	4 - 6 (5.1)	0 - 1 (0.2)	4 - 6 (4.8)
S.f.timagamiensis	7 - 9 (7.6)	14 - 25 (21.4)	14 - 24 (18.6)	7 -11 (8.3)	4 - 6 (4.9)	0 - 1 (0.4)	4 - 6 (5.0)
Salmo gairdnerii	5 - 9 (7.7)	20 - 40 (29.3)	14 - 26 (19.12)	13 - 25 (19.1)	5 - 7 (5.5)	0 - 1 (0.1)	5 - 6 (5.3)

species. The number of teeth on the maxilla is highest in rainbow trout and ranged between 20 - 40. The number is lowest in blueback char and ranged between 13 - 24. See Table 8.

In Brachymystax the head of the maxilla is short and knob-like, the body of the maxilla is short and broad from the anterior to the posterior end, and teeth on the maxilla are weak (Pl. 4, K). In the genus Hucho the head of the maxilla is short, the body projects a little (about half the size of the orbit) behind the eye, it is wider at the posterior end, and has strong teeth (Pl. 3, F). In Salmothymus the head of the maxilla is short. The body of the maxilla is wide at the posterior end and reaches to about the middle of the orbit. In the posterior half of the maxilla a slight crescent-like depression is found on the upper margin (Pl. 3, E). In Salmo the head of the maxilla is not knob-like but straight and in line with the body of the maxilla. The body of the maxilla is broad posteriorly (Pl. 4, J). The maxilla projects slightly behind the orbit of the eye. In Oncorhynchus the head of the maxilla is straight, not knob-like, and in line with the body of the maxilla. The body of the maxilla is straight, slightly or strongly curved upward, not broad posteriorly, and with strong teeth in spawning fish.

Supramaxilla. In namaycush the supramaxillae are a pair of thin, narrow bones tapered at both ends (Pl. 3, A). The width of the supramaxilla is about the same in the anterior and posterior regions. Most of its dorsal edge is smooth while the ventral edge has a few notches. The supramaxilla lies on and partly covers the dorsal margin of nearly three quarters of the posterior portion of the maxilla. It is attached by ligaments to the lachrymal, the suborbitals, and the bones of the palate.

The supramaxilla in the genus *Salvelinus* is broader at the posterior end (Pl. 3, B-D) than that of the genus *Cristivomer* and covers a little over half the posterior portion of the maxilla. Its general shape is similar in Arctic, Quebec red, blueback, and Sunapee chars. However, posteriorly the supramaxilla in Quebec red char is thinner (Pl. 4, D) than that in Sunapee char (Pl. 4, F), while the condition of the supramaxilla in blueback char is intermediate (Pl. 4, E) between that of Quebec red and Sunapee chars. The shape of the supramaxilla in aurora char (Pl. 4, I) is different from that of the other species of *Salvelinus*. In rainbow trout (Pl. 4, J) the supramaxilla is shorter than that in the genera *Cristivomer* and *Salvelinus*. It is about half the size of the maxilla and is very broad in the posterior region.

The shape of the supramaxilla in the genus *Brachymystax* is different from that in *Cristivomer*, *Salvelinus*, and *Salmo*. The supramaxilla in *Salmothymus* is broad in the middle region and pointed at both ends (Pl. 3, E). In *Oncorhynchus* the supramaxilla is short and pointed anteriorly and very broad posteriorly (Vladykov, 1962).

In Table 7 the proportional values of $\frac{W}{L}\%$ in namaycush, chars and rainbow trout are given. The mean for namaycush is 12.3. Arctic, Quebec red, blueback, Sunapee, and Dolly Varden chars all seem to fall in one group. Brook and aurora chars seem to belong to another group. In brook char this particular measurement (mean 10.8) overlaps with that of namaycush but the shape of the bone in the two species is very different; therefore these fish are considered to belong to two different groups. The value in rainbow trout is higher than but still close to that in chars.

Circumorbital series. It has been pointed out by earlier workers (Ridewood, 1904 a; Norden, 1961) that the circumorbital series and in particular the postorbital bones have little morphological value in a comparative study. However, Vladykov (1963) pointed out the importance of the postorbitals in separating the subgenus Parasalmo from Salmo. Vladykov (1954) has also emphasized the importance of the supraorbital 2 and lachrymal in the study of chars. In the present study the postorbital 1 is found to be of taxonomic importance. The circumorbital series is made up of 7, occasionally 8, bones encircling the greater part of the orbit, except for the dorsal part of the orbit which is bordered by the frontal. With the exception of the supraorbitals all the bones bear a sensory canal in the adult stage.

Supraorbital 1. In namaycush the supraorbitals 1 are a pair of small, thin, flat bones, slightly curved dorsally. Posteriorly the supraorbital 1 comes in contact with the prefrontal. Anteriorly it barely reaches to the supraorbital 2, and forms the anterodorsal margin of the orbit. It does not carry the sensory canal (Pl. 3, A; Pl. 4, A). This bone is of no taxonomic significance in chars.

Supraorbital 2. In namaycush the supraorbitals 2 are a pair of narrow and inwardly curved bones (Pl. 3, A; Pl. 4, A). The supraorbital 2 forms a part of the anterior margin of the orbit and the posterior margin of the nasal capsule. Its ventro-anterior pointed arm comes in contact with the anterior rounded edge of the lachrymal. It does not carry the sensory canal.

This bone in namaycush (Pl. 4, A) differs slightly in shape from those in other chars (Pl. 4, C-I) and rainbow trout (Pl. 4, J). In the last two groups it is smaller, broader, and more compact than that of namaycush. However, too much importance should not be attached to this bone as its shape is variable.

Lachrymal. In namaycush the lachrymal is a distinctively large bone on each side of the skull and carries a sensory canal (Pl. 3, A; Pl. 4, A). It is round at the anterior end and tapers caudad. The posterior pointed end has a notch into which the infraorbital bone fits. It forms part of the anterior and ventral orbital rim and lies just above the maxilla. A small dorsal projection of the maxilla comes in contact with the anterior rounded edge of the lachrymal. After entering the lachrymal the infraorbital canal of the lateral line system branches into 6 - 8 very short canals that open ventrally through external pores.

Slight variations in the shape of the bone are noticed in namaycush and other salmonoids examined. For several species of the genus Salvelinus its shape is presented in Pl. 3, B-D, and Pl. 4, C-I. Its shape in rainbow trout (Pl. 4, J) is different from that in Salmothymus (Pl. 3, G).

Infraorbital. The infraorbitals are a pair of long, thin bones in namaycush. The anterior end of the infraorbital is narrow and projects beneath the posterior end of the lachrymal (Pl. 3, A). The sensory canal is present and opens externally by means of 4 - 7 pores. It articulates posteriorly with the postorbital 1.

The bone in namaycush (Pl. 4, A), chars (Pl. 3, B-D; Pl. 4, C-I) and rainbow trout (Pl. 3, J) is reasonably similar.

Postorbital 1. In namaycush the postorbitals 1 are a pair of thin and plate-like bones (Pl. 3, A; Pl. 4, A). The anterior end of the postorbital 1 is somewhat elongated and lies over the posterior part of the infraorbital. Its ventrolateral margin is curved. Its upper margin is nearly straight and is in contact with the postorbital 2. Its posterior edge is fringed but does not bear a notch. The sensory canal has 1 - 2 openings which face caudad. Usually the postorbital 1 is about the same size as the postorbital 2 (Pl. 3, A).

In the case of Arctic (Pl. 3, B; Pl. 4, C), Quebec red, blueback, and Sunapee chars (Pl. 4, D-F) there is a notch near the upper posterior margin of the bone. The shape in brook and aurora chars (Pl. 3, D; Pl. 4, H, and I) is slightly different from but close to that of Arctic char. The shape in the Dolly Varden char (Pl. 3, C; Pl. 4, G) is still different. In rainbow trout the postorbital 1 (Pl. 4, J) is larger and dissimilar to that in chars and namaycush. In the genus Salvelinus the postorbital 1 is the longest of the 3 (occasionally 4) postorbital bones.

Postorbital 2. The postorbitals 2 are a pair of plate-like bones (Pl. 4, A) in namaycush. The posterior edge of postorbital 2 is fringed. The sensory canal opens with a single pore. The postorbital 2 is about the same size as postorbital 1 in namaycush but in chars it is broader than the postorbitals 1 and 3.

Postorbital 3. In namaycush the postorbitals 3 are the smallest of the postorbital series. (On rare occasions there are 4 postorbitals. See Pl. 3, A). Its upper posterior edge is curved outward. Dorsally this bone articulates with the frontal and pterotic bones; ventrally, with the postorbital 2. Usually the sensory canal has no opening on the bone, and is transmitted directly to the lateral line canal system in the pterotic.

In namaycush all the postorbitals border the posterior margin of the orbit. They extend about one third across the cheek and do not reach the preopercle (Pl. 3, A). In the genus Salvelinus the postorbitals extend halfway or more across the cheek (Pl. 3, B-D). In Brachymystax (Pl. 3, E) and Hucho (Pl. 3, F) the gap between the postorbitals and the preopercle is slightly larger than that in namaycush. In Salmothymus (Pl. 3, E) the distance between the postorbitals and the preopercle is smaller than that in Salvelinus. The postorbitals do reach the preopercle in Oncorhynchus (Tchernavin, 1938a).

Dentary. In namaycush the dentaries are paired bones and form a major support to the lower jaw (Pl. 3, A; Pl. 4, B; Pl. 5, A). The posterior end of the dentary is<- shaped. The anterior ends of the two dentary bones meet in a loose symphysis. The upper limb of the dentary is shorter than the lower limb and bears a single row of 17 - 20 teeth. The alveoles are counted with the teeth. About one tenth of the posterior edge of the upper limb does not bear teeth. Also present are 2 - 8 weak teeth in the conjunctive tissue beside the above mentioned row of teeth. These are not enumerated with the total count of teeth. The size of the teeth is slightly variable. In namaycush the teeth are quite strong, have wider bases and are not sharp as compared to those of chars and rainbow trout. Occasionally the most anterior and posterior teeth are somewhat smaller in size. The posterior teeth in namaycush are attached to the dentary. The upper posterior limb of the dentary connects with the back end of the maxilla by a fold of skin and ligaments and draws that bone into a slanted position as the lower jaw is depressed, thus widening the gape. The longer lower limb encloses the sensory mandibular canal but does not touch the quadrate as it does in grayling. The canal of the lateral line system has 7 - 9 openings. The crotch of the dentary completely envelops about one third of the angular bone. The Meckel's cartilage is almost entirely enclosed by the dentary.

The posterior < - shaped end of the dentary has a much deeper notch between the two arms of the < in chars (except Dolly Varden) than in namaycush. There are slight variations in the shape and size of the notch among different chars (Pl. 5, C-I). The notch is deep in rainbow trout (Pl. 5, J) and Brachymystax (Pl. 5, K). The tooth-bearing area in rainbow trout is smaller than that in chars. In the mature males of Salmo gairdnerii the anterior end of the dentary is slightly developed into a hook (Pl. 5, J). The shape of the dentary in Brachymystax is noticeably different from that in the other salmonids; the dentary in this fish has a much longer ventral arm.

Table 7 shows the values for various proportions in namaycush, chars, and rainbow trout. The number of pores of the sensory dentary canal is highest in namaycush (mean 8.0). With respect to the number of pores, Arctic, Quebec red, Sunapee, and blueback chars appear to form one group. Of these, the first two and the last two are closely related. See Table 9.

Angular. In the lower jaw of namaycush the pair of angulars are the second largest bones (Pl. 5, A). The development and origin of the angular are controversial (de Beer, 1927). It has been called the articular by some workers. Berg (1940), and Lekander (1949) prefer to call it the angular. The angular arises in part as an endochondral ossification at the posterior end of the Meckel's cartilage, but most of it is intramembranous. This bone is thin and toothless. It is narrow anteriorly and slips into the dentary. It is arched in cross

TABLE 9. Total number of pores on the canals of the lateral line system of 3 cranial bones of different Salmonidae.

	Dentary	Preopercle	Frontal
C.namaycush	7 - 9 (8.0)	5 -11 (8.0)	5 -10 (7.9)
S.a.alpinus	4 - 5 (4.5)	6 - 8 (6.6)	6 - 8 (7.4)
S.a.oquassa - Quebec	4 - 5 (4.8)	5 - 7 (6.0)	6 -10 (7.5)
S.a.oquassa - Pushineer Lake, Maine	5 - 7 (5.7)	5 - 7 (5.8)	6 - 9 (7.9)
S.a.oquassa - Floods Pond, Maine	5 - 7 (5.6)	6 - 8 (6.5)	6 - 9 (7.6)
S.malma	5 - 8 (6.6)	5 - 7 (6.4)	6 - 8 (6.4)
S.f.fontinalis	6 - 8 (7.0)	7 - 8 (7.1)	8 -10 (8.5)
S.f.timagamiensis	6 - 7 (6.9)	5 - 7 (6.1)	7 - 8 (7.8)
Salmo gairdnerii	5 - 8 (6.7)	7 - 9 (7.6)	7 - 8 (7.3)

section throughout most of its length. The grooves on its mesial surface are occupied by Meckel's cartilage. The angular is thick and massive posteriorly and its hind edge is straight. The angular has a transverse depression on its upper surface which is deeper posteriorly. This depression articulates with the ventral bar of the quadrate. The dentary canal occupies the outer face of the angular and has 2 - 3 openings. The upper margin of the angular is connected to the maxilla and preopercle by ligament.

The shape of the angular in namaycush (Pl. 5, A), several chars (Pl. 5, C-I), and rainbow trout (Pl. 5, J) is similar. In Brachymystax (Pl. 5, K) it is broad anteriorly and differs from that in other Salmonidae; the shape being intermediate between whitefishes and chars and trouts.

Retroarticular. The retroarticular in namaycush is somewhat triangular in shape (Pl. 5, A). It is located at the posteroventral corner of the angular. It is easily separable from that bone, and is mainly of dermal origin although it does have a small core of endochondral material. It is shown for a few chars in Pl. 5, E and G-I), and for rainbow trout in Pl. 5, J.

Cronomeckelian. In namaycush the cronomeckelians are a pair of triangular bones of dermal origin. The cronomeckelian is located on the mesial surface of the angular and loosely attached to the Meckel's cartilage. It provides for a part of the insertion of the adductor mandibularis muscle and, according to Ridewood (1904) is an ossified tendon. At times it can be seen through the translucent dorsal surface of the angular.

Preopercle. In namaycush the preopercles are a pair of bones (Pl. 6, A). The preopercle does not belong to the opercular series (Ridewood, 1904 ; Hubbs, 1919). The preopercle is considered to belong to the orbital series by Ridewood (1904) and Westoll (1937). It carries the sensory preopercular canal, which in namaycush has 5 - 11 external pores (Table 9). The preopercle in namaycush is narrow at the top but expanded at the bottom. The anterior margin of the preopercle is gently curved, offers a large area for the articulation of the large adductor mandibularis muscle, and has a prominent bony knob in the middle. The horizontal arm is about one fourth the length of the vertical arm. It is attached by strong facia to the corner of the lower jaw and the quadrate. The preopercle also comes in contact with the symplectic and the hyomandibular underneath it. Anteriorly it does not touch the postorbital bones as in the adult Oncorhynchus, Thymallus, Coregonus, and Prosopium. At the upper end the suprapreopercle is attached to it. The sensory canal which runs the preopercular length passes through the suprapreopercle before entering the pterotic.

In chars (Pl. 3, B-D; Pl. 6, B-H) and rainbow trout (Pl. 6, I) the preopercle is also gently curved but is broader toward the upper end. In Brachymystax (Pl. 6, J) and Salmothymus (Pl. 3, E) it is more curved than in chars. The preopercle is prominently arched in Hucho hucho (Pl. 3, F).

The $\frac{W}{L}$ % value in Table 6 shows that in namaycush the mean value is minimum (25.2). In chars and rainbow trout this value is definitely higher than that of namaycush and lies between 29.6 and 36.3.

Suprapreopercle. In namaycush the suprapreopercle is a small tube-like bone and carries a sensory canal of the lateral line system on each side of the skull. The canal has a single opening at about the middle of the bone. The suprapreopercle lies between the upper tip of the preopercle and the pterotic, and makes a sensory connection between these two bones through its canal (Pl. 3, A; Pl. 6, A). It is present in the family Salmonidae but absent in Thymallidae and Coregonidae. The suprapreopercle is of no significance in separating various chars (Pl. 6, B-H), and rainbow trout (Pl. 6, I).

Opercular series. The opercular series include the opercle, the subopercle, and the interopercle, as well as the expanded branchiostegal rays (Hubbs 1919). McAllister (1964) includes the opercular bones with the branchiostegal series.

Opercle. In namaycush the opercles are a pair of thin, somewhat rectangular bones and cover the dorsal half of the gill arches (Pl. 3, A; Pl. 6, A). Anteriorly the opercle is partially overlaid by the preopercle. It partly covers the subopercle and the interopercle at the anteroventral end. Anterodorsally it comes close to the suprapreopercle.

The opercle is slightly broader dorsally in Arctic, Quebec red, Sunapee, and blueback chars (Pl. 6, D-E) and is different from that of namaycush, Dolly Varden, brook, and aurora chars and rainbow trout (Pl. 6, A, and H-I). In Brachymystax it is quite broad dorsally (Pl. 6, J).

Subopercle. The subopercles in namaycush are a pair of bones. At the time of ossification the subopercle resembles a branchiostegal ray. Later it develops posteriorly and acquires the shape of a plate. Anteriorly its long dorsally pointed projection is covered by the preopercle. When the gill cover is closed the subopercle covers the anterior part of the cleithrum. Ventrally the subopercle partly covers the posterior branchiostegal ray (Pl. 3, A).

The shape of the anterior margin and the hook-like process of the subopercle (Pl. 6, A) in namaycush is narrow and distinctive from that in all the other Salmonidae.

In Salvelinus (Pl. 6, B-H) and rainbow trout (Pl. 6, I) it is somewhat similar. The subopercle in Brachymystax (Pl. 6, J) is intermediate between that in whitefishes and chars.

Interopercle. The interopercles in namaycush are a pair of thin, smooth, and somewhat rectangular bones (Pl. 6, A). The interopercle covers the lower part of the gill region. It originates and ossifies in the fashion of the branchiostegal rays. Ridewood (1904a) considers it to belong with the preopercle rather than with the branchiostegal series. Hubbs (1919) and McAllister (1964) include it with the branchiostegal series because it does not carry a sensory canal. Ventrally the interopercle partly covers the last 3 - 4 branchiostegal rays. Posteriorly it overlaps to some extent the anterior edge of the subopercle. Dorsally the interopercle is partly covered by the preopercle (Pl. 3, A).

The interopercle in aurora char (Pl. 6, H) is slightly different from that in other chars and in rainbow trout (Pl. 6, B-G, I). It is rather an unimportant bone for the separation of the chars and trouts. It is distinctive in Brachymystax.

Branchiostegal ray. The number of branchiostegal rays in namaycush is 11 - 14. The few anterior rays are sabre-shaped, curved dorsally, and pointed posteriorly (Pl. 7, C). The ones behind them are progressively longer, expanded, and fan-like. The last ray is about 4 times as wide as the first. The anterior 8 - 9 are attached to the ceratohyal and the posterior most 3 - 4 to the epihyal. Their number is usually higher by 1 on the left side of the fish (Vladykov, 1954).

The number of bronchiostegal rays is different for various species of fish. Rounsefell (1962) reported 8 - 12 in Salvelinus and 10 - 12 in Salmo. Clemens (1935) counted 10 - 19 in various species of Oncorhynchus. In Hucho perryi and Salmothymus their number is 11 (Norden, 1961). The minimum number 8 (7 in Coregonus) is found in many species of Prosopium, and also in Salmo gairdnerii (Needham and Gard, 1959). Nine to 10 are found in grayling.

Ventral Bones

The bones which are found on the floor of the cranium are the vomer and the parasphenoid.

Vomer. In namaycush the elongated vomer is composed of a distinct head and a distinct trough-like shaft (Pl. 5, A and B). The shaft is without teeth. The vomer has a raised crest which extends and points backwards from the head and is usually not free from the shaft, but is joined to the shaft. The crest bears conical teeth. There are 6 - 12 teeth on the bone, and up to 4 in the conjunctive tissue around the bone. In rare cases teeth occur on the posterior edge of the head. The posterior lateral edges of the head are projected caudad. The vomer covers about one fourth of the anterior part of the parasphenoid.

Although in a few cases the crest of the vomer is slightly short in namaycush, it is usually much longer than that of the chars. Morton and Miller (1954), since they found a few long crested vomer in Arctic char, suggested that the length of the crest should not be considered a stable character to separate the genera Cristivomer and

TABLE 10. Proportional measurements, in percentages, of 2 cranial bones of different Salmonidae.

Species	Vomer		Lingual plate		
	$\frac{L_1}{L}$	$\frac{W}{L}$	$\frac{L_2}{L}$	$\frac{W_1}{W_1}$	$\frac{W}{W}$
C. namaycush	52.3-93.4 (76.7)	25.5-39.4 (31.9)	7.2-23.3 (11.8)	73.7-118.8 (96.4)	62.3-141.7 (95.1)
S. a. alpinus	37.6-77.9 (51.2)	22.8-45.1 (32.3)	20.3-34.7 (24.8)	36.7-85.0 (54.2)	53.3-85.7 (69.3)
S. a. oquassa - Quebec	43.2-60.9 (49.5)	26.6-45.5 (36.2)	28.2-50.0 (34.7)	25.6-55.6 (46.5)	62.5-90.9 (77.0)
S. a. oquassa - Pushineer Lake, Maine	24.8-61.5 (44.7)	21.4-40.6 (33.2)	25.3-42.5 (32.4)	5.0-58.8 (22.5)	42.3-80.8 (62.9)
S. a. oquassa - Floods Pond, Maine	43.1-71.4 (52.8)	26.9-52.5 (35.5)	28.7-44.9 (33.9)	5.0-47.6 (19.2)	47.5-77.4 (59.6)
S. malma	35.7-562 (41.1)	27.1-43.9 (35.6)	19.2-32.1 (23.5)	40.0-106.7 (73.7)	71.4-111.5 (88.7)
S. f. fontinalis	39.7-51.0 (46.7)	26.7-37.5 (33.4)	32.9-40.2 (36.2)	0-45.0 (20.6)	25.0-75.6 (50.5)
S. f. timagamiensis	46.2-56.9 (49.2)	35.4-61.7 (45.2)	33.7-43.8 (40.2)	0-52.4 (24.3)	38.3-80.6 (59.0)
Salmo gairdnerii	80.8-93.9 (88.7)	17.4-23.3 (20.8)	15.8-33.3 (27.0)	25.0-57.1 (38.4)	52.4-81.8 (64.2)

Salvelinus. Besides this character the general shape of the vomer and also the attachment of the crest to the shaft are distinctive to namaycush. The vomer is similar in Arctic, Quebec red, blueback, and Sunapee chars (Pl. 5, C-F). In brook and aurora chars (Pl. 5, H and I) the teeth on the vomer are somewhat stronger than in the other chars. In Salmo (Pl. 5, J) and Oncorhynchus the teeth are present on the shaft. In Brachymystax (Pl. 5, K and L) and Hucho, the teeth are seen on the head of the vomer only.

Table 10 shows that the mean value of $\frac{L1}{L}$ % for namaycush is 76.7. The mean values for the various chars ranged between 41.1 and 52.8. In rainbow trout the mean value is highest (88.7).

The mean value of $\frac{W}{L}$ % in rainbow trout is 20.8 and segregates it from chars and namaycush (Table 10). The mean number of teeth on the vomer is highest (19.1) in rainbow trout. In namaycush the mean number of teeth is slightly higher than that in Arctic char, but the ranges in both fish overlap. With respect to number of teeth Arctic char is close to Quebec red char, blueback char to Sunapee char, and brook char to aurora and Dolly Varden chars (Table 8).

Parasphenoid. The parasphenoid in namaycush covers most of the ventral surface of the chondrocranium. It is a long, narrow, and intramembranous bone (Pl. 5, A). The anterior one-third to one-fourth is grooved; the shaft of the vomer fits into this groove. This groove runs medially from near the anterior tip as far back as the basisphenoid. The parasphenoid bears a marked dorsal ridge which fits into the groove. The posterior edge of the interorbital septum has two small lateral projections which look like the chela of a scorpion. With the help of these projections and a very small median spine the parasphenoid is attached to the basisphenoid. Posterior to this spine the parasphenoid forms a deep trough with lateral bony flanges. These flanges curve dorsad and form the floor and part of the side walls of the myodome. These flanges touch similar downward-projecting flanges from the prootics and the basioccipital. Anteriorly these flanges are serrated. The posterior end of the parasphenoid is < - shaped, does not cover the basioccipital completely, and does not reach the atlas. It also leaves an opening in the myodome. The internal carotid arteries pass through a pair of foramina. This pair of foramina lie just posterolaterad to the small median dorsal spine. A second pair of foramina through which passes the posterior palatine branch of the facial nerve is present in namaycush. This is also observed by Norden (1961) in the grayling.

In namaycush the parasphenoid is slightly longer than the dentary; the wings in the anterior region of the bone are not spread. In Arctic char and Quebec red char (Pl. 5, C and D) the wings are broad and the bone is slightly shorter than the dentary. In blueback and Sunapee chars (Pl. 5, E and F) the wings and the shape of the bone are similar to those of Arctic char but the bone in the first two fishes is slightly longer than the dentary. The shape of the bone in brook and aurora chars is similar (Pl. 5, H and I) and resembles that of Arctic char. It is slightly smaller than the dentary in aurora char but equal to the dentary in brook char. The anterior region of the bone in Dolly Varden char (Pl. 5, G) is different from that in other chars, being broader and without the developed wings. In Dolly Varden char the parasphenoid is equal in size to the dentary bone. This bone is smaller than the dentary in rainbow trout (Pl. 5, J). In Brachymystax (Pl. 5, K) the parasphenoid is long and thin, about twice as long as the dentary.

Visceral Arches

The visceral arches include the palatoquadrate arch, the hyoid arch, and the branchial arches.

Palatoquadrate arch. The bones of the palatoquadrate arch did not seem to be of much significance in the taxonomy of chars and rainbow trout and hence their comparative account is omitted.

Palatine. The palatines in namaycush are a pair of splint-shaped bones of mixed origin. The palatine is broader anteriorly and pointed posteriorly (Pl. 7, A), and bears 17 - 21 teeth in a single row which are well attached to the bone. There are 2 - 5 teeth embedded in the conjunctive tissue lateral to the row of teeth mentioned above. The palatine articulates mesially with the chondrocranium at two points, one at the anteroventral corner and the other at the posteroventral corner of the nasal capsule, in a manner described by Saunderson (1935) for Salmo salar. The anterior rostro-palatine articulation (de Beer, 1927) bears a cartilaginous knob which fits into a depression formed partly by the incurved maxilla and by the enlargement of the rostrum. Slightly posterior to this knob it has another cartilaginous projection which attaches to the ethmoid cartilage just beneath the anteroventral projection of the prefrontal. The remainder of the lateral edge of the palatine is separated by a thin strip of cartilage from the mesopterygoid. Little over one third of the posterior part of the palatine is overlapped by the ectopterygoid. The palatine does not reach the quadrate. The lateral margin of the palatine has a ligamentous attachment to the maxilla.

Epihyal. In namaycush the epihyals are a pair of somewhat semilunar and endochondral bones (Pl. 7, B). The broad anterior end of the epihyal is connected to the ceratohyal by the cartilage. The postero-dorsal tip, which is about one-fourth of the anterior border is attached to the interhyal by the cartilage. The epihyal is nearly covered by the interopercle. The last 3 - 4 branchiostegal rays are borne on the epihyal.

Ceratohyal. In namaycush the ceratohyals are a pair of endochonoral bones and are flat and long (Pl. 7, B). The posterior border of the ceratohyal is about one and one-half the size of the anterior border. The ceratohyal extends along the pharyngeal cavity and bears 8 - 9 branchiostegal rays. The anterior carilaginous edge of the ceratohyal articulates with the upper and lower hypohyals.

Hypohyal. In namaycush the hypohyals are endochondral in origin. They are two pairs of conical bones (Pl. 7, B; Pl. 8, A) and connect the pair of ceratohyals to the median basihyal. Both the smaller upper and the larger lower hypohyals meet their fellows from the opposite side at the midline in a suture that is covered dorsally by the median basibranchials. The lower hypohyal, larger of the two, with its projecting knob, attaches to the anterior part of the second basibranchial. The upper and smaller of the two hypohyals joins to the first basibranchial with the help of a much smaller knob. The upper and lower hypohyals are separated by cartilage. Anteriorly the hypohyals meet the cartilaginous basihyal.

Ectopterygoid. In namaycush each ectopterygoid is a thin, slightly curved bone of dermal origin. It is pointed at both ends, more so anteriorly (Pl. 7, A). It is about the same length as the palatine. Its dorsal margin is separated from the mesopterygoid by a thin cartilage. Posteriorly about one third of the ectopterygoid lies against the anterior border of the quadrate. Anteriorly about one half of the ectopterygoid lies over the palatine. The ventral margin of the ectopterygoid is attached to the maxilla by ligaments.

Quadrate. In namaycush the quadrates are a pair of fan-shaped endochondral bones (Pl. 7, A). The area around the articular condyle ossifies first during the development. The quadrate has a ventral articular condyle which fits into the depression of the angular bone. Dorsally it is separated from both the mesopterygoid and the metapterygoid by the palatoquadrate cartilage. Posteriorly the quadrate bears a thin acuminate strut of dermal bone. Three-fourths of the grooved posterior side of the strut receives the anterior and lower part of the preopercle. One-third of the base of the strut is not grooved. The quadrate in namaycush lies well back of the orbit, whereas in grayling and whitefishes its articulation with the angular is below the eye (Norden, 1961), and in Brachymystax the quadrate is located in a line with the posterior border of the eye.

Mesopterygoid. In namaycush the mesopterygoids are a pair of thin triangular and intramembranous bones lying in front of the metapterygoid (Pl. 7, A). The dorsal surface of the mesopterygoid lies inward and under the eyeball. It covers most of the palate but barely reaches the parasphenoid. Its posterior surface is overlapped by the metapterygoid and also partly by the quadrate. The entire outer margin of the mesopterygoid is bordered by the ectopterygoid and the palatine. The anterior end of the mesopterygoid touches the ethmoid cartilage.

Metapterygoid. In namaycush the metapterygoids are a pair of somewhat triangular and endochondral bones (Pl. 7, A). The metapterygoid fits into the semicircular space formed by the quadrate, the symplectic, and the hyomandibular bones. Anteriorly it overlaps the posterior margin of the mesopterygoid and lies under the first postorbital bone. Anterodorsally it is free but posterodorsally it overlaps the anterior part of the hyomandibular. Ventrally the metapterygoid is connected to the quadrate and the symplectic by the palatoquadrate cartilage.

Hyoid arch. The bones of the hyoid arch in chars and trouts are very similar to thoseof namaycush and hence are not included in this study.

Hyomandibular. In namaycush the pair of hyomandibular bones are endochondral in origin. The hyomandibular suspends the jaw from the cranium and is hatchet-shaped (Pl. 7, A). It contains a hyomandibular foramen through which a branch of the facial nerve passes. This foramen extends from the mesial surface of the upper part of the bone to the deep groove below the posteriorly directed opercular condyle. The anterior flange which forms about one-third of the bone is overlapped by the dorsoposterior portion of the metapterygoid. Dorsally the hyomandibular articulates with the pterotic and the posterior end of the sphenotic bones. This articulation is cartilaginous. The opercular condyle, which has a cartilaginous cap, joins the hyomandibular to the opercle. The opercular condyle is overlapped by the preopercle. Posterodorsally the hyomandibular is overlapped by the suprapreopercle. The posteroventral border is narrowly overlapped by the preopercle. An open space is left on the posterior border of the hyomandibular where it is connected by the cartilage to the preopercle. Ventrally the hyomandibular is connected to the symplectic and to the interhyal with the help of cartilage. The hyomandibular is overlapped by the large adductor mandibularis muscle and by the postorbital bones.

Symplectic. In namaycush the pair of symplectic bones are endochondral. The symplectics lie between the quadrate proper and the strut of the quadrate (Pl. 7, A), and originate at the back of the quadrate near the articular condyle. It extends beyond the quadrate proper and the strut. This bone is narrow at the lower end and broad at the upper end, respectively. It is separated by the palatoquadrate cartilage from both the metapterygoid and the hyomandibular bones. Anteriorly it is slightly curved. The symplectic serves as a brace for the articulating bones of the jaw.

Interhyal. In namaycush the pair of interhyals are stout, small, and cylindrical bones (Pl. 7, A and B). The interhyal is endochondral in origin and connects the posterodorsal tip of the epihyal with the small triangular piece of cartilage which separates the symplectic from the hyomandibular. It holds the lower hyoid elements and the hyomandibular together. The interhyal barely comes in contact with the interopercle.

Basihyal. In namaycush the basihyal is single, entirely cartilaginous, and is heart-shaped (Pl. 7, B). It is twice as broad at the posterior end than at the anterior end. It forms the base for the support of the bony lingual plate (supralingual of Vladykov, 1954). This plate has a dermal ossification. Teeth on this plate are arranged on the outer edges in two parallel rows, one on each side of the plate (Pl. 5, B). The total number of teeth for both the rows varies from 12 - 19.

From 1 - 4 (in rare cases, up to 10) teeth are observed in the middle of the plate. The position of the median teeth is not fixed. They may occur in the anterior, central, or posterior region of the plate. Almost invariably the anterior end of the plate has a slight notch. Posteriorly the plate covers a part of the first basibranchial bone; this condition was also observed in S. salar (Tchernavin, 1938b).

The shape of the lingual plate and the structure of the teeth on it are similar in Arctic and Quebec red chars (Pl. 5, C and D), and in blueback and Sunapee chars (Pl. 5, E and F). But the structure of the plate seems to integrate the 4 populations. The teeth on the plate and the shape of the plate in brook and aurora chars are similar. Teeth in these 2 forms are stronger (Pl. 5, H and I) than those in other chars. The shape of the plate in Dolly Varden char (Pl. 5, G) is dissimilar to that in the other chars. In rainbow trout the configuration of the plate and the position of the teeth on the plate are distinctive (Pl. 5, J). In appearance the plate in Brachymystax (Pl. 5, K) is similar to that in chars but the plate is different from that in whitefishes. In chars, trouts, and Brachymystax the teeth on the outer edges of the plate are usually arranged in a triangle as opposed to the parallel rows in namaycush.

The notch on the anterior end of the plate is rarely present in chars and rainbow trout.

The mean value of $\frac{L_2}{L}$ % (Table 10) for namaycush is minimum (11.8). Chars form a separate group. Brook and aurora chars are closely related. The mean value of $\frac{w_1}{W_1}$ % is maximum (96.4) for namaycush. Arctic and Quebec red chars are close to each other, as are blueback and Sunapee chars, and brook and aurora chars. The mean value of $\frac{w}{W}$ % is maximum (95.1) in namaycush. See Table 10.

Teeth on the lingual plate were counted separately on each of the two rows and on the middle of the plate (Fig. 2, D). The number of teeth is highest in Arctic char. This may be the result of the northern locality of the sample. Vladykov (1954) pointed out that the number of teeth on the plate was highest in namaycush. In this study the number of teeth on the plate in namaycush is close to that in Arctic char. In Quebec red char the number of teeth is less than that in Arctic char. In blueback and Sunapee chars the number of teeth is identical. In Dolly Varden, brook, and aurora chars and in rainbow trout the number of teeth on the plate is similar. See Table 8.

The extent of the dentigerous tissue is greater in namaycush than that in chars and rainbow trout.

Branchial arches. The skeleton of the branchial region in namaycush is mostly cartilaginous. Only the dentigerous pharyngeal plates are intramembranous in origin.

Pharyngobranchial. Three pairs of pharyngobranchials are present in namaycush. They are somewhat Y-shaped (Pl. 8, A). The first pharyngobranchial is attached to the ventral surface of the parasphenoid. Posteriorly one of the remaining arms of the Y is attached to the first epibranchial, while the third arm is joined to the pharyngobranchial of the second arch. Posteriorly the second pharyngobranchial connects to its own epibranchial with a cartilaginous joint. Anteriorly 1 branch is connected to the epibranchial of the first arch. The second branch makes contacts with the pharyngobranchials of the first and third arches. Posteriorly the third pharyngobranchial articulates broadly with its own epibranchial and anteriorly with 1 arm of the Y of the epibranchial of the second arch. Also anteriorly the third arm of the third pharyngobranchial articulates with the pharyngobranchial of the second arch. This last articulation is brought about by a long piece of cartilage. The third pharyngobranchial bears a small but distinct toothed plate on its lower surface (Pl. 8, A, UPP-2). The number of teeth on the third pharyngobranchial plate varies between 7 - 9 in namaycush (Pl. 8, C, UPP-2). The pharyngobranchial of the fourth arch is cartilaginous and joins the epibranchial of the fourth arch to the pharyngobranchial of the third arch. No gill rakers are found on these pharyngobranchials.

Teeth on the third pharyngobranchial plates in Arctic char are slightly more developed than those in Quebec red, blueback, and Sunapee chars (Pl. 8, E-H). In brook char (Pl. 8, J) the teeth are stronger than in the other chars and the trout examined. At times the teeth are barely visible and are hidden between the skin folds (Pl. 8, L). In rainbow trout the teeth are weakly developed (Pl. 8, M).

Epibranchial. There are 4 pairs of epibranchials in namaycush (Pl. 8, A). The fifth branchial arch does not have an epibranchial. The first epibranchial is the longest. The second, third, and fourth in succession get shorter in length. The posterior prong of the Y is longest in the first 3 epibranchials, and their cartilaginous connections to the ceratobranchials are curved. Each of the first 3 epibranchials bears on its upper surface a deep groove which carries the efferent and afferent branchial arteries. The fourth epibranchial is expanded dorsally and has a well developed toothed pharyngeal plate (Pl. 8, A, UPP-1). This plate is not fused to the fourth epibranchial and lies partly on it and partly on the cartilaginous fourth pharyngobranchial. Teeth are pointed and slightly hooked and their number varies from 25 - 37. The first 3 pairs of epibranchials bear short gill rakers both anteriorly and posteriorly, but those on the posterior edge are much smaller and fewer in number. The fourth epibranchial bears no gill rakers.

Teeth on the fourth epibranchial (upper pharyngeal teeth) are more numerous in namaycush (Pl. 8, C, UPT-1) than in chars and trout (Pl. 8, E-J, L, and M). However, it is impossible to segregate the species by considering the number of the upper pharyngeal teeth.

Ceratobranchial. There are 5 pairs of ceratobranchials in namaycush (Pl. 8, A). These are the longest bones in the branchial arches. The first bone is the longest. The second is longer than the third, and the fourth and fifth are of about equal lengths but shorter than the third. The first 4 are broader at their anterior ends. However, the fifth ceratobranchial is much more expanded near its base than the first 4. Each ceratobranchial except the last has a groove on its ventral surface which partly surrounds the branchial arteries. All ceratobranchials bear gill rakers on their anterior edges. The gill rakers on the posterior edges of the first 4 ceratobranchials are short. The fifth pair of ceratobranchials do not bear gill rakers on their posterior edges. The first 3 ceratobranchials articulate anteromesally with their hypobranchials; the last 2 articulate with the posterior copula. The fifth ceratobranchial bears a toothed pharyngeal plate on its dorsal surface (Pl. 8, A and B, LPP). The number of teeth is about 38 - 45. The toothed plate covers the anterior three-fourths of the fifth ceratobranchial dorsally. The plate is broader and slightly curved in the middle and tapers at both ends. Just caudad to the posterior edge of the lower pharyngeal plate there is another very small plate which bears 2 - 4 well developed teeth.

Hypobranchial. Three pairs of hypobranchials are present in nanaycush (Pl. 8 A). The first pair is anterior to and longer and broader than the others, and is slightly tapered posteriorly. Its posterior end is about one-half the size of its anterior end. It articulates anterolaterally with the cartilage between the second and third basibranchial bones. Posteriorly it articulates with the ceratobranchial. The second hypobranchial is slightly smaller than the first one. Its anterior and posterior ends are of about equal size. Its lateral side which faces the fourth basibranchial slightly bulges toward that bone. The second hypobranchial articulates anteriorly with the cartilage between the third and fourth basibranchial bones. The third hypobranchial is widest at its articulation with the third ceratobranchial, becoming narrower as it arches around the fourth basibranchial. The 2 hypobranchials of the third pair meet anterior but ventral to the fourth basibranchial bone. Their articulation is cartilaginous. The third pair of hypobranchials is the smallest. All the hypobranchials bear short gill rakers on their anterolateral edges only.

Basibranchial. The 4 basibranchial bones lie in a median series on the floor of the pharynx (Pl. 7, B). The first basibranchial is the smallest of the 4 and is connected posteriorly to the second by a thin strip of cartilage. It lies between the hypohyals. Anteriorly the first basibranchial bone joins the basihyal cartilage. The second basibranchial bone is about one and one-half times the length of the first bone. It lies partly between the hypohyals. Anteriorly it joins with the first basibranchial. Posteriorly it is articulated, with the help of cartilage, with the third basibranchial. The cartilage between the second and the third basibranchial bones is as long as the second basibranchial bone and is pushed in laterally. This is where the hypobranchial of the first branchial arch attaches. The third basibranchial bone is about one and one-half times as long as the second. Anteriorly it joins to the cartilage behind the second and posteriorly to the cartilage in front of the fourth basibranchial bones. The cartilaginous articulation between the third and the fourth basibranchials is slightly longer than the one between the second and third basibranchial bones. On the lateral side the cartilage between the third and fourth basibranchials is pressed inward at a point where the hypobranchial of the second branchial arch joins it. The fourth basibranchial is a little longer than the third and tapers posteriorly. The 4 basibranchial bones, together with the interspaced cartilage, are called the anterior copula (Tchernavin, 1938b). The posterior copula is entirely cartilaginous and is composed of a broad plate and a long thin tail. The posterior copula lies between the fifth ceratobranchials. The third pair of hypobranchials connects the posterior copula with the fourth basibranchial of the anterior copula.

There are from 1 - 2 dermal and dentigerous basibranchial plates which cover part of the second, third and fourth basibranchial bones. They are fused to the third basibranchial bone and bear well developed teeth in a broad patch (Vladykov, 1954). The number of teeth varies from 28 - 62. The plate or plates  are about as wide as the third basibranchial bone and a little narrower at the anterior and posterior ends.

It was pointed out by earlier workers that Arctic char has a uniserial or biserial row of basibranchial teeth and thus can be easily separated from namaycush which has multiserial rows of teeth. In this study it is clearly shown that the different populations of Arctic char have from uniserial to multiserial rows of basibranchial teeth (Pl. 8, D, and F-H). It was also pointed out by several authors that the brook char has no teeth on the basibranchial and can be put aside from the other chars. Kendall (1914) and Stokell (1951) observed basibranchial teeth in brook char. I have observed teeth in some specimens of brook char from Laurentide Park, Quebec (Pl. 8, K), and also in some aurora char. To segregate species on the basis of the presence or absence of the basibranchial teeth is not safe in the genus Salvelinus. No basibranchial teeth were observed in rainbow trout (Pl. 8, M).

Urohyal. The urohyal in namaycush is intramembranous in origin (Ridewood, 1904a) and does not belong to the branchial skeleton (Pl. 7, B). Anteriorly it is attached to the hypohyals by a small round head. Posteriorly the urohyal broadens to form lateral flanges which have jagged posterior margins. The thin crest extends dorsally like a sail with a jagged posterior margin. The urohyal is located dorsal to the branchiostegal rays. It is the ossified tendon of the sternohyoideus muscles in which it is embedded.

Median Fins and Appendicular Skeleton

Dorsal fin. In namaycush there are 13 - 16 rays (all the rays counted) in the dorsal fin (Pl. 9, A). Of these, 4 - 5 anterior rays are unbranched. The dorsal rays are supported by a series of distal (first series) pterygiophores. Each ray is more closely associated with the distal pterygiophore of the next posterior ray than with its own. The distal pterygiophores are small, hourglass-shaped, and are clasped between the bases of the paired rays. The cartilaginous distal pterygiophores for the first 3 proximal pterygiophores are tightly packed.

The intermediate (second) series of pterygiophores are larger and rod-like, and function as spacer bars between the bases of the rays. There are 9 - 10 of these. The first of the intermediate pterygiophores is half the size of the last one. The anterior most 2 - 3 proximal pterygiophores do not have intermediate pterygiophores.

The proximal (third) series of pterygiophores are long and dorsally expanded (Pl. 9, A). At their lower ends they touch the upper surfaces of the neural spines. The first proximal pterygiophore is much stronger than the others and usually supports the 3 anterior dorsal fin rays. The proximal pterygiophores number 11 - 14. The last proximal pterygiophore is usually about half the size of the first 3 pterygiophores. The proximal pterygiophore for the attachment of the last dorsal fin ray is missing.

In namaycush there are 17 - 21 interneurals. At times one or more of these  .. is forked. Almost all have cartilaginous upper ends. The first 3 - 4 (close to cranium) interneurals are shorter and more deeply seated between the neural spines than the posterior ones, which are twice as long and barely touch the neural spines. The first interneural is expanded and plate-like.

Anal fin. In namaycush 13-15 rays are found in the anal fin (Pl. 9, E). The anterior 4 - 5 of these are unbranched. The first ray is T-shaped and strong. The rays are supported by a series of pterygiophores. The first 3 distal pterygiophores are cartilaginous and usually support the first 3 rays. The first ossified distal pterygiophore is the fourth one, which supports the third and fourth anal fin rays. These small distal pterygiophores are clasped between the bases of the paired anal fin rays. There are 10 - 11 distal pterygiophores. The first 3 are tightly packed.

There are 7 - 9 intermediate pterygiophores. No evidence of ossification of the intermediate pterygiophores is noticed between the first and second, and the second and third proximal pterygiophores. The first ossified pterygiophore of the intermediate series occurs between the fourth and fifth proximal pterygiophores. There is also no evidence of its fusion with the pterygiophores of the distal or the proximal series. Probably the pterygiophores of the intermediate series are not needed, as the anterior end of the anal fin has to be rigid; thus their presence would make it disadvantageously flexible. Or instead they may be completely cartilaginous and fused unidentifiably with the pterygiophores of the distal series. The first ossified intermediate pterygiophore between the fourth and fifth proximal pterygiophores is half the size of the last pterygiophore of the intermediate series. This last intermediate pterygiophore is joined anteriorly to the last proximal pterygiophore and posteriorly to the last distal pterygiophore. The intermediate pterygiophores are spacer bars and probably help give the flexibility to the posteroventral end of the anal fin.

The long proximal pterygiophores directed anterodorsally are barely inserted between the haemal spines. The distal ends of the proximal pterygiophores are expanded but not so much as in the dorsal fin pterygiophores. The anterior most 2 - 4 proximal pterygiophores are about twice as long and slightly stronger than the most posterior proximal pterygiophore. In other words, the length of these elements decreases posteriorly. There are fewer proximal pterygiophores than there are anal rays. The usual number of proximal pterygiophores is from 11 - 13. The first 3 do not have intermediate pterygiophores to associate with. The first 4 proximal pterygiophores support the first 6 anal fin rays.

Pectoral girdle. In namaycush the pectoral girdle consists of 9 pairs of bones plus 4 actinosts (Pl. 9, C and D). The girdle is attached dorsally to the skull by means of ligaments.

With the development of a bony secondary girdle (posttemporal, supracleithrum, cleithrum, postcleithra 1, 2 and 3) the primary girdle (scapula, mesocorocoid, and coracoid) becomes much reduced and, as a rule, does little more than connect the fin with the cleithrum.

Posttemporal. In namaycush the posttemporals are a pair of curved, forked, intramembranous bones. The pectoral girdle is attached to the cranium by the posttemporal bone. The dorsal fork of this bone is long and pointed anteriorly and has a broad base (Pl. 9, C). This fork almost meets its fellow from the opposite side at the midline of the skull. It is attached to the epiotic by a strong ligament. The spine-like ventral fork is much shorter, about one-third of the dorsal fork, and is the posterior ossification of a ligament between the posttemporal and the opisthotic bones. The ventral fork originates near the posterior broad end of the posttemporal at a point at about one-quarter the length of the dorsal fork. A sensory canal, with two pores, is present on the dorsal surface of the posttemporal. This canal connects the canals of the extrascapulars and the supracleithrum. The posttemporal overlaps about one-fifth of the supracleithrum.

Supracleithrum. In namaycush the supracleithra are a pair of concave intramembranous bones with a dorsal thickening at the anterior end (Pl. 9, C). The anterior end of the supracleithrum barely passes beyond the ventral fork of the posttemporal. Posteriorly and ventrally the supracleithrum is a little expanded and thinner. It overlaps the anterior pointed end of the cleithrum.

Cleithrum. In namaycush the pair of cleithra are a large, triangular, dorsally curved, intramembranous bones (Pl. 9, C). The cleithrum is similar to that of grayling (Norden, 1961).

Postcleithrum. Namaycush has 3 pairs of intramembranous postcleithra. The first 2 are similar in form and shape (Pl. 9, C). However, the first is a little broader at the dorsal end while the second is expanded ventrally. The dorsal one-third of the first postcleithrum is covered by the supracleithrum. Ventrally most of the first postcleithrum is covered by the cleithrum. The second postcleithrum is separated from the first and lies almost completely beneath the cleithrum. The second postcleithrum overlaps a very small portion of the third postcleithrum. The third postcleithrum is expanded dorsally and pointed ventrally, is arched (concave posteriorly), and lies in the muscle beneath the pectoral fin.

Scapula. In namaycush the pair of scapulas are endochondral bones (Pl. 9, C) lying ventral to the cleithrum and articulating with it. Anteriorly the scapula is circular and separated from the coracoid and the upper 2, possibly 3, actinosts by a narrow strip of cartilage. Posteriorly the scapula is rather straight with grooved facets to receive the cartilaginous parts of the actinosts and the knob of cartilage to which the first strong pectoral fin ray is attached. It articulates mesially with the mesocoracoid. The scapular foramen, which is about one-third the size of the scapula, lies completely within the scapula.

Mesocoracoid. The mesocoracoids are a pair of bones. The mesocoracoid in namaycush is strongly arched and acts mainly as a brace between the cleithrum and the primary shoulder girdle (Pl. 9, C). It is similar to that of grayling (Norden, 1961).

Coracoid. The coracoids are a pair of bones in namaycush. The shape of the coracoid in namaycush is shown in Pl. 9, C. Its description is similar to that of *Salmo* (Bruch, 1861).

Pectoral fin. Four actinosts are present at the base of each of the two pectoral fins in namaycush. The upper actinost articulates with the scapula and the lower 3 articulate with a piece of cartilage lying between the coracoid and the scapula (Pl. 9, D). The upper actinost is the shortest; the others become progressively longer ventrally. There are 13 - 15 pectoral fin rays. The outer and uppermost ray is unbranched, and is the longest and heaviest ray, having a big knob at the anterior end. It articulates directly with the scapula. The remainder of the rays become progressively smaller and articulate with the posterior cartilaginous ends of the actinosts.

Pelvic girdle. In namaycush the pelvic girdle consists of a pair of L-shaped bones, the basipterygia (Pl. 9, E) and resembles that of *Salmo* (Bruch, 1861). There are slight differences in the number and structure of the pterygiophores between namaycush and *Salmo*. On the posterior surface of each basipterygium there are 3 pterygiophores lying between the basipterygium and the pelvic fin rays. The pterygiophore to which the 4 - 5 medial fin rays are attached is ossified and resembles a hook. The other two pterygiophores are not ossified and show very feeble lines of demarcation. There is a curved spine (splint of Gosline, 1961) on the outer side of the fin at the junction of the posterior end of the basipterygium and the fin rays. This spine is covered with skin, and is loosely attached to the fin. A total of 9 - 10 rays is present in the pelvic fin of namaycush. The first outer one is not branched.

An axillary scale lies along the outer angle of each of the two pelvic fins.

Axial Skeleton

Vertebral column. The vertebral column of namaycush is composed of 61 - 66 vertebrae. The range of the number of trunk vertebrae is 29 - 34, precaudal 5 - 8, and caudal 25 - 29.

The centra, except the first 2, are hour-glass shaped and amphicoelous. The atlas articulates with the basioccipital and the exoccipitals. The first vertebral centrum is about half the size of each of the trunk centra numbers 10 - 15. The second vertebral centrum is slightly larger than the first. The remaining centra increase in size up to the precaudal vertebrae, after which they gradually decrease in size.

The middle portion of each trunk centrum is marked by horizontal bony ridges (Pl. 10, A). Toward the anterior and posterior edges of the centrum the pattern is different; the hexagonal and circular cavities are surrounded by ridges. The number of these circular, hexagonal, and octagonal cavities increases in the caudal region. In the last 3 upturned caudal vertebrae, horizontal bony ridges are lost; the cavities fuse and become enlarged. The ridges are the areas of origin and insertion for fascia from the myotomes.

The neural arches are situated dorsally to the centra. These arches are larger and lower caudally. The arches are expanded anteriorly and posteriorly. In the trunk region the anterior expanded parts (wings) of the arch are broader and heavier than the posterior wings. From about centra 29 - 32 and beyond, the size of the anterior wing shortens. In the caudal region the shape of the anterior and the posterior wings is nearly the same. The anterior neural arches lie in the pits on the centra. The first 30 - 35 arches are not co-ossified with the centra. In isospondylus fishes, Ford (1937) has observed that the anterior arches are not co-ossified with the vertebrae. In grayling Norden (1961) has pointed out that the first 24 - 26 anterior arches are not co-ossified with the centra. The neural arches terminate in posteriorly directed neural spines. The first 30 - 35 neural spines are paired. The last 25 - 32 are single. From the latter group 5 - 6 neural spines are flat and blunt. See Pl. 10, A.

In namaycush the prezygopophyses and the postzygopophyses on the neural arches in the anterior region of the vertebral column are not prominent. The first prominent postzygopophysis is observed on the twenty-eighth to thirty-first neural arches. In this species it seems that the prezygopophyses are the outgrowth of the neural arches and the postzygopophyses are the outgrowth of the centra. However, at about the twenty-ninth to thirty-first centra, these processes seem to be the outgrowth of the fused complex (the neural arch and the centrum). The postzygopophyses are not strong in the last 4 centra prior to the 3 upturned centra in the caudal region.

The epineurals are intermuscular bones. They articulate dorsolaterally with the bases of the neural arches, and their heads fit into small depressions on the arches. They begin on the first or the second vertebra and terminate between the twenty-ninth and thirty-sixth. The first epineural is about half the length of the second. In general the anterior epineurals are stronger than the posterior ones. The last 8 - 9 epineurals are situated a little higher on the neural arches.

The centra of the vertebrae bear ventral paired parapophyses which occupy most of the length of each centrum. The anterior trunk parapophyses lie in the pits on the centra. The parapophysis of the first centrum consists of a bony nodule and is fused to the centrum. Parapophyses on centra 2 - 36 are not fused to the centra but are held in place by ligaments (Ford, 1937).

Parapophyses of the centra 31 - 38 increase in length ventrally. Transverse but incomplete bony bridges are formed on each centrum from numbers 33 - 38, thus forming a closed haemal arch on each vertebra. The remaining haemal arches, beyond the bridges, extend ventrally and form haemal spines (Pl. 10, B and C). There are from 22 - 26 haemal spines. Out of these the last 3 - 5 are expanded. In addition 7 expanded hypurals of the tail are present. The caudal artery and vein pass through the haemal canal and open as far back as the first or second hypural. The parapophyses of the sixtieth and sixty-first vertebrae and of 7 hypurals are not fused with the centra. From centrum 33 and beyond, the haemal arches shift to the anterior part of the centrum.

Most parapophyses bear ventral prezygopophyses and postzygopophyses which help in the articulation of the vertebrae. These are not seen on the first 9 - 11 vertebrae. Beyond these vertebrae they are present but are not well developed. The prezygopophyses on vertebrae 53 - 59 are well developed. Beyond these vertebrae the size and shape of the prezygopophyses are variable.

The pleural ribs curve ventrally between the muscles and the peritoneum around the peritoneal cavity, ending in cartilaginous points near the midline. The ribs start on the second or third vertebra. There are 36 - 39 pairs of ribs. The first rib is one-fourth to one-half the size of the second. The second and third are longer. The last 6 - 7 ribs are thin and weak. Generally the ribs are stronger in the anterior trunk region and become weaker caudally. They are somewhat expanded dorsoventrally. The anterior thoracic ribs have bifid, T-shaped heads and attach to the parapophyses at two points. The more posterior ribs have single heads and are attached by ligaments near the tips of the lengthened transverse processes of the vertebrae. There are 5 - 9 pairs of ribs with single heads. This number is included in the total number of ribs (36 - 39).

Caudal skeleton. The caudal fin of namaycush is deeply forked. There are 40 - 46 caudal fin rays, out of which 19 are principal rays. Seventeen of these 19 are branched. The supporting elements of the caudal fin consist of 9 - 10 centra, and expanded neural and haemal spines. The last 3 centra are upturned and become progressively smaller. Gosline (1960) termed the first upturned vertebra as the terminal vertebra, and the 6 - 7 vertebrae which immediately precede this as the preterminal vertebrae. The ones posterior to the terminal vertebra are the postterminal vertebrae (always 2).

Of the expanded neural spines (4 - 7) the anterior most (nearer to the adipose fin) 3 - 5 are fused with the neural arches. The posterior (closer to the first uroneural) 1 - 3 are free from the neural arches (Table 11). At times the posterior most neural arch does not bear a spine. There are 2 unpaired epurals, median endochondral bones which have lost their proximal contact with the neural arches and articulate with the first uroneural. In namaycush the epurals are slanted more caudad, toward the second uroneural, than in chars. The second epural is longer and distally broader than the first. The first uroneural and the first or second neural arches immediately anterior to it are free from the centra.

There are 3 pairs of serially homologous uroneurals. Goodrich (1909), Regan (1910), Hollister (1936), and Gosline (1960) interpreted the uroneurals as specialized neural arches of the last 2 upturned centra. Vladykov (1954) called the first extended uroneural the caudal bony plate, and Dineen and Stokely (1954) called it the extra neural arch. The first uroneural covers the dorsolateral surface of the last 4 centra and bears a posterior projection which extends over the anterior part of the urostyle (Pl. 11, A) and often reaches the seventh hypural. The first uroneural is forked; its anterolateral limb which flanks the vertebral column is longer than the posterior limb. The first uroneural on either side bears a high dorsal crest between which the front ends of the epurals project. For the first uroneural the mean value of $\frac{W}{L_1}$ % (Table 11) is 36.0. The second uroneural is posterior to the first and lies dorsolateral to the urostyle. Anteriorly it covers about 3 - 6 mm of the first uroneural. The third uroneural is small and lies dorsolateral (at

TABLE 11. Proportional measurements, in percentages, of the uroneurals of the caudal skeleton of different Salmonidae. Also are included the total numbers of the epurals, expanded neural processes, and haemal processes.

Species	Uroneurals		No. of Epurals	No.of expanded processes	
	$\frac{W}{L_1}$	$\frac{L_3}{L_2}$		Neural	Haemal
C.namaycush	26.7-47.5 (36.0)	30.9-83.2 (60.6)	2 - 3 (2.0)	4 - 7 (5.5)	5 - 9 (6.5)
S.a.alpinus	34.2-56.9 (41.4)	21.1-91.3 (71.8)	1 - 2 (1.8)	4 - 7 (5.8)	4 - 7 (5.4)
S.a.oquassa - Quebec	25.4-38.8 (32.1)	56.6-86.4 (71.7)	2 - 2 (2)	6 - 8 (6.7)	7 -10 (8)
S.a.oquassa - Pushineer Lake, Maine	27.3-43.2 (33.8)	30.8-88.9 (63.1)	1 - 2 (1.9)	5 - 9 (6.7)	5 -10 (7.4)
S.a.oquassa - Floods Pond, Maine	24.8-42.9 (31.1)	48.3-78.0 (64.4)	1 - 2 (1.9)	7 -10 (8)	5 -11 (8.6)
S.malma	Not examined				
S.f.fontinalis	32.9-47.6 (38.9)	52.5-100.0 (73.1)	2 - 2 (2)	6 -11 (8)	7 -11 (8.3)
S.f.timagamiensis	43.6-60.9 (53.3)	25.0-50.7 (39.4)	2 - 2 (2)	6 - 7 (6.1)	6 - 8 (7.2)
Salmo gairdnerii	38.6-57.1 (48.5)	60.9-95.2 (83.2)	3 - 3 (3)	4 - 6 (5.5)	4 - 6 (5.2)

times lateral) to the urostyle, and is situated far posterior to the second uroneural. It is smaller and stouter in namaycush as compared to that in chars. The mean value of $\frac{L3}{L2}$ % in namaycush is 60.6 (Table 11). Probably the long uroneurals stiffen the upturned terminal portion of the vertebral column.

Developmentally, ossification commences in the haemal arches and spines a little earlier than in the centra.

The haemal spines which lie ventral to the last 3 upturned centra and urostyle are highly modified and expanded and are called the hypurals. They support the principal caudal fin rays. In namaycush, chars, and trouts there are 7 hypurals. In namaycush 5 - 9 expanded haemal spines (haemal processes of Berg, 1940) are also present. Out of these, 2 - 4 are not fused to the centra. The first and part of the second hypurals are attached to the first upturned vertebra. The hypurals 2 and 3 (at times partly 4) are associated with the second upturned centra. The hypurals 5 and 6 and partly 4 are associated with the last upturned centra, and hypural 7 (at times 6 also) with the urostyle. The second and third hypurals are very close and occasionally distinctly fused.

The term urostyle has been used in literature to cover a variety of structures (Gosline, 1960). I have considered the urostyle to be that cartilaginous structure which extends beyond the last centrum and terminates near the base of the longest caudal ray. In adult namaycush, chars, and trouts, bony nodules have been observed in the cartilaginous matrix of the urostyle (Pl. 11, A).

In namaycush the first uroneural is crescent shaped (Pl. 11, A); its shape is different from that in a few chars (brook and Dolly Varden chars) and rainbow trout. Also, in namaycush the expanded neural and haemal spines which are broader proximally and pointed distally, are decidedly dissimilar in shape to those of the other species examined.

The shapes of the caudal skeleton in Arctic char (Pl. 11, B) and Quebec red char (Pl. 11, C) are identical. Structurally the caudal skeletons of blueback and Sunapee chars are not appreciably different from each other or from that of Quebec red char. Waters (1960) did not evidence any structural difference in the caudal skeleton of blueback and Sunapee chars except the wider second hypural in Sunapee char. I did not see any appreciable difference in the second hypural of blueback and Sunapee chars (Pl. 11, D_1 and D_2).

In appearance the caudal fin of Dolly Varden char (Pl. 11, E) is not very different from that of Arctic char.

The first uroneural is broad (not crescent-like) in brook char (Pl. 11, F) and aurora char (Pl. 11, G). Also, the second haemal spine is broad distally in the 2 forms. These 2 characteristics separate brook and aurora chars from the other chars.

In rainbow trout the first uroneural (Pl. 11, H) is different in shape from that in namaycush and chars, and is not extended posteriorly, The third haemal spine is wider than in namaycush and chars. The first uroneural in *Hucho hucho* (Pl. 11, J) and in *Salmothymus* (Pl. 11, I) is less developed than in rainbow trout. In all the genera of Salmonidae ossified nodules on the urostyle were present in at least 50 per cent of the specimens of each species.

The number of epurals is basically 2 in namaycush and chars and 3 in the Pacific trouts. However, in a few cases in Arctic, Quebec red, blueback, and Sunapee chars the 2 epurals fuse (demarcation still distinct) and the number is reduced to 1 (Table 11).

The mean values of $\frac{W}{L_1}$ % (Table 11) for the first uroneural show that it is broadest in aurora char (53.3), followed by rainbow trout (48.5), and Arctic char (41.4). The values for namaycush and Quebec red, blueback, and Sunapee chars are quite similar. The values for brook char are different (38.9) from those for aurora char, although the shape of the first uroneural is similar in the two fishes.

The mean value of $\frac{L_3}{L_2}$ % (Table 11) is minimum for aurora char (39.4) and maximum for rainbow trout (83.2). Here again Arctic and Quebec red chars, and blueback and Sunapee chars are closely related. The value for brook char is in accordance with those of the other chars. The mean number of expanded neural spines is highest (8) in Sunapee char and lowest (5.5) in rainbow trout. The mean number of haemal spines is also highest in Sunapee char and lowest in rainbow trout (Table 11).

Waters' (1960) separation of Sunapee char from blueback char on the basis of a higher number of expanded neural and haemal spines in the Sunapee char can be contested. There is considerable overlap between them (Table 11).

The conclusions which can be drawn from the study of the caudal skeleton are: namaycush can be separated from chars and rainbow trout; Arctic and Quebec red chars, and also blueback and Sunapee chars are closely related; Dolly Varden char is somewhat similar to Arctic char; brook and aurora chars are similar; and the rainbow trout is segregated from namaycush and chars.

Morphology

Plasticity of body proportions in Salmonidae exposed to different environmental influences has been reported by many authors (Mottley, 1934; Vladykov, 1934; Taning, 1952; Seymour, 1959). Nevertheless, numerous workers have undertaken morphometric studies on this group of fishes; for example, Mottley (1934), Milne (1948), Martin (1949), Wilder (1952), Vladykov (1954), and Hartman (1956). Most of these authors have shown that generally in Salmonidae some body proportions differ between young and adults and also between adult males and females.

Body proportions expressed as percentage of the fork length. In the present study 18 body proportions are used for morphological analysis. Some of the more important ones are discussed below. The total means for particular characters for the various species were calculated (Tables 12 - 15). The means were treated by Duncan's test (Table 20) at 1 percent level of significance.

Total length (Tl). The proportion of total length in fork length indicates that fork of the tail in namaycush is deeper than that in chars and trouts. In namaycush the mean (108.2) is significantly higher than the means for other species, which range from 102.0 (brook char) to 104.6 (Arctic char). Arctic, Quebec red, blueback, and Sunapee chars are very similar. Rainbow trout is close to Dolly Varden char. No sexual dimorphism is observed for this character between males and females of a species. Our values are in accordance with those of Morton and Miller (1954), who have shown that the values in namaycush are higher and those in brook char lower than the values in Arctic and Dolly Varden chars. The latter 2 fish are closely related. However, Morton and Miller have used standard length instead of total length in their calculations. Slastenenko (1958), and Carl, Clemens, and Lindsey (1959) have mentioned the deeply forked nature of the tail. Among the foreign species Hucho hucho has the lowest value. See Tables 12 - 15 and 20.

Head length (T). In namaycush the mean for this proportion is maximum (23.5) and is significantly different from the means for other chars and trout, which range between 18.9 (Arctic char) and 21.7 (Dolly Varden char). This ratio is slightly higher in males than in females of all the species except namaycush. Our values are similar to those of Vladykov (1954) except that his value for spawning Arctic char males is much higher than that for females of Arctic char. See Tables 12 - 15 and 20.

Body length (BdL_1). The mean value (88.3) of body length for Arctic char differs significantly from those for the other chars, namaycush, and rainbow trout, in which the means range between 83.4 (namaycush) and 85.7 (aurora char). This ratio shows that the head is smaller in Arctic char from the Canadian Arctic than in other populations of S.a. oquassa. It has been suggested by Martin (1949) and Vladykov (1957) that in a species with a wide north-to-south distribution, the northerly distributed individuals have smaller heads and head parts than the southerly distributed ones. This proportion is slightly smaller in adult males than in females of all the species examined, except namaycush and blueback char. See Tables 12 - 14 and 20.

TABLE 12. Body proportions expressed as percentages of the fork length in Salmonidae. Explanation of abbreviations in this and subsequent tables on proportions, is given under the section on "Methods". In morphometric study fishes less than 130 mm in fork length were not used for statistical analysis. However, in the following tables on proportions the data on these fishes are incorporated. Also in all the tables on proportions, range, mean (in parentheses) and standard error of the mean are given. M = Male; F = Female.

Species	Locality	Sex	No.	Fork length mm	Body proportions in percentages										
					TL	T	BdL_1	aD	pDF	V-A	pc	D-ad	ma-V	P-V	ma-P
<u>C.namaycush</u>	A_1- A_5	M	53	188 - 586 (403.4)	103.7-111.6 (108.4) 0.27	20.8-25.8 (23.3) 0.18	79.5-87.3 (83.3) 0.18	43.6-52.7 (47.1) 0.25	41.2-59.0 (44.3) 0.33	15.0-20.8 (18.5) 0.17	19.5-25.0 (21.9) 0.14	17.9-23.4 (20.2) 0.16	46.5-57.6 (53.6) 0.28	28.5-34.8 (31.6) 0.22	20.7-24.8 (22.6) 0.15
		F	35	304 - 614 (469.4)	104.9-111.4 (108.1) 0.28	22.0-25.9 (23.8) 0.17	80.8-86.2 (83.5) 0.26	44.9-50.6 (47.7) 0.22	41.9-46.2 (44.2) 0.17	16.2-21.8 (19.0) 0.21	20.0-23.2 (21.8) 0.11	17.8-22.8 (20.3) 0.17	51.8-56.6 (54.3) 0.23	29.2-33.9 (31.6) 0.19	21.0-25.9 (22.9) 0.18
		M F	88	188 - 614 (429.7)	103.7-111.6 (108.2) 0.21	20.8-25.9 (23.5) 0.14	79.5-87.3 (83.4) 0.15	43.6-52.7 (47.4) 0.17	41.2-59.0 (44.3) 0.21	15.0-21.8 (18.7) 0.13	19.5-25.0 (21.9) 0.11	17.8-23.4 (20.3) 0.11	46.5-57.6 (53.8) 0.20	28.5-34.8 (31.6) 0.15	20.8-25.9 (22.7) 0.11
<u>S.a.alpinus</u>	B_1	M	7	476 - 722 (602,0)	104.7-106.6 (105.4) 0.51	17.7-20.9 (19.3) 0.41	83.7-90.9 (87.3) 0.94	42.4-47.9 (45.2) 0.73	47.7-50.4 (48.9) 0.22	21.4-26.3 (23.4) 0.64	22.3-25.5 (24.3) 0.37	21.0-25.4 (23.3) 0.54	44.8-52.9 (49.4) 1.14	28.5-32.8 (30.8) 0.52	18.1-20.9 (19.9) 0.49
		F	14	420 - 715 (536.4)	102.4-105.0 (104.3) 0.29	17.7-21.4 (18.8) 0.36	85.0-92.6 (88.7) 0.60	38.9-47.8 (43.2) 0.64	46.5-51.8 (49.2) 0.40	19.0-24.4 (22.2) 0.48	23.2-26.3 (24.6) 0.28	19.9-26.1 (23.6) 0.56	42.1-53.4 (49.6) 0.82	27.9-36.5 (31.7) 0.70	14.7-20.9 (18.8) 0.50
		M F	21	420 - 722 (558.3)	102.4-106.6 (104.6) 0.20	17.7-21.4 (18.9) 0.27	83.6-92.6 (88.2) 0.55	38.9-47.9 (43.8) 0.53	46.6-51.8 (49.1) 0.37	19.0-26.3 (22.6) 0.39	22.3-26.3 (24.5) 0.24	19.9-26.1 (23.5) 0.41	42.1-53.4 (49.6) 0.65	27.9-36.5 (31.4) 0.51	14.7-20.9 (19.2) 0.38
<u>S.a.oquassa</u> - Quebec	C_1- C_5	M	19	142 - 470 (258.8)	102.1-105.6 (103.9) 0.31	17.7-21.9 (20.6) 0.13	82.7-87.0 (84.5) 0.08	38.2-44.0 (41.1) 0.32	45.0-50.8 (47.5) 0.41	17.2-22.5 (20.2) 0.29	21.3-26.4 (25.3) 0.17)	19.4-24.0 (21.9) 0.32	44.5-52.6 (48.2) 0.46	24.9-30.1 (28.2) 0.26	18.9-24.0 (21.2) 0.27
		F	29	135 - 473 (240.1)	102.3-109.4 (104.9) 0.35	17.7-20.7 (19.5) 0.12	83.7-87.7 (85.8) 0.24	35.4-43.9 (40.9) 0.33	45.1-50.9 (48.1) 0.26	18.0-23.4 (21.6) 0.27	23.9-26.1 (25.1) 0.12	20.6-24.6 (21.9) 0.22	45.4-50.3 (47.2) 0.28	26.4-31.8 (28.5) 0.26	18.2-21.5 (19.5) 0.15
		M F	48	135 - 473 (247.5)	102.1-109.40 (104.5) 0.17	17.7-21.9 (19.9) 0.14	82.7-87.7 (85.3) 0.17	35.4-44.0 (41.0) 0.26	45.0-50.9 (47.9) 0.23	17.2-23.4 (21.0) 0.25	21.3-26.4 (25.1) 0.07	19.4-24.1 (21.9) 0.19	44.5-52.6 (47.6) 0.26	29.9-31.8 (28.4) 0.18	18.2-24.0 (20.1) 0.19

TABLE 13. Body proportions expressed as percentages of the fork length in Salmonidae.

Species	Local-ity	Sex	No.	Fork length mm	Body proportions in percentages TL	T	BdI$_1$	aD	pDF	V-A	pc	D-ad	ma-V	P-V	ma-P
S.a.oquassa-Pushineer Lake, Maine	D$_1$	M	9	136 - 296 (213.2)	101.4-105.3 (103.4) 0.37	18.2-21.3 (20.1) 0.32	84.5-86.8 (85.5) 0.17	40.2-44.4 (42.2) 0.56	46.1-49.5 (48.0) 0.29	19.7-22.0 (20.6) 0.28	23.8-26.1 (24.9) 0.35	21.6-24.8 (23.3) 0.42	47.8-49.3 (48.9) 0.20	29.0-32.2 (30.7) 0.82	18.43-20.5 (19.6) 0.27
		F	16	158 - 239 (212.0)	101.0-104.3 (102.8) 0.33	18.4-20.5 (19.4) 0.15	82.2-87.5 (85.1) 0.19	40.1-45.1 (42.1) 0.33	47.3-49.7 (48.5) 0.05	19.4-23.0 (21.4) 0.29	23.0-26.0 (24.6) 0.24	22.6-26.2 (24.1) 0.25	45.7-50.7 (48.4) 0.34	28.5-34.8 (31.1) 0.44	17.9-24.6 (19.3) 0.40
		M F	25	136 - 296 (212.4)	101.0-105.3 (103.1) 0.15	18.2-21.3 (19.6) 0.20	82.2-87.5 (85.2) 0.28	40.1-45.1 (42.1) 0.29	46.1-49.7 (48.3) 0.22	19.4-23.0 (21.1) 0.23	23.0-26.1 (24.7) 0.22	21.6-26.2 (23.8) 0.26	45.7-50.7 (48.6) 0.23	28.5-34.8 (30.9) 0.32	17.9-24.6 (19.4) 0.27
S.a.oquassa - Floods Pond, Maine	E$_1$	M	11	184 - 276 (227.3)	100.9-104.1 (103.2) 0.13	20.4-22.6 (21.6) 0.25	82.0-85.0 (83.5) 0.31	43.0-45.6 (44.1) 0.17	43.4-46.7 (45.1) 0.38	17.0-20.7 (19.2) 0.34	22.8-26.1 (24.5) 0.34	19.0-21.7 (20.2) 0.26	48.5-52.7 (50.6) 0.45	29.0-33.0 (31.1) 0.32	20.6-23.4 (21.7) 0.23
		F	12	198 - 302 (259.9)	103.3-105.6 (104.3) 0.25	20.0-21.9 (20.9) 0.23	82.6-87.0 (85.1) 0.35	43.4-44.9 (43.9) 0.10	45.7-48.0 (46.5) 0.30	17.3-21.1 (19.4) 0.35	24.2-25.8 (25.0) 0.18	20.1-22.2 (21.2) 0.17	49.1-52.3 (50.3) 0.25	28.4-33.3 (31.3) 0.42	19.7-22.3 (21.0) 0.26
		M F	23	184 - 302 (244.3)	100.9-105.6 (103.8) 0.11	20.0-22.6 (21.3) 0.16	82.0-87.0 (84.3) 0.29	43.0-45.6 (44.0) 0.09	43.4-48.0 (45.8) 0.25	17.0-21.1 (19.3) 0.24	22.8-26.1 (24.8) 0.14	19.0-22.2 (20.7) 0.20	48.5-52.7 (50.4) 0.19	28.4-33.3 (31.2) 0.28	19.7-23.4 (21.4) 0.19
S.malma[1]	F$_1$- F$_4$	M	22	92 - 663 (197.2)	101.8-104.7 (103.3) 0.16	20.4-23.7 (22.4) 0.19	79.2-85.5 (83.5) 0.33	39.9-48.2 (43.3) 0.55	45.9-49.5 (47.5) 0.24	16.3-21.8 (19.8) 0.26	23.7-26.6 (25.2) 0.18	18.4-23.3 (20.5) 0.27	42.2-53.0 (48.2) 0.56	21.2-30.5 (27.8) 0.42	18.6-23.1 (20.7) 0.26
		F	29	84 - 487 (166.9)	101.2-105.5 (103.4) 0.25	18.4-23.4 (21.3) 0.24	82.7-86.2 (84.1) 0.12	39.3-46.2 (41.8) 0.32	46.3-50.0 (48.4) 0.18	17.8-23.6 (20.7) 0.22	23.5-27.3 (25.5) 0.16	18.7-22.8 (20.8) 0.24	43.7-51.9 (46.9) 0.39	25.2-30.6 (28.2) 0.22	16.9-22.4 (19.6) 0.24
		M F	51	84 - 663 (180.0)	101.2-105.5 (103.4) 0.10	18.4-23.7 (21.7) 0.18	79.2-86.2 (83.8) 0.22	39.3-48.2 (42.4) 0.30	45.9-50.0 (48.1) 0.13	16.3-23.6 (20.3) 0.17	23.5-27.3 (20.7) 0.17	18.4-23.3 (20.7) 0.17	42.2-53.0 (47.1) 0.34	21.2-30.6 (28.0) 0.24	16.9-23.1 (20.3) 0.18

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[1] In this and Table 17, 29 specimens of S.malma were used for statistical analysis.

TABLE 14. Body proportions expressed as percentages of the fork length in Salmonidae.

Species	Locality	Sex	No.	Fork length mm	Body proportions in percentages										
					TL	T	BdL_1	aD	pDF	V-A	pc	D-ad	ma-V	P-V	ma-P
<u>S.f.fontinalis</u>	G_1 - G_4	M	12	150.0-392.0 (257.1)	100.3-105.1 (102.4) 0.37	20.0-22.3 (20.9) 0.22	81.7-87.2 (84.8) 2.38	41.1-43.7 (42.1) 0.29	47.1-51.9 (48.9) 0.38	20.0-22.5 (21.1) 0.26	24.7-27.8 (26.2) 0.34	20.7-24.5 (22.5) 0.36	44.6-51.0 (46.9) 0.56	26.4-32.0 (28.6) 0.43	19.6-22.3 (20.1) 0.32
		F	15	181.0-432.0 (260.5)	100.2-102.7 (101.6) 0.19	18.7-21.7 (20.4) 0.22	81.3-87.8 (85.1) 0.40	38.8-44.6 (41.3) 0.45	44.7-50.3 (48.4) 0.44)	19.5-24.5 (21.2) 0.36	20.9-25.1 (25.9) 1.32	20.5-25.1 (23.5) 1.31	45.2-49.3 (47.1) 0.34	27.8-31.2 (28.8) 0.26	17.6-21.2 (19.6) 0.34
		M F	27	150.0-432.0 (259.0)	100.2-105.1 (102.0) 0.28	18.7-22.3 (20.6) 0.17	81.7-87.8 (85.0) 0.19	38.8-44.6 (41.7) 0.27	44.7-51.9 (48.6) 0.30	19.5-24.5 (21.1) 0.21	20.9-27.8 (26.0) 0.26	20.5-25.1 (23.1) 0.72	44.6-51.0 (47.0) 0.26	26.4-32.1 (28.7) 0.24	17.6-22.3 (19.8) 0.23
<u>S.f.timagamiensis</u>	H_1 - H_3	M	9	165.0-418.0 (285.9)	102.7-104.6 (103.7) 0.43	20.0-23.4 (21.6) 0.33	82.7-86.8 (84.5) 0.45	42.4-45.0 (44.1) 0.28	45.5-48.1 (47.0) 0.45	16.6-19.5 (18.5) 0.30	24.6-26.9 (26.0) 0.23	18.5-21.1 (19.7) 0.27	47.8-51.9 (49.9) 0.40	28.4-31.1 (29.7) 0.36	18.4-22.1 (20.8) 0.42
		F	11	146.0-390.0 (304.1)	102.2-103.9 (103.3) 0.30	19.7-21.3 (20.5) 0.21	84.0-87.7 (86.7) 0.45	42.1-43.6 (42.9) 0.33	47.4-49.8 (48.6) 0.21	17.5-20.5 (18.8) 0.27	26.1-28.0 (26.7) 0.24	19.2-22.5 (21.0) 0.31	47.2-50.1 (48.9) 0.32	29.4-31.4 (30.6) 0.09	19.7-20.6 (19.8) 0.18
		M F	20	146.0-418.0 (295.9)	102.2-104.6 (103.5) 0.23	19.7-23.4 (21.0) 0.20	82.7-87.7 (85.7) 0.40	42.1-45.0 (43.5) 0.24	45.5-49.8 (47.9) 0.29	16.6-20.5 (18.7) 0.18	24.6-28.0 (26.4) 0.14	18.5-22.5 (20.4) 0.27	42.2-51.9 (49.3) 0.24	28.4-31.4 (30.2) 0.25	18.4-22.1 (20.3) 0.21
<u>Salmo gairdnerii</u>[1]	I_1 - I_3	M	22	110.0-835.0 (354.6)	100.7-104.8 (102.5) 0.20	19.2-24.0 (21.0) 0.21	82.3-87.6 (84.8) 0.33	41.7-46.3 (44.1) 0.24	44.0-48.6 (45.6) 0.22	17.4-25.1 (20.8) 0.40	23.0-26.3 (24.8) 0.17	15.8-19.6 (17.8) 0.23	45.4-54.1 (48.3) 0.36	17.8-22.9 (19.6) 0.30	27.2-33.1 (29.5) 0.36
		F	23	91.0-811.0 (344.2)	101.1-106.3 (103.1) 0.21	17.3-22.1 (19.6) 0.29	82.3-89.8 (85.7) 0.51	40.5-48.1 (43.5) 0.41	42.7-49.6 (46.2) 0.37	18.5-23.3 (21.0) 0.30	20.4-26.6 (25.0) 0.29	14.2- 21.9 (18.5) 0.36	42.2-50.3 (46.5) 0.43	16.3-20.9 (18.6) 0.27	25.8-32.4 (28.7) 0.35
		M F	45	91.0-835.0 (349.3)	100.7-106.3 (102.8) 0.22	17.3-24.0 (20.3) 0.21	82.3-89.8 (85.3) 0.31	40.5-48.1 (43.7) 0.25	42.7-49.6 (45.9) 0.22	17.4-25.1 (20.9) 0.23	20.4-26.6 (24.9) 0.16	14.2-21.9 (18.2) 0.22	42.2-54.1 (47.4) 0.31	16.3-22.9 (19.1) 0.21	25.8-33.1 (29.1) 0.26

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[1] Only 36 specimens of <u>Salmo gairdnerii</u> were used for statistical analysis. This remark also refers to Table 18.

TABLE 15. Body proportions expressed as percentages of the fork length in Salmonidae.[1]

Species	Locality	Sex	No.	Fork length mm	Body proportions in percentages										
					TL	T	BdL_1	aD	pDF	V-A	pc	D-ad	ma-V	P-V	ma-P
<u>Salmothymus ohridanus</u>	J_1	M	1	154.0	105.8	22.4	83.1	43.5	46.8	18.3	23.1	20.8	50.7	31.2	20.0
		F	1	250.0	106.4	20.6	86.0	44.5	49.6	18.4	23.2	24.6	50.4	32.4	18.2
		M F	2	154.0-250.0 (202.0)	105.8-106.4 (106.1) 0.83	20.6-22.4 (21.5) 0.92	83.1-86.0 (84.6) 1.44	43.5-44.5 (43.9) 0.82	46.8-49.6 (48.2) 1.58	18.3-18.4 (18.4) 0.01	23.1-23.2 (23.1) 0.09	20.8-24.6 (22.7) 2.02	50.4-50.7 (50.5) 0.72	31.2-32.4 (31.8) 0.77	18.2-20.2 (19.1) 0.90
<u>H.hucho</u>[2]	$K_1 - K_4$	M F	5	87.0-528.0 (289.2)	103.6-105.7 (104.8) 0.41	23.4-28.2 (25.2) 0.89	78.0-83.9 (81.3) 1.17	45.1-47.7 (46.3) 0.47	43.2-45.1 (44.3) 0.24	16.3-19.6 (18.2) 1.31	19.3-20.7 (19.9) 0.22	16.1-20.5 (18.7) 0.90	53.9-57.7 (55.5) 0.58	30.7-36.4 (33.3) 0.99	21.4-24.4 (22.9) 0.60
<u>H.perryi</u>[2]	$K_5 - K_7$	M F	7	226.0-430.0 (283.8)	104.7-108.3 (105.6) 0.56	23.3-24.3 (23.6) 0.03	82.7-86.1 (84.3) 0.48	43.8-46.9 (45.7) 0.39	44.0-45.6 (44.9) 0.34	20.0-21.6 (20.6) 0.23	20.0-22.2 (21.0) 0.34	18.9-21.2 (19.9) 0.24	51.3-56.1 (53.5) 0.48	29.7-34.2 (31.7) 0.54	21.9-23.7 (23.1) 0.27
<u>B.lenok</u>[2]	$L_1 - L_3$	M F	6	122.0-372.0 (245.3)	104.9-108.9 (106.5) 0.69	25.5-30.3 (27.4) 1.67	81.2-86.6 (84.6) 0.78	42.6-46.6 (44.4) 0.74	45.9-48.5 (47.2) 0.49	18.4-22.9 (20.5) 0.67	20.7-22.5 (22.0) 0.30	16.4-20.7 (19.2) 0.68	48.7-51.1 (49.5) 0.49	26.7-32.5 (29.8) 0.57	17.7-21.1 (19.9) 0.47

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[1] Fishes of the genera <u>Salmothymus</u>, <u>Hucho</u>, and <u>Brachymystax</u>, were not used for statistical analysis. This remark also refers to Table 19.
[2] Most of the borrowed specimens were not dissected; therefore, the males and females were not separated. This remark also refers to Table 19.

Predorsal fin length (aD). This distance is longest in namaycush. The mean for the ratio (47.4) is significantly different from the means of chars and rainbow trout, which range from 41 (Quebec red char) to 44 (Sunapee char). Tables 12 - 15, and 20. Morton and Miller (1954), and Slastenenko (1958) have also shown that aD is longer in namaycush than in Arctic, Dolly Varden and brook chars. The values in Dolly Varden and brook chars overlap. Our findings are similar to those of Vladykov (1954), except for his value of spawning males of Arctic char. The males of Arctic char in our samples were not spawning. The proportion is slightly higher in males than in females of all the species except namaycush. Tables 12 - 15, and 20.

Distance from the insertion of the dorsal fin to the fork of the tail (pDF). This proportion segregates namaycush, with a minimum mean of 44.3, from all the chars and trout studied, in which the means range between 45.9 (Sunapee char) and 49.1 (Arctic char). Sunapee char and rainbow trout form a separate group. No differences are observed in males and females of a species. Also there is considerable overlapping among the various species of chars. See Tables 12 - 15 and 20.

Distance from the origin of the ventral fin to the origin of the anal fin (V-A). The mean for this proportion in Arctic char is maximum (22.6) and is significantly different from those in all chars, namaycush, and rainbow trout, in which the mean values range from 18.7 (aurora char) to 21.6 (rainbow trout). Namaycush, Sunapee char, and aurora char form one group. No sexual dimorphism is observed in the various species. See Tables 12 - 15 and 20.

Distance from the insertion of the anal to the fork of the tail (pc). In namaycush the mean for this proportion is minimum (21.9) and is significantly different from those of chars, in which the means range from 24.5 (Arctic char) to 26.4 (aurora char). This value reveals that the tail in namaycush is deeply forked. No differences were observed in males and females of the various species. Tables 12 - 15 and 20.

Distance from the insertion of the dorsal to the origin of the adipose (D-ad). The mean for this proportion is minimum (18.2) in rainbow trout and is significantly different from those of the other fishes. The means for namaycush and chars range between 20.3 (namaycush) and 23.8 (blueback char). Blueback, Arctic, and brook chars form a separate group. No sexual dimorphism is seen for this character. See Tables 12 - 15 and 20.

Distance from the anterior tip of the lower jaw to the origin of the ventral fin (ma-V). In namaycush the mean for this proportion is maximum (53.8) and is significantly different from those of chars and trout. Quebec red, Dolly Varden, and brook chars and rainbow trout, with their respective means of 47.6, 47.1, 47.0, and 47.4 form a group. The means for the remaining chars range from 48.6 (blueback char) to 50.4 (Sunapee char). The proportional values are slightly higher in males than in females of all Salmonidae examined except namaycush. However, these differences were not significant. Our values are in accordance with those of Vladykov (1954). See Tables 12 - 15 and 20.

Distance from the origin of the pectoral to the origin of the ventral fins (P-V). No significant differences are noticed for this proportion between the species. The mean is maximum (31.6) in namaycush and minimum (28.0) in Dolly Varden char. Usually the values are slightly higher in females than in males. See Tables 12 - 15.

Distance from anterior tip of the lower jaw to the origin of the pectoral fin (ma-P). The mean of this proportion for namaycush and Sunapee char are 22.7 and 21.4, respectively. These 2 values are significantly different from each other and from those of other chars and trout, which are lower and range from 19.2 (rainbow trout) to 20.3 (aurora char). In all species except namaycush this proportional value is slightly higher in males than in females. See Tables 12 - 15, and 20.

Head parts expressed as percentages of the head length and the post-orbital distance. These proportions are interesting to watch in spawning males and females.

Interorbital space (I). In namaycush the mean is minimum (29.4) for this proportion and is significantly different from those of chars and rainbow trout, in which the means range from 32.2 (brook char) to 35.9 (rainbow trout). Kendall (1919) and Vladykov (1954) have already pointed out that the interorbital space in namaycush is narrower than in Salvelinus and Salmo. Tables 16 - 19 and 20.

Length of the snout (ML). The means for this proportion are minimum (22.2) in blueback char and maximum (28.6) in aurora char. The means overlap in chars and trout. In adult males (more so, if mature) of Salmonidae the snout is somewhat longer than that in the females. See Tables 16 - 19.

TABLE 16. Selected parts of head expressed as percentages of the head length and postorbital distance in Salmonidae. The specimens listed in this Table are identical to those of Table 12.

Species	Locality	Sex	No.	I	ML	Head length		Postorbital distance	
						Mx	ma	I	ML
C. namaycush	A_1- A_5	M	53	25.0-35.1 (29.6) 0.32	22.4-30.7 (27.2) 0.24	50.4-66.6 (57.1) 0.39	60.8-73.7 (68.3) 0.44	47.2-65.8 (54.8) 0.59	39.3-58.2 (50.7) 0.50
		F	35	25.6-33.3 (29.1) 0.36	24.5-31.4 (26.9) 0.27	52.0-62.0 (56.0) 0.38	60.9-74.6 (67.8) 0.50	45.6-62.2 (53.8) 0.73	45.3-56.2 (49.6) 0.44
		M F	88	24.8-35.0 (29.4) 0.24	22.4-31.4 (27.1) 0.17	50.4-66.6 (56.6) 0.28	60.8-74.6 (68.1) 0.33	45.6-65.8 (54.4) 0.45	39.3-58.2 (50.3) 0.35
S. a. alpinus	B_1	M	7	32.3-37.4 (34.8) 0.71	20.9-31.5 (26.1) 1.37	47.6-58.7 (52.8) 2.06	64.6-75.5 (69.5) 1.59	58.8-70.4 (64.3) 1.38	38.2-63.4 (48.4) 3.13
		F	14	29.1-38.5 (34.9) 0.50	20.3-28.6 (24.8) 0.72	45.6-58.9 (51.9) 1.01	60.1-73.2 (66.5) 1.02	52.3-72.3 (63.6) 1.36	36.4-51.1 (44.9) 1.47
		M F	21	29.1-38.5 (34.9) 0.26	20.3-31.5 (25.2) 0.65	45.6-58.9 (52.2) 0.81	60.1-75.5 (67.5) 0.92	52.3-72.3 (63.8) 1.02	36.4-63.4 (46.0) 1.43
S. a. oquassa - Quebec	C_1- C_5	M	19	28.9-37.7 (33.0) 0.52	20.3-30.1 (24.7) 0.66	48.6-52.6 (50.9) 0.88	58.1-74.8 (66.2) 0.83	56.3-70.2 (64.1) 0.91	40.0-58.5 (47.8) 1.25
		F	29	30.3-37.3 (33.5) 0.35	18.2-29.0 (24.0) 0.41	42.9-55.9 (48.8) 0.55	54.3-68.9 (62.4) 0.38	55.9-68.9 (63.8) 0.76	37.5-51.2 (45.6) 0.68
		M F	48	28.9-37.7 (33.3) 0.29	18.2-30.1 (24.3) 0.35	42.9-55.9 (50.1) 0.70	54.3-74.8 (63.9) 0.46	55.8-70.3 (63.8) 0.57	37.5-58.5 (46.5) 0.63

TABLE 17. Selected parts of head expressed as percentages of the head length and postorbital distance in Salmonidae. The specimens listed in this Table are identical to those of Table 13.

Species	Locality	Sex	No.	I	ML	Head length		Postorbital distance	
						Mx	ma	I	ML
S. a. oquassa - Pushineer Lake, Maine	D_1	M	9	26.7-35.0 (32.7) 0.82	19.6-26.9 (22.6) 0.71	46.3-55.5 (51.8) 0.97	57.1-69.8 (64.6) 1.22	53.5-68.2 (63.7) 1.52	39.2-46.7 (44.0) 1.77
		F	16	28.2-37.8 (33.2) 0.57	19.0-25.0 (21.9) 0.45	46.1-57.4 (49.6) 0.68	58.0-69.1 (63.6) 0.70	53.7-70.4 (64.5) 1.16	36.3-51.1 (42.6) 0.97
		M F	25	26.7-37.8 (33.0) 0.46	19.0-26.9 (22.2) 0.38	46.1-57.4 (50.4) 0.62	57.1-69.8 (64.1) 0.61	53.5-70.4 (64.2) 0.90	36.3-51.1 (43.1) 0.74
S. a. oquassa - Floods Pond, Maine	E_1	M	11	31.2-34.7 (33.0) 0.28	21.4-27.0 (24.5) 0.54	50.0-57.6 (53.9) 0.65	60.9-67.3 (65.0) 0.63	61.2-66.6 (63.2) 0.60	40.0-53.8 (47.0) 1.31
		F	12	30.7-35.9 (33.8) 0.53	21.2-26.9 (24.2) 0.50	48.1-54.7 (52.1) 0.49	61.6-68.4 (64.6) 0.61	58.0-69.4 (64.4) 1.15	40.0-53.1 (46.2) 1.21
		M F	23	30.7-35.9 (33.4) 0.32	21.2-27.0 (24.4) 0.34	48.1-57.6 (52.9) 0.44	60.9-68.4 (64.8) 0.44	58.0-69.4 (63.9) 0.64	40.0-53.8 (46.6) 0.88
S. malma	F_1 - F_4	M	22	28.0-38.2 (34.6) 0.62	19.1-33.1 (25.1) 0.77	46.0-63.0 (51.8) 0.85	58.0-75.1 (62.6) 0.84	53.8-73.9 (63.3) 1.35	38.1-59.7 (48.7) 1.38
		F	29	26.7-40.6 (33.6) 0.49	19.6-30.9 (24.8) 0.44	47.0-57.2 (50.9) 0.44	54.5-70.1 (61.7) 0.54	51.7-75.0 (64.8) 0.96	38.4-55.5 (48.0) 0.83
		M F	51	26.7-40.6 (33.1) 0.38	19.1-33.1 (25.0) 0.40	46.0-63.0 (51.3) 0.44	54.5-75.1 (62.1) 0.49	51.7-75.0 (64.1) 0.80	38.6-59.7 (48.3) 0.74

TABLE 18. Selected parts of head expressed as percentages of the head length and postorbital distance in Salmonidae. The specimens listed in this Table are identical to those of Table 14.

Species	Locality	Sex	No.	Head length				Postorbital distance	
				I	ML	Mx	ma	I	ML
<u>S.f.</u> <u>fontinalis</u>	$G_1 - G_4$	M	12	26.8-35.1 (31.3) 0.72	20.5-27.5 (23.8) 0.67	53.9-66.0 (59.7) 0.75	62.1-76.0 (70.0) 1.28	59.1-71.4 (60.5) 1.30	37.7-54.1 (45.7) 1.47
		F	15	28.3-36.3 (32.9) 0.73	20.2-29.5 (24.1) 0.74	55.0-64.7 (58.3) 0.60	65.0-75.6 (69.8) 0.95	53.0-76.1 (61.1) 1.79	36.3-56.5 (44.8) 1.56
		M F	27	26.8-36.3 (32.2) 0.51	20.2-29.5 (24.0) 0.48	53.9-66.0 (59.1) 0.68	62.1-76.0 (69.9) 0.75	59.0-76.1 (60.8) 1.25	36.3-56.5 (45.2) 1.04
<u>S.f.</u> <u>timagamiensis</u>	$H_1 - H_3$	M	9	34.1-38.1 (36.1) 0.48	27.6-32.4 (30.3) 0.49	57.5-68.9 (64.8) 0.57	71.6-81.6 (76.7) 1.03	64.7-76.6 (69.6) 1.34	52.1-66.7 (58.5) 1.62
		F	11	33.3-38.9 (36.2) 0.54	23.3-30.5 (27.3) 1.79	57.8-68.0 (61.4) 0.87	66.6-77.7 (72.5) 2.25	58.1-81.2 (69.4) 2.18	44.1-68.7 (52.1) 1.82
		M F	20	33.3-38.9 (36.2) 0.43	23.3-32.4 (28.6) 0.52	57.5-68.9 (62.9) 1.01	66.6-81.6 (74.4) 1.36	58.1-81.2 (69.5) 1.31	44.1-68.7 (54.9) 1.43
<u>Salmo</u> <u>gairdnerii</u>	$I_1 - I_3$	M	22	29.1-39.8 (35.3) 0.62	19.3-37.2 (27.3) 1.25	46.7-66.6 (55.5) 1.35	58.0-76.8 (65.5) 1.33	62.5-90.5 (73.5) 1.55	37.5-89.1 (56.9) 2.81
		F	23	30.6-41.6 (36.5) 0.68	20.0-30.6 (25.4) 0.64	48.0-57.6 (52.4) 0.57	57.5-68.1 (62.0) 0.61	63.1-84.6 (73.7) 1.15	40.0-61.6 (51.3) 1.11
		M F	45	29.1-41.6 (35.9) 0.45	19.3-37.3 (26.3) 0.70	46.7-66.6 (53.9) 0.76	57.5-76.8 (63.7) 0.76	62.5-90.5 (73.6) 0.94	37.5-89.1 (54.0) 1.53

TABLE 19. Selected parts of head expressed as percentages of the head length and postorbital distance in Salmonidae. The specimens listed in this Table are identical to those of Table 15.

Species	Locality	Sex	No.	Head length				Postorbital distance	
				I'	[illegible]	Mx	ma	I	ML
Salmothymus ohridanus	J_1	M	1	26,1	23.2	37.9	51.6	53.6	47.6
		F	1	29.2	21.4	37.4	54.5	59.5	43.7
		M F	2	26,1-29,2 (27.6) 1.78	21.4-23.2 (22.3) 1.02	37,4-37.9 (37.7) 0.30	51,6-54.5 (53.0) 1.44	53.6-59.5 (56.5) 3.02	43.7-47.6 (45.6) 2.10
H. hucho	K_1 - K_4	M F	5	26.1-29,0 (26.9) 0.55	26.6-[illegible].2 (26.4) 0.42	47.3-50.2 (47.3) 1.03	59.1-63.7 (61.2) 0.69	47.1-50.9 (49.1) 0.64	45.7-50.9 (48.2) 0.94
H. perryi	K_5 - K_7	M F	7	28.2-34.2 (31.3) 0.72	26.3-29.8 (27.6) 0.50	48.4-51.4 (49.9) 0.36	63.3-65.2 (63.3) 0.78	51.6-60.6 (56.1) 0.64	47.9-55.9 (50.9) 0.97
B. lenok	L_1 - L_3	M F	6	25.5-30.3 (27.4) 1.67	27.6-31.1 (28.9) 0.58	36.7-44.2 (40.1) 1.34	47.5-52.9 (49.5) 0.94	53.3-60.0 (57.2) 1.07	56.7-66.0 (60.5) 1.35

Length of the upper jaw (Mx). The upper jaw is longest in aurora char (mean 62.9). The means for the other species range from 50.1 (Quebec red char) to 59.1 (brook char). In males of all the species, especially in mature males, the upper jaw is longer than in females. Henn and Rinkenbach (1925) pointed out that the maxilla is extremely long in aurora char as compared to those in other chars. Vladykov (1954) showed that the maxilla is longest in brook char. See Tables 16 - 19 and 20.

Length of the lower jaw (ma). The lower jaw is longest (mean 74.4) in aurora char and is significantly different from those of namaycush, rainbow trout, and other chars. In the remaining species the means range from 62.1 (Dolly Varden char) to 69.9 (brook char). In all the species the upper jaw is slightly longer in males than in females. See Tables 16 - 19 and 20.

Head length (T) as a proportion of body length (BdL_2). The mean value for the proportion is minimum (22.2) in Arctic char and maximum (27.8) in namaycush. The two values are significantly different from each other and from those of the other species. Quebec red char, blueback char, and rainbow trout form another group. Brook, aurora, Sunapee, and Dolly Varden chars also form a separate group. This value is higher for adult males than for females in all species except namaycush. See Table 20.for various groupings.

Interorbital space (I) as a proportion of the postorbital distance (O-p). The mean is minimum (54.4) in namaycush and maximum (73.6) in rainbow trout. The mean for aurora char is 69.5. These 3 fishes are signi-

TABLE 20. Separation of the namaycush, various chars, and rainbow trout into groups based on the morphologic characters. Samples treated by the Duncan's multiple F range test (at 1%) for the means as modified by Kramer. Numerals used for scientific names: 1. *C.namaycush*; 2. *S.a.alpinus*; 3. *S.a.oquassa* - Quebec; 4. *S.a.oquassa* - Pushineer Lake, Maine; 5. *S.a.oquassa* - Floods Pond, Maine; 6. *S.malma*; 7. *S.f.fontinalis*; 8. *S.f.timagamiensis*; 9. *Salmo gairdnerii*.

Characters	One species(sub-species) grouping	Three species(sub-species) grouping	Two or more species (sub-species)grouping with rainbow trout	Four or more species (sub-species)grouping
$\frac{TL}{FL}$	1			
$\frac{BdL_1}{FL}$	2			
$\frac{aD}{FL}$	1			
$\frac{pDF}{FL}$	1		5 9	
$\frac{V-A}{FL}$	2	1 5 8		
$\frac{pc}{FL}$	1			
$\frac{D-ad}{FL}$	9	2 4 7		
$\frac{ma-V}{FL}$	1		3 6 7 9	
$\frac{T}{FL}$	1			
$\frac{ma-P}{FL}$	1 5			
$\frac{I}{T}$	1			
$\frac{Mx}{T}$	8			
$\frac{ma}{T}$	8			
$\frac{aD}{pDF}$	1			
$\frac{T}{BdL_2}$	1 2		3 4 9	5 6 7 8
$\frac{I}{O-p}$	1 8 9			
$\frac{ML}{O-p}$				2 3 4 5 7

ficantly different from each other and from other species considered. The means for the remaining chars range between 60.8 (brook char) and 64.1 (Dolly Varden char). See Tables 16 - 19 and 20.

Length of the snout (ML) as a proportion of the postorbital distance O-p). This proportional value puts all chars except Dolly Varden and aurora chars into 1 group, and segregates them from namaycush and rainbow trout. The means are 43.1, 45.3, 46.0, 46.5, and 46.6 for blueback, brook, Arctic, Quebec red, and Sunapee chars, respectively. Usually this value is slightly higher for males than for females of a species. Vladykov (1954) showed that this value is a little higher in males than in females of *Salvelinus*. See Tables 16 - 19 and 20.

Many proportions were treated by Duncan's (1955) new multiple range test. Namaycush is found to be significantly different from all chars and trout in 11 characters, as for example, $\frac{TL}{FL}$, $\frac{BdL_1}{FL}$, $\frac{aD}{FL}$, etc. (Table 20). In namaycush the means for these characters are either extremely high or extremely low. Also, in some other ratios, such as $\frac{V-A}{FL}$, $\frac{P-V}{FL}$, etc. the means are not significantly different but still have the extreme values. Only in one proportion, $\frac{V-A}{FL}$, has namaycush stood with the chars. This data leads to the conclusion that *Cristivomer* differs in many characters and can be separated from other Salmonoid genera.

In Arctic char the values $\frac{BdL_1}{FL}$ and $\frac{V-A}{FL}$ are extremely high and $\frac{T}{BdL_2}$ is low and suggest that Arctic char should be separated from the other chars.

Quebec red and blueback chars do not separate themselves into groups in any of the characters. In Sunapee char the mean value of only 1 character, $\frac{ma\text{-}P}{FL}$ is 21.4, and significantly different from the means in other chars and trout. In most other morphological features, Quebec red, blueback, and Sunapee chars have similar proportional values. The mean values for the different proportions of the 3 populations of *S.a. oquassa* are close to those of Arctic char.

In aurora char the mean values for $\frac{Mx}{T}$, $\frac{ma}{T}$, and $\frac{I}{O\text{-}p}$ are higher than and significantly different from those in other chars. The above values in brook char are very similar to those in aurora char. These 2 forms form a single species group and are considered as *S.f. fontinalis* and *S.f. timagamiensis*.

Morphologically Dolly Varden char is not separated into a group by itself but has associated with Quebec red, brook, and Sunapee chars and rainbow trout. Recently, Dolly Varden char has been recognized as a distinct species because of skeletal and meristic characters (McPhail, 1961).

In rainbow trout the mean values of $\frac{D\text{-}ad}{FL}$ and $\frac{I}{O\text{-}p}$ are lowest and highest, respectively, and are significantly different from those in other chars and namaycush. In a few other values, $\frac{pDF}{FL}$, $\frac{ma\text{-}v}{FL}$, and $\frac{T}{Bd\text{-}L_2}$, rainbow trout groups with the species or subspecies of *Salvelinus* (Table 20) and not with *Cristivomer*. *Salmo* has been universally recognized as a distinct genus on the basis of skeletal characters.

Meristic Characters

Many authors, especially Mottley (1934), Taning (1952), Wilder (1952), and Seymour (1959), have demonstrated the variability of meristic characters under different environmental conditions. Nevertheless, usage of these characters with prudence can still be helpful in taxonomic studies. More than 20 characters are considered here. Only some of these are discussed in detail.

Number of vertebrae. The total number of vertebrae, and number of trunk vertebrae, precaudal, and caudal vertebrae were counted.

Total number of vertebrae is an index commonly used in taxonomic study. Table 21 shows that among chars, brook char have the minimum mean number of vertebrae (59.5) and Arctic char the maximum (67.4).

Andrews and Lear (1956) furnished data on total vertebrae counts on Arctic char from northern Labrador. Their mean and range of vertebrae counts were about 66 and 63 - 68, respectively. Our values are similar. McPhail's (1961) data for vertebral counts from various areas showed a great deal of variability. His lowest and highest means for Arctic char were 66 and 69, respectively, and for Dolly Varden char, 63 and 68. Our values for different Salmonidae are about the same as those of Rounsefell (1962) who has presented data from various sources.

The data analysed by Duncan's (1955) test of significance show that Arctic, brook, and aurora chars are separated from all the other species.

The coefficient of difference (C.D.) values show that Arctic char can be segregated from Quebec red char.

TABLE 21. Total number of vertebrae in several salmonoid fishes. In this and subsequent tables on meristic characters the localities of the samples and the fork length and number of fish in each species are the same. The symbols $\bar{X}$, Me, Mo, s, $s_{\bar{x}}$ and V are used for the arithmetic mean, median, mode, standard deviation, standard error of the mean, and coefficient of variation, respectively.

Species	Locality	No. of fish	Fork length mm	Total vertebrae																		
				55	58	59	60	61	62	63	64	65	66	67	68	69	$\bar{X}$	Me	Mo	s	$s_{\bar{x}}$	V
Cristivomer namaycush	$A_2 - A_5$	58	276 - 614 (468.9)	-	-	-	-	1	3	8	23	18	5	-	-	-	64.2	64.0	63.6	1.07	0.14	1.66
Salvelinus alpinus alpinus	B_1	20	446 - 722 (566.7)	-	-	-	-	-	-	-	-	-	2	10	7	1	67.4	67.0	66.3	0.74	0.17	1.10
Salvelinus alpinus oquassa - Quebec[1]	C_3, C_4	18	135 - 473 (237.3)	-	-	-	-	-	2	3	6	4	1	1	-	-	64.1	64.0	63.7	1.31	0.33	2.05
Salvelinus alpinus oquassa - Pushineer Lake, Maine [2]	D_1	23	136 - 245 (210.0)	-	-	-	1	-	1	1	7	6	-	-	-	-	64.5	65.0	65.9	1.44	0.31	2.23
Salvelinus alpinus oquassa- Floods Pond, Maine [3]	E_1	20	184 - 282 (241.1)	-	-	-	-	2	1	2	11	4	-	-	-	-	63.7	64.0	64.6	1.84	0.27	1.84
Salvelinus malma	F_3, F_4	17	136 - 663 (203.8)	-	-	-	-	-	-	1	7	6	3	-	-	-	64.7	65.0	65.7	1.09	0.27	1.68
Salvelinus fontinalis fontinalis	G_1, G_2, G_4	24	150 - 419 (244.6)	-	4	8	9	3	-	-	-	-	-	-	-	-	59.5	59.5	59.5	0.93	0.19	1.56
Salvelinus fontinalis timagamiensis	$H_1 - H_3$	15	146 - 418 (281.2)	-	-	-	8	7	-	-	-	-	-	-	-	-	60.5	60.0	59.1	0.51	0.14	0.85
Salmo gairdnerii	I_1, I_2	16	110 - 775 (388.9)	-	-	-	-	-	3	3	7	3	-	-	-	-	63.6	64.0	64.7	1.02	0.26	1.60
Salmothymus ohridanus	J_1	2	154 - 250 (202.0)	2	-	-	-	-	-	-	-	-	-	-	-	-	55.0	55.0	55.0	0	0	0
Hucho hucho	$K_1 - K_4$	4	87 - 378 (229.5)	-	-	-	-	-	-	-	-	1	1	-	2	-	66.8	67.5	67.5	1.97	0.9	2.95
Hucho perryi	$K_5 - K_7$	7	226 - 430) (283.9)	-	6	-	-	1	-	-	-	-	-	-	-	-	58.4	58.0	57.1	0.54	0.21	0.93
Brachymystax lenok	$L_1 - L_3$	5	122 - 372 (232.4)	-	-	3	1	1	-	-	-	-	-	-	-	-	59.6	59.0	59.8	0.89	0.42	1.52

[1] Common name for Salvelinus alpinus oquassa population from Quebec, is Quebec red char.

[2] Common name for Salvelinus alpinus oquassa population from Pushineer Lake, Maine, is blueback char.

[3] Common name for Salvelinus alpinus oquassa population from Floods Pond, Maine, is Sunapee char.

Among foreign genera, Salmothymus has the minimum (mean 55) number of vertebrae. See Tables 21, 40, and 41.

In namaycush the mean and range for the number of trunk vertebrae are 31.7 and 29-34, respectively. Arctic char has the highest mean (33.5) and range (32-35) and can be separated from Quebec red char (mean 30.4; range 28-33). Brook char (mean 27.6; range 26-29) can be separated from aurora char (mean 30; range 29-31). However, Quebec red, blueback, and Sunapee chars have no measureable differences from each other. The table showing the number of trunk vertebrae is not included.

In namaycush the mean and range for the number of precaudal vertebrae are 6 and 5-8, respectively. The highest number (mean 6.9; range 6-8) is seen in Arctic char. Quebec red, blueback, and Sunapee chars are similar. On the basis of Table 41 brook char, with the lowest values (mean 6.3; range 5-7), can be separated from aurora char (mean5; range 4-6). Our values for precaudal vertebrae checked well with those of Vladykov (1954). The table showing the number of precaudal vertebrae is not included.

The numbers of caudal vertebrae in brook, aurora, and Dolly Varden chars have about the same means (25.5-25.8). The highest mean number (28) is observed in blueback char. Our values for blueback char are in accordance with those of Waters (1960). Waters used the number of caudal vertebrae as one of the characters to separate blueback and Sunapee chars, but this character does not show any significant difference in the present study.

Quebec red and blueback chars form a group and can be segregated from all other groups because of this character. Among the foreign genera the number of caudal vertebrae is minimum (21) in Brachymystax. See Tables 22 and 40.

TABLE 22. Number of caudal vertebrae in several salmonoid fishes.

Species	Caudal vertebrae						
	Range	$\overline{X}$	Me	Mo	s	$s_{\overline{x}}$	V
C.namaycush	25 - 29	26.5	26.0	25.2	0.79	0.11	3.02
S.a.alpinus	25 - 28	27.0	27.0	27.0	0.86	0.20	3.17
S.a.oquassa - Quebec	26 - 30	27.9	28.0	28.1	1.03	0.26	3.68
S.a.oquassa - Pushineer Lake, Maine	26 - 29	28.0	28.0	27.9	0.88	0.19	3.13
S.a.oquassa - Floods Pond, Maine	26 - 28	27.0	27.0	27.0	0.65	0.15	2.40
S.malma	25 - 27	25.8	26.0	26.4	0.64	0.16	2.46
S.f.fontinalis	24 - 27	25.6	26.0	26.8	0.97	0.20	3.78
S.f.timagamiensis	25 - 26	25.5	25.0	25.6	0.52	0.14	2.02
S.gairdnerii	25 - 28	26.4	26.5	26.6	0.96	0.24	3.61
H.perryi	21 - 23	21.5	21.0	21.1	0.84	0.33	3.88
B.lenok	21 - 21	21.0	21.0	21.0	0	0	0

TABLE 23. Number of neural arches not fused with the vertebrae in the anterior and posterior caudal regions in several salmonoid fishes.

Species	Neural arches not fused						
	Range	$\bar{X}$	Me	Mo	s	$s_{\bar{x}}$	V
C.namaycush	30 - 35	31.9	32.0	32.0	1.15	0.15	3.61
S.a.alpinus	32 - 36	33.9	34.0	34.2	1.02	0.23	3.00
S.a.oquassa - Quebec	29 - 33	31.2	31.0	30.5	1.52	0.38	4.86
S.a.oquassa - Pushineer Lake, Maine	29 - 33	31.4	32.0	33.1	1.07	0.23	3.43
S.a.oquassa - Floods Pond, Maine	30 - 33	31.4	31.0	30.3	1.08	0.25	3.47
S.malma	30 - 33	31.2	31.0	30.5	0.90	0.23	2.89
S.f.fontinalis	26 - 30	29.1	29.0	30.3	1.18	0.25	4.08
S.f.timagamiensis	26 - 29	27.8	28.0	28.4	0.65	0.17	2.34
S.gairdnerii	30 - 33	31.7	32.0	32.6	0.79	0.20	2.49

TABLE 24. Number of neural arches fused with the vertebrae in several salmonoid fishes.

Species	Neural arches fused with vertebrae						
	Range	$\bar{X}$	Me	Mo	s	$s_{\bar{x}}$	V
C.namaycush	27 - 32	29.4	30.0	31.0	1.44	0.19	4.88
S.a.alpinus	27 - 33	30.9	31.0	31.2	1.48	0.34	4.79
S.a.oquassa - Quebec	28 - 32	29.8	30.0	30.2	1.36	0.13	4.56
S.a.oquassa - Pushineer Lake, Maine	27 - 32	30.2	30.0	29.6	1.20	0.27	3.98
S.a.oquassa - Floods Pond, Maine	28 - 32	29.9	30.0	30.2	1.07	0.24	3.58
S.malma	28 - 33	30.5	30.0	28.9	1.07	0.27	3.49
S.f.fontinalis	25 - 30	27.4	27.5	27.7	1.14	0.24	4.15
S.f.timagamiensis	28 - 32	30.3	30.0	28.7	1.27	0.34	4.21
Salmo gairdnerii	27 - 31	29.0	29.0	29.0	1.44	0.37	4.97

Number of neural arches not fused and number fused with vertebrae. For the number of neural arches not fused, brook and aurora chars have the lowest mean values, 29.1 and 27.8, respectively, and Arctic char the highest at 33.9 (Table 23). These 3 groups can be separated from each other and from other chars, namaycush, and rainbow trout. See Tables 23 and 40.

The mean number of neural arches fused with the vertebrae is lowest (27.4) in brook char and highest (30.9) in Arctic char (Table 24).

Number of paired neural spines. Because of this character Arctic char (mean 33.6) and Dolly Varden char (mean 33.9) can be separated from other chars, namaycush, and rainbow trout. Brook char (mean 30.6) and aurora char (mean 29.8) are similar. There is a considerable overlap in the ranges of various fishes (Tables 25 and 40).

Number of single neural spines and haemal spines, normal and expanded. Among the chars the number of single neural spines is minimum (mean 26.3) in brook char and maximum (mean 31.1) in Arctic char. Two groups, brook char, and Arctic char and rainbow trout, can be separated from other chars. The C.D. value (1.31) between brook and aurora chars signifies subspecific difference. See Tables 26, 40, and 41.

The number of haemal spines is somewhat similar in Arctic, Quebec red, blueback, and Sunapee chars. Brook, aurora, and Dolly Varden chars are similar. Among the foreign genera the number of haemal spines is minimum (approx. 18) in Brachymystax lenok and Hucho perryi. See Table 27.

Number of ribs. The total number of ribs, number of ribs with strong

TABLE 25. Number of paired neural spines in several salmonoid fishes.

Species	Paired neural spines						
	Range	$\overline{X}$	Me	Mo	s	$s_{\overline{X}}$	V
C.namaycush	30 - 35	32.4	32.0	31.2	1.15	0.15	3.55
S.a.alpinus	31 - 35	33.6	34.0	34.8	1.35	0.31	4.02
S.a.oquassa - Quebec	30 - 34	31.4	32.0	33.2	1.28	0.32	4.06
S.a.oquassa - *Pushineer* Lake, Maine	30 - 35	32.4	32.0	31.2	1.72	0.38	5.29
S.a.oquassa - Floods Pond, Maine	29 - 35	32.2	32.0	31.6	1.54	0.35	4.78
S.malma	30 - 37	33.9	34.0	34.1	1.71	0.43	5.04
S.f.fontinalis	27 - 33	30.6	30.5	30.3	1.83	0.38	5.99
S.f.timagamiensis	27 - 32	29.8	30.0	30.4	1.26	0.84	3.15
Salmo gairdnerii	25 - 31	29.0	29.5	30.5	1.82	0.47	6.29

TABLE 26. Number of single neural spines (normal and expanded) in several salmonoid fishes.

Species	Neural spines						
	Range	$\bar{X}$	Me	Mo	s	$s_{\bar{X}}$	V
C.namaycush	25 - 32	29.1	29.0	28.8	1.46	0.19	5.02
S.a.alpinus	29 - 34	31.1	31.0	30.8	1.51	0.35	4.88
S.a.oquassa - Quebec	26 - 32	29.4	30.0	31.2	1.54	0.39	5.24
S.a.oquassa - Pushineer Lake, Maine	23 - 32	29.3	29.0	28.3	2.08	0.47	7.09
S.a.oquassa - Floods Pond, Maine	26 - 32	29.1	29.0	28.8	1.74	0.40	5.99
S.malma	25 - 32	28.2	28.0	27.5	1.75	0.44	6.20
S.f.fontinalis	21 - 29	26.3	26.0	25.4	2.14	0.45	8.16
S.f.timagamiensis	27 - 32	28.5	28.0	27.9	1.30	0.35	4.55
Salmo gairdnerii	30 - 35	31.7	31.5	31.0	1.34	0.34	4.22

TABLE 27. Number of haemal spines (normal and expanded) in several salmonoid fishes.

Species	Haemal spines						
	Range	$\bar{X}$	Me	Mo	s	$s_{\bar{x}}$	V
C. namaycush	22 - 26	23.4	23.0	22.2	0.87	0.12	3.74
S. a. alpinus	23 - 26	24.2	24.0	23.7	0.81	0.19	3.36
S. a. oquassa - Quebec	23 - 27	24.8	25.0	25.4	0.97	0.24	3.91
S. a. oquassa - Pushineer Lake, Maine	24 - 27	25.2	25.0	24.6	0.83	0.71	3.31
S. a. oquassa - Floods Pond, Maine	23 - 25	24.1	24.0	23.9	0.60	0.14	2.51
S. malma	22 - 24	22.9	23.0	23.1	0.66	0.16	2.87
S. f. fontinalis	21 - 24	22.6	23.0	23.7	1.01	0.21	4.47
S. f. timagamiensis	22 - 23	22.5	22.0	21.0	0.51	0.14	2.29
Salmo gairdnerii	22 - 25	23.4	23.5	23.7	1.02	0.26	4.38
H. perryi	17 - 20	18.1	18.0	17.7	0.43	0.17	2.38
B. lenok	18 - 18	18.0	18.0	18.0	0	0	0

bifid heads, and number of ribs with single heads were enumerated.

The mean total number of ribs is minimum (33.1) in brook char and maximum (40.5) in Arctic char. In namaycush the mean and range are 37.9 and 36-40, respectively. Among the foreign species, *Salmothymus ohridanus* has the lowest mean (30.5).

Duncan's test separates Arctic char and brook char from each other and from all the other chars, namaycush, and rainbow trout.

The C.D. values segregate Arctic char from Quebec red char. Quebec red, blueback, and Sunapee chars are closely related. See Tables 28, 40, and 41.

In namaycush the mean number of ribs with bifid heads is 30.3 (range 27-33). In Arctic char from the Canadian Arctic the mean and range are 30.9 and 30-33, respectively. On the basis of ribs with strong bifid heads brook char is separated from aurora char (Table 41). The mean and range in brook char are 24.8 and 21-27, respectively, and in aurora char, 28.4 and 27-30, respectively.

The mean number of ribs with single heads in namaycush is 7.6 (range 5-9). On the basis of this character Arctic char is segregated from Quebec red char (Table 41). In Arctic char the mean and range are 9.6 and 9-11, respectively, and in Quebec red char the values are 7.2 and 7-8, respectively.

Number of epineurals. The mean number of epineurals is minimum (28.5) in Sunapee char and maximum (36.3) in aurora char. This character puts Quebec red, blueback, and Sunapee chars into one group, and Arctic, Dolly Varden chars, and rainbow trout into another. The C.D. value of 1.31 segregates brook char from aurora char. See Tables 29, 40, and 41.

TABLE 28. Total number of ribs in several salmonoid fishes.

Species	Ribs						
	Range	$\bar{X}$	Me	Mo	s	$s_{\bar{x}}$	V
C.namaycush	36 - 40	37.9	38.0	38.2	1.08	0.51	2.84
S.a.alpinus	39 - 42	40.5	41.0	41.9	0.87	0.20	2.14
S.a.oquassa - Quebec	34 - 38	36.2	36.0	35.5	0.94	0.22	2.60
S.a.oquassa - Pushineer Lake, Maine	34 - 39	37.6	38.0	38.8	1.15	0.24	3.05
S.a.oquassa - Floods Pond, Maine	37 - 39	37.8	38.0	38.3	0.81	0.19	2.14
S.malma	36 - 39	37.4	37.0	36.2	1.02	0.26	2.73
S.f.fontinalis	32 - 36	33.1	33.0	32.6	1.01	0.21	3.03
S.f.timagamiensis	33 - 36	34.6	35.0	35.8	0.76	0.21	2.18
Salmo gairdnerii	36 - 38	37.4	38.0	38.5	0.73	0.19	1.94
Salmothymus ohridanus	30 - 31	30.5	30.5	30.5	0.71	0.18	2.31
H.hucho	40 - 41	40.2	40.5	41.5	0.65	0.32	1.61
H.perryi	34 - 38	35.5	35.0	33.8	1.51	0.60	4.25
B.lenok	36 - 39	37.2	36.0	35.6	1.64	0.82	4.41

TABLE 29. Total number of epineurals in several salmonoid fishes.

Species	Epineurals						
	Range	$\overline{X}$	Me	Mo	s	$s_{\overline{x}}$	V
C.namaycush	29 - 36	32.1	32.0	31.8	1.63	0.22	5.07
S.a.alpinus	32 - 37	34.4	34.5	34.7	1.39	0.32	4.06
S.a.oquassa - Quebec	26 - 32	29.2	29.0	28.6	1.55	0.39	5.31
S.a.oquassa - Pushineer Lake, Maine	27 - 33	29.1	29.0	28.9	1.67	1.32	5.74
S.a.oquassa - Floods Pond, Maine	25 - 32	28.5	28.5	28.6	1.60	0.37	5.64
S.malma	33 - 38	35.4	35.0	34.2	0.98	0.24	2.76
S.f.fontinalis	29 - 35	32.6	33.0	33.8	0.74	0.15	2.27
S.f.timagamiensis	34 - 42	36.3	36.0	35.5	2.05	0.54	5.65
Salmo gairdnerii	29 - 33	31.7	32.0	32.6	1.46	0.37	4.60
H.perryi	29 - 32	30.3	30.0	29.4	1.11	0.44	3.67
B.lenok	33 - 34	33.7	34.0	34.7	0.59	0.43	1.75

Number of dorsal fin pterygiophores. Aurora char have the minimum mean number (11.2) of dorsal pterygiophores and Quebec red char the maximum (12.8) among chars and namaycush (Table 30). Among the foreign genera, Salmothymus has the minimum mean (10). Aurora and brook chars are segregated from the other chars and from trouts to form a single species group (Table 40).

Number of dorsal fin rays. This meristic character signifies that the mean is lowest (12.9) in brook char and highest (14.5) in rainbow trout. Arctic, Quebec red, blueback, Sunapee, and Dolly Varden chars are similar (Table 31). In each case our values are higher than those reported by Kendall (1914) for namaycush, blueback, and Sunapee chars, by Delacy and Morton (1943) for Dolly Varden char, Wilder (1952) for brook char, and Vladykov (1954) for chars and namaycush. Our values for Arctic char are slightly lower than those of Andrews and Lear (1956), who mentioned that there was an increase in the mean count with increase in latitude.

Number of anal fin pterygiophores. The mean value for this character is lowest (9.9) in brook and aurora chars and highest (11.4) in namaycush. Arctic, Quebec red, blueback, Sunapee, and Dolly Varden chars are related. The genus Salmothymus has the lowest mean (9.5) among the non-American genera. See Table 32.

Number of anal fin rays. Table 33 specifies that among namaycush, chars, and trout the number of anal rays is lowest (11.9) in brook char. Quebec red, blueback, Sunapee, and Dolly Varden chars group together. Dolly Varden char form an intermediate group between Arctic

TABLE 30. Number of dorsal fin pterygiophores in several salmonoid fishes

Species	Dorsal pterygiophores						
	Range	$\overline{X}$	Me	Mo	s	$s_{\overline{x}}$	V
C. namaycush	11 - 14	12.7	13.0	13.6	0.68	0.09	5.39
S. a. alpinus	11 - 13	12.2	12.0	11.7	0.58	0.13	4.83
S. a. oquassa - Quebec	12 - 14	12.8	13.0	13.4	0.53	0.13	4.16
S. a. oquassa - Pushineer Lake, Maine	12 - 14	12.8	13.0	13.3	0.71	0.15	5.52
S. a. oquassa - Floods Pond, Maine	12 - 13	12.7	13.0	13.6	0.65	0.15	5.16
S. malma	12 - 14	12.4	12.0	11.2	0.42	0.10	3.46
S. f. fontinalis	10 - 12	11.5	11.5	12.6	0.58	0.12	5.13
S. f. timagamiensis	11 - 12	11.2	11.0	12.6	0.41	0.11	3.69
Salmo gairdnerii	12 - 14	13.1	13.0	12.9	0.77	0.19	5.90
Salmothymus ohridanus	10 -10	10.0	10.0	10.0	0	0	0
H. hucho	13 - 14	13.5	13.5	13.5	0.70	0.50	5.24
H. perryi	11 - 13	11.9	12.0	12.3	0.69	0.28	5.81
B. lenok	12 - 13	12.4	12.0	11.2	0.54	0.27	4.11

TABLE 31. Total number of dorsal fin rays in several salmonoid fishes.

Species	Dorsal rays						
	Range	$\overline{X}$	Me	Mo	s	$s_{\overline{X}}$	V
C.namaycush	13 - 16	13.9	14.0	14.1	0.65	0.06	4.67
S.a.alpinus	13 - 15	14.0	14.0	14.0	0.56	0.13	4.00
S.a.oquassa - Quebec	13 - 15	14.7	15.0	15.7	0.59	0.85	4.05
S.a.oquassa - Pushineer Lake, Maine	13 - 15	14.1	14.0	13.7	0.63	0.14	4.52
S.a.oquassa - Floods Pond, Maine	14 - 16	14.2	14.0	13.0	0.60	0.14	4.17
S.malma	13 - 15	14.1	14.0	13.8	1.07	0.35	7.61
S.f.fontinalis	12 - 15	12.9	13.0	13.2	0.78	0.16	6.07
S.f.timagamiensis	13 - 14	13.5	13.0	13.1	0.51	0.14	3.83
Salmo gairdnerii	12 - 15	14.5	15.0	16.0	0.89	0.23	6.16
Salmothymus ohridanus	13 - 13	12.0	12.0	12.0	0	0	0
Hucho hucho	13 - 15	14.0	14.0	14.0	1.08	0.64	7.71
H.perryi	13 - 14	13.4	13.0	12.1	0.53	0.21	3.97
B.lenok	14 - 15	14.2	14.0	13.6	0.44	0.22	3.14

TABLE 32. Number of anal fin pterygiophores in several salmonoid fishes.

Species	Anal pterygiophores						
	Range	$\bar{X}$	Me	Mo	s	$s_{\bar{X}}$	V
C.namaycush	11 - 13	11.4	11.0	10.3	0.51	0.07	4.55
S.a.alpinus	10 - 12	10.2	10.0	9.6	0.39	0.10	3.84
S.a.oquassa - Quebec	10 - 12	10.7	11.0	11.6	0.59	0.13	5.55
S.a.oquassa - Pushineer Lake, Maine	9 - 12	10.8	11.0	11.4	0.74	0.17	6.93
S.a. oquassa - Floods Pond, Maine	10 - 11	10.6	11.0	11.8	0.50	0.12	4.73
S.malma	9 - 11	10.3	10.0	9.5	0.68	0.18	6.67
S.f.fontinalis	9 - 11	9.9	10.0	10.1	0.69	0.14	6.93
S.f.timagamiensis	9 - 10	9.9	10.0	10.2	0.35	0.09	3.55
Salmo gairdnerii	10 - 13	11.2	11.0	10.6	0.94	0.24	8.40
Salmothymus ohridanus	9 - 10	9.5	9.5	9.5	0.70	0.43	7.44
H.hucho	11 - 11	11.0	11.0	11.0	0	0	0
H.perryi	10 - 12	11.0	11.0	11.0	0.81	0.32	7.41
B.lenok	10 - 11	10.8	11.0	11.4	0.44	0.22	4.13

TABLE 33. Total number of anal fin rays in several salmonoid fishes.

Species	Anal rays						
	Range	$\overline{X}$	Me	Mo	s	$s_{\overline{x}}$	V
C.namaycush	13 - 15	13.6	13.0	11.9	0.62	0.08	4.61
S.a.alpinus	12 - 14	13.1	13.0	12.7	0.75	0.18	5.78
S.a.oquassa - Quebec	12 - 14	12.5	12.0	11.0	0.61	0.15	4.94
S.a.oquassa - Pushineer Lake, Maine	11 - 14	12.5	13.0	13.9	0.68	0.54	5.42
S.a.oquassa - Floods Pond, Maine	11 - 13	12.3	12.0	11.8	0.65	0.15	5.33
S.malma	11 - 13	12.1	12.0	11.7	0.72	0.30	5.92
S.f.fontinalis	10 - 13	11.9	12.0	12.3	0.79	0.17	6.71
S.f.timagamiensis	11 - 13	12.1	12.0	11.8	0.46	0.12	3.78
Salmo gairdnerii	12 - 15	13.6	13.5	13.4	0.81	0.21	5.99
Salmothymus ohridanus	11 - 11	11.0	11.0	11.0	0	0	0
H.hucho	12 - 13	12.8	13.0	13.5	0.29	0.15	2.29
H.perryi	12 - 13	12.6	13.0	13.8	0.53	0.22	4.25
B.lenok	11 - 13	12.2	12.0	11.6	0.84	0.42	6.85

char and brook char. Again, for this character, the values are higher by 2 - 3 rays for each species in the genus Salvelinus than those reported by Kendall (1914) for various chars, Delacy and Morton (1943) for Dolly Varden char, and Wilder (1952) for brook char. Our values for Arctic char are similar to those of Andrews and Lear (1956).

Pectoral fin rays. Brook and aurora chars (mean 13.2) and Quebec red, blueback, and Sunapee chars group together. The number of rays is highest (mean 14.7 and 14.6) for Dolly Varden char and rainbow trout. Among the non-American genera, Brachymystax has the highest mean value (16). See Table 34.

Number of ventral fin rays. For this character brook and aurora chars form a separate group, with a mean of 8.3 (Table 40). Arctic, Quebec red, blueback, and Sunapee chars and namaycush are related (Table 35). Our values for Arctic char are slightly lower (by 1.2) than those of Andrews and Lear (1956). Rainbow trout have the highest mean (10.1).

Total number of gill rakers. This character has been used extensively in fish taxonomy (Svärdson, 1957; McPhail, 1961). The total number of gill rakers is lowest (mean 16.8) in Dolly Varden char and highest (mean 27.8) in Arctic char. This character supports the separation of namaycush, Arctic char, and Dolly Varden char from each other and from the other chars and rainbow trout. Quebec red, blueback, and Sunapee chars, and also brook char, aurora char, and rainbow trout form two groups. Arctic char are separated from Quebec red char. See Tables 36, 40, and 41.

Our gill raker counts are higher, particularly for Arctic char,

TABLE 34. Total number of pectoral fin rays in several salmonoid fishes.

Species	Pectoral rays						
	Range	$\overline{X}$	Me	Mo	s	$s_{\bar{x}}$	V
C. namaycush	13 - 15	14.0	14.0	14.0	0.54	0.20	3.85
S. a. alpinus	13 - 15	14.3	14.0	13.4	0.57	0.13	3.97
S. a. oquassa - Quebec	12 - 15	13.3	13.0	12.3	0.76	0.19	5.74
S. a. oquassa - Pushineer Lake, Maine	12 - 15	13.1	13.0	12.6	0.65	0.14	4.93
S. a. oquassa - Floods Pond, Maine	12 - 14	13.3	13.0	12.3	0.67	0.15	5.01
S. malma	14 - 15	14.7	15.0	15.5	0.46	0.32	3.19
S. f. fontinalis	12 - 15	13.2	13.0	12.6	0.76	0.16	5.78
S. f. timagamiensis	13 - 14	13.2	13.0	12.8	0.81	0.22	2.62
Salmo gairdnerii	13 - 17	14.6	15.0	15.8	0.96	0.25	6.61
H. perryi	15 - 16	15.1	15.0	14.7	0.92	0.37	6.55
H. hucho	15 - 17	16.0	16.0	16.0	0.82	0.41	5.10
B. lenok	15 - 17	16.0	16.0	16.0	0.82	0.41	5.10

TABLE 35. Number of ventral fin rays in several salmonoid fishes.

Species	Ventral rays						
	Range	$\bar{X}$	Me	Mo	s	$s_{\bar{X}}$	V
C.namaycush	9 - 10	9.3	9.0	8.2	0.48	0.07	5.20
S.a.alpinus	9 - 10	9.4	9.0	8.1	0.51	1.17	5.40
S.a.oquassa - Quebec	8 - 9	8.9	9.0	9.1	0.23	0.06	2.62
S.a.oquassa - Pushineer Lake, Maine	8 - 10	9.3	9.0	8.3	0.58	0.13	6.27
S.a.oquassa -Floods Pond, Maine	9 - 10	9.1	9.0	8.9	0.21	0.05	2.32
S.malma	9 - 10	9.8	10.0	10.2	0.38	0.39	3.91
S.f.fontinalis	8 - 9	8.3	8.0	7.6	0.31	0.17	3.72
S.f.timagamiensis	8 - 9	8.3	8.0	7.5	0.45	0.12	5.54
Salmo gairdnerii	10 - 11	10.1	10.0	9.6	0.34	0.08	3.36
H.perryi	9 - 9	9.0	9.0	9.0	0	0	0
B.lenok	9 - 10	9.5	9.5	9.5	0.76	0.38	8.00

than those tabulated by Delacy and Morton (1943), whose mean numbers of rakers for 2 samples of Arctic char were 21.3 and 23.4. However, our value for Arctic char (27.8) is in accordance with those of McPhail's (1961) samples from the eastern North American Arctic where the lowest and highest means were 25 and 29, respectively. Also, our mean value (16.8) for Dolly Varden char compares well with those for several samples of McPhail's southern form. Our range values for blueback and Sunapee chars are similar to those of Kendall (1914). In Waters' (1960) study the means for various samples of blueback char ranged between 18.4 and 20.1. The minimum and maximum numbers of rakers for his 4 samples were 16 and 22, respectively; our mean (21.4) for blueback char is slightly higher than his. Waters' mean number of rakers for Sunapee char was 18.9 and the range was 17 - 21; our mean (20.7) is slightly higher.

Number of developed gill rakers. The gill rakers which projected from the basal discs and which were easily moved by a needle were considered to be developed. The number of developed gill rakers segregates Arctic char from Quebec red char (Table 41).

Two samples of namaycush, 1 from Lake Louisa, Ontario, and the other from Lake Lavielle, Ontario, are compared by us on the basis of the number of developed and undeveloped gill rakers. It is reported here that the Lake Louisa population, which is a plankton feeder, has more developed gill rakers, the mean and range being 17.2 and 16 - 19, respectively. The mean and range for the Lake Lavielle population are 13.9 and 12 - 17, respectively. The C.D. value is 1.38.

For the 2 populations of namaycush, the total number of rakers

TABLE 36. Total number of gill rakers in several salmonoid fishes.

Species	Gill rakers						
	Range	$\overline{X}$	Me	Mo	s	$s_{\overline{X}}$	V
C. namaycush	20 - 25	22.4	22.0	21.2	1.19	0.07	5.30
S.a. alpinus	26 - 31	27.8	27.5	27.0	1.40	0.32	5.07
S.a. oquassa - Quebec	19 - 23	21.3	21.0	20.5	1.31	0.32	6.19
S.a. oquassa - Pushineer Lake, Maine	19 - 24	21.4	21.0	20.2	1.04	0.23	4.86
S.a. oquassa - Floods Pond, Maine	19 - 22	20.7	21.0	21.6	0.65	0.15	3.16
S. malma	15 - 19	16.8	16.5	16.0	1.19	0.31	7.10
S.f. fontinalis	15 - 20	19.3	19.0	18.4	1.37	0.40	7.13
S.f. timagamiensis	17 - 20	18.0	18.0	18.0	0.84	0.23	4.69
Salmo gairdnerii	17 - 21	19.0	18.5	17.5	1.49	0.38	7.84

TABLE 37. Number of branchiostegal rays in several salmonoid fishes.

Species	Branchiostegal rays						
	Range	$\bar{X}$	Me	Mo	s	$s_{\bar{x}}$	V
C.namaycush	11 - 14	12.3	12.0	11.3	0.69	0.09	5.60
S.a.alpinus	10 - 13	11.7	12.0	12.6	0.73	0.17	6.25
S.a.oquassa - Quebec	9 - 11	9.9	10.0	10.1	0.80	0.20	8.08
S.a.oquassa - Pushineer Lake, Maine	8 - 11	9.6	9.0	8.7	0.46	0.10	5.12
S.a.oquassa - Floods Pond, Maine	9 - 11	10.6	11.0	11.8	0.59	0.14	5.64
S.malma	13 - 14	13.6	14.0	14.7	1.05	0.23	7.71
S.f.fontinalis	10 - 12	11.3	11.5	11.8	0.84	0.18	8.18
S.f.timagamiensis	11 - 14	12.3	12.0	11.4	0.79	0.21	6.50
Salmo gairdnerii	10 - 13	11.4	12.0	13.2	0.91	0.24	8.06

TABLE 38. Number of pyloric caeca in several salmonoid fishes.[1]

Species	Pyloric caeca							
	No. of fish	Range	$\overline{X}$	Me	Mo	s	$s_{\overline{X}}$	V
C.namaycush	34	97 - 171	138.5	141.5	147.4	22.20	3.86	16.02
S.a.alpinus	Not counted							
S.a.oquassa - Quebec	15	33 - 46	41.7	42.0	42.6	3.13	0.84	7.51
S.a.oquassa - Pushineer Lake, Maine	7	30 - 46	35.0	35.6	33.8	5.44	2.22	15.29
S.a.oquassa - Floods Pond, Maine	15	39 - 55	46.9	46.0	44.1	4.83	1.29	10.29
S.malma	20	20 - 31	23.9	25.0	27.3	9.44	2.17	39.60
S.f.fontinalis	8	32 - 43	37.1	36.5	35.2	4.15	1.57	11.19
S.f.timagamiensis	13	31 - 40	35.9	36.0	36.3	3.60	1.04	10.04
Salmo gairdnerii	11	38 - 52	40.0	38.0	34.0	8.31	2.60	20.79

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[1] In this table the ranges of fork length for various species are about the same as in previous tables on meristic characters, though the number of fish used is considerably less.

is about the same. The means and ranges are 22.8 and 21 - 24, respectively, for the Lake Louisa population and 22.2 and 20 - 24 for the Lake Lavielle population. Further work on some other characters is in progress to decide the taxonomy of these 2 populations.

Number of branchiostegal rays. The mean for this character is lowest (9.6) in blueback char and highest (13.6) in Dolly Varden char. This character separates Dolly Varden char from all the other chars and from rainbow trout. Blueback, Quebec red, Sunapee, and brook chars group together. See Tables 37 and 40.

Our mean value (13.6) for Dolly Varden char is higher than that (11.3) reported by Delacy and Morton (1943). Our range values for blueback and Sunapee chars are in accordance with those of Kendall (1914).

Number of pyloric caeca. Namaycush have the highest number of pyloric caeca (mean 138.5). The higher mean and range separate namaycush from all chars and from rainbow trout (Tables 38 and 40). The mean number of pyloric caeca is minimum (23.9) for Dolly Varden char; this value is in accordance with those for several samples of the southern forms of McPhail (1961). The numbers of pyloric caeca for the other chars are within the ranges reported by Morton and Miller (1954), Vladykov (1954), and Rounsefell (1962).

Number of pores on lateral line scales. The number of pores is minimum (about 117) in brook and aurora chars and maximum (143) in Arctic char. Arctic char is separated from other chars, namaycush, and rainbow trout. Quebec red and blueback chars, and also brook and

TABLE 39. Total number of lateral line scales with pores in several salmonoid fishes.

Species	Pores on lateral line scales						
	Range	$\bar{X}$	Me	Mo	s	$s_{\bar{x}}$	V
C. namaycush	120 - 134	126.4	126.0	125.8	4.18	0.54	3.30
S. a. alpinus	139 - 1[illegible]	143.0	143.0	143.0	2.15	0.51	1.50
S. a. oquassa - Quebec	131 - 1[illegible]	135.5	135.5	135.5	3.03	0.54	2.23
S. a. oquassa - Pushineer Lake, Maine	126 - 150	136.4	135.0	134.0	8.44	1.80	6.20
S. a. oquassa - Floods Pond, Maine	118 - [illegible]	127.1	124.5	127.4	12.33	2.82	10.02
S. malma	122 - 126	126.3	127.0	128.5	1.07	0.25	0.84
S. f. fontinalis	112 - 123	116.8	116.5	115.8	3.11	0.65	2.66
S. f. timagamiensis	112 - 126	116.5	114.5	113.5	4.80	1.28	4.12
Salmo gairdnerii	106 - [illegible]	125.4	123.5	119.7	5.42	1.39	4.32

aurora chars form 2 separate groups. Our values for namaycush, brook char, and Dolly Varden char compare well with those of Morton and Miller (1954). Our mean (143) for Arctic char is higher than theirs (122). See Tables 39, 40, and 41. The number of pores on the lateral line scales in several samples of Arctic char ranged from 123 - 155 (McPhail, 1961); our range is in accordance with his.

The overall impression which one draws by considering meristic characters is that namaycush, Arctic char, Dolly Varden char, and brook char are separated into distinct forms. Dolly Varden char seems to be an intermediate form between Arctic char and brook char.

Quebec red, blueback, and Sunapee chars form one group and are closely associated with Arctic char. Brook and aurora chars form another group. Rainbow trout have slightly more affinity with chars than with namaycush.

Coefficient of difference (C.D.) values signify that Quebec red char can be separated from Arctic char in 7 characters (Table 41) and may be given a subspecific rank (Mayr, Linsley, and Usinger, 1953). Quebec red char cannot be distinguished from blueback or Sunapee chars in any meristic character. Blueback char are inseparable from Sunapee char in all the meristic characters studied. Aurora char can be separated from brook char in 5 characters and possibly may be considered a subspecies of brook char (Table 41).

TABLE 40. Group separation of namaycush, various chars, and rainbow trout based on meristic characters; samples treated by the Duncan's test as modified by Kramer. Numerals used for scientific names: 1. *C.namaycush*; 2. *S.a.alpinus*; 3. *S.a.oquassa* - Quebec; 4. *S.a.oquassa* - Pushineer Lake, Maine; 5. *S.a.oquassa* - Floods Pond, Maine; 6. *S.malma*; 7. *S.f.fontinalis*; 8. *S.f.timagamiensis*; 9. *Salmo gairdnerii*.

Characters	Single species(sub-species) grouping	Two species(sub-species) grouping	Three species (sub-species)grouping	Two or three species (sub-species)grouping with rainbow trout
Total no.of vertebrae	2 7 8			
No.of caudal vertebrae		3 4		
No.of neural arches not fused with vertebrae	2 7 8			
No.of paired neural spines		2 6		
No.of single neural spines normal & expanded	7			2 9
Total no.of ribs	2 7			
No.of epineurals			3 4 5	2 6 9
No.of dorsal fin pterygiophore		7 8		
No.of ventral fin rays		7 8		
Total no.of gillrakers	1 2 6		3 4 5	7 8 9
No.of branchio-stegal rays	6		3 5 7	
No.of pyloric caeca	1			
No.of pores on lateral line scales	2	3 4 7 8		

TABLE 41. Coefficient of difference (C.D.) values, higher than 1.28, to show sub-specific differences among the various chars. The letter "O" shows that the comparisons were made but no differences were observed.

Characters	Arctic char against Quebec red char	Quebec red char against		Blueback char against Sunapee char	Aurora char against Brook char
		Blueback char	Sunapee char		
Total no. of vertebrae	1.56	0	0	0	0
No. of trunk vertebrae	1.58	0	0	0	2.21
No. of precaudal vertebrae	0	0	0	0	1.44
No. of single neural spines - normal and expanded	0	0	0	0	1.31
Total no. of ribs	2.39	0	0	0	0
No. of ribs with strong bifid heads	0	0	0	0	1.60
No. of ribs with weak single head	1.44	0	0	0	0
Total no. of epineurals	0	0	0	0	1.31
Total no. of gill rakers	2.54	0	0	0	0
No. of developed gill rakers	2.15	0	0	0	0
No. of pores on lateral line scales	1.44	0	0	0	0

FRY

Osteology

Skull

In fry of Salmonidae ossification of bones of the chondrocranium began after hatching. The age and length at the beginning of ossification differed in namaycush, two species of chars, and cutthroat trout. However, in these fishes the position, pattern, and sequence of appearance of most of the skull bones were similar and in accordance with the findings of earlier workers. For drawings showing the position and development of bones in Salmonidae standard works (Schleip, 1904; Böker, 1913; de Beer, 1927 and 1937) may be consulted. The account of ossification of various bones is given here for namaycush, and comparisons are made with chars and the genus *Salmo*. Unfortunately we are unaware of the environmental and ecological conditions, particularly temperature and food, during the early development of *Salmo*. Therefore, comparisons on the basis of lengths alone should be viewed with caution.

In the following description, the cartilage bones and the membrane bones are treated separately. Similarly subdivided are the membrane bones of the skull with the lateral line canals, the membrane bones of the skull without the lateral line canals, and the bones of the mouth cavity.

Cartilage Bones

Of more than 35 bones studied, the basioccipital, exoccipital, prootic, hyomandibular, gill rakers, and uroneural are discussed in some detail. Information on the ceratohyal, hypurals, and epurals is provided in Tables 43 and 44.

Basioccipital. In adult Salmonidae the basioccipital is a single bone, but in fry it appears in the form of 4 perichondral lamellae around the notochord. These lamellae later fuse together and form a single bone. In namaycush fry the 4 lamellae ossified at a younger age, 20 days (21 mm), than in chars (Table 43). In Salmo salar fry they appeared at a length of 24 mm (de Beer, 1937).

Exoccipital. The exoccipitals are a pair of bones. The exoccipital ossifies as a pair of perichondral lamellae on the outer and inner surfaces of the occipital arch. Ossification later spreads ventrally and anteriorly. The lamellae ossified at a younger age, 8 days (17.5 mm), in namaycush than in chars (Fig. 5).

Prootic. The prootics are a pair of bones. The prootic appears as an endochondral ossification on the anterior wall of the auditory capsule and on the lateral commissure. Ossification spreads inward to the anterior region of the basal plate and the prootic bridge. In namaycush the bone ossified at an earlier age, 33 days (24 mm), than in chars (Table 43). In Salmo salar it appeared at 24 mm (de Beer, 1937).

Hyomandibular. The hyomandibulars are a pair of bones. The hyomandibular ossifies first in a cartilaginous area around the hyomandibular foramen. Ossification spreads in all directions until the bone assumes its final shape. In namaycush fry the bone appeared at an

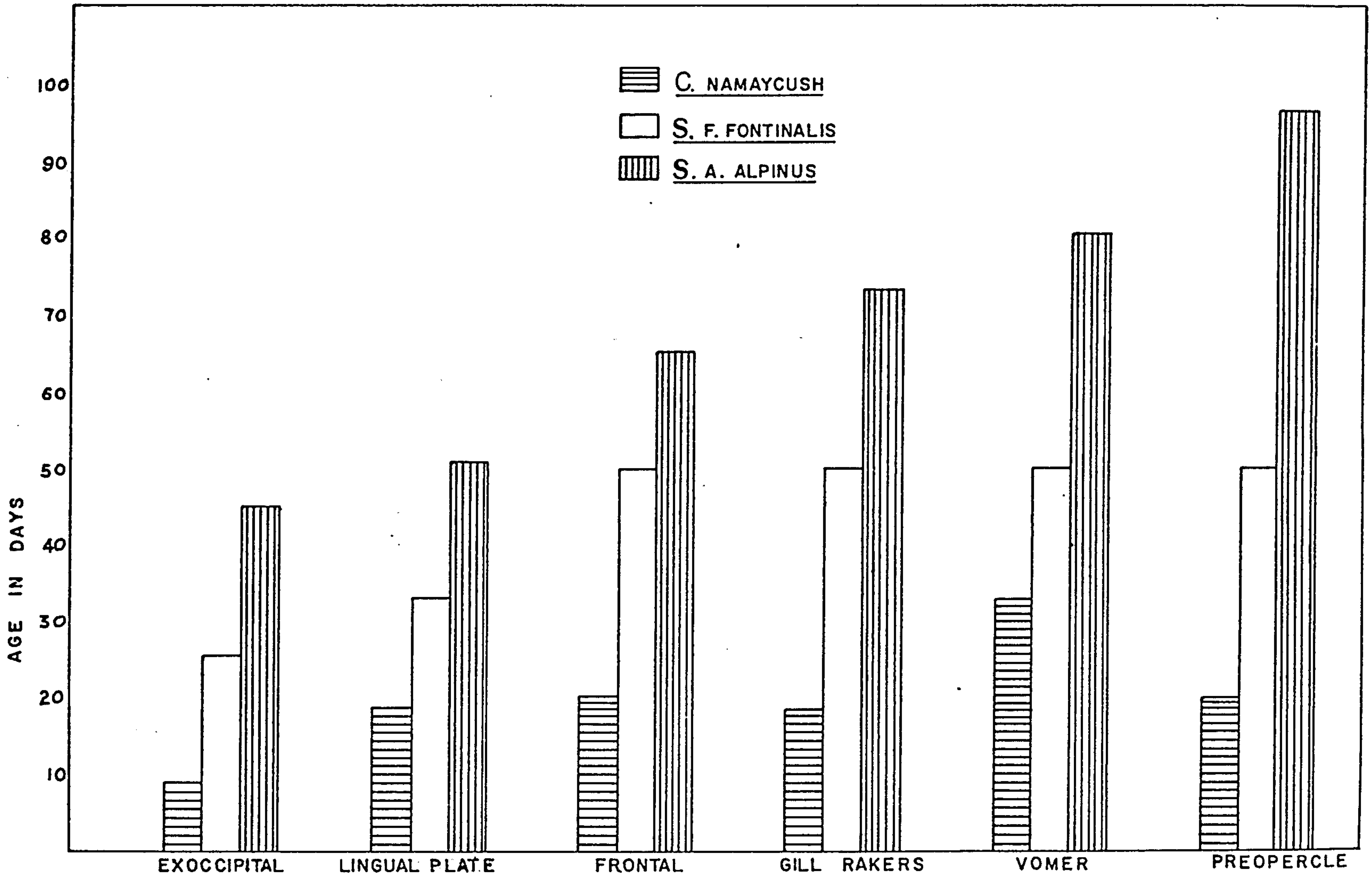

Fig. 5. Histograms showing the ages in days at the beginning of ossification in 5 skull bones and the gill rakers in fry of C. namaycush, S.f.fontinalis, and S.a.alpinus.

earlier age, 26 days (22 mm), than in chars (Table 43).

Gill rakers. The gill rakers were studied on the first gill arch only. In namaycush 3 - 4 gill rakers appeared independently above the lower arm (absent above the upper arm) of the first gill arch, at an age of 17 days (18 mm). These and other gill rakers become attached to the arch later. Their number and size increased with the size of the fry. At an age of about 50 days (25 mm), 8 rakers were present on the lower arm. The gill rakers were not developed on the posterior surface of the arch at the above mentioned lengths. The rakers appeared at a later age in chars than in namaycush (Table 44, and Fig. 5).

Membrane Bones

Membrane bones containing the canals of the lateral line system. Eighteen of these bones were studied. These include the bones of the skull proper, the orbital and opercular regions, the lower jaw, and the pectoral girdle. Only the following 4 bones are dealt with in detail: the nasal, frontal, lachrymal, and preopercle. For information on the suprapreopercle and dentary see Table 42.

Nasal. The nasals are a pair of bones. The nasal ossifies over the fossa nasalis and lodges the anterior part of the supraorbital canal of the lateral line system. At first the ossification appears around the sensory canal, then gradually spreads from this centre. The nasal ossified at a younger age, 49 days (25 mm), in namaycush than in chars (Table 42). In Salmo fario (= Salmo trutta) the nasal bone appeared in fry of 18 mm in length (de Beer, 1937), and in Thymallus

TABLE 42. The minimum (total) length and age of fry of five species of Salmonidae at the beginning of ossification of five cranial bones containing the canals of the lateral line system. In this and Tables 43-44 the total length in mm and age in days after hatching are presented.

Species	Locality	Nasal		Frontal		Lachrymal		Suprapreopercle		Dentary	
		Length (mm)	Age (days)	Length (mm)	Age (days)	Length (mm)	Age (days)	Length (mm)	Age (days)	Length (mm)	Age (days)
C.namaycush[1]	B	25	49	21	20	25	49	27	84	17	1
S.a.alpinus[1]	E	Not ossified at 21	Not ossified at 97	19	64	21	97	Not ossified at 21	Not ossified at 97	13	1
S.f.fontinalis[1]	I	30	92	23	50	26	85	Not ossified at 30	Not ossified at 92	14	1
S.f.timagamiensis[2]	J	Not ossified at 23	Not ossified at 72	23[3]	72	Not ossified at 23	Not ossified at 72	Not ossified at 23	Not ossified at 72	23[3]	72
Salmo clarkii	M	23	-	23	-	23	-	33	-	23	-

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[1] Fry above 22 mm of S.a.alpinus, or above 30 mm of C.namaycush and S.f.fontinalis were not available for this and Tables 43 and 44. Unfortunately all the fry died due to sudden rise in p^H of water.

[2] Fry of S.f.timagamiensis smaller than 23 mm were not available for this and Tables 43 and 44.

[3] In the case of the frontal bone and other bones of S.f.timagamiensis fry, it is quite possible that the ossification started at shorter length than 23 mm, or at younger age than 72 days. This remark is also applicable for Tables 43 and 44.

TABLE 43. The minimum length and age of fry of five species of Salmonidae at the beginning of ossification of some cranial bones and the bones of the mouth cavity.

Species	Locality	Vomer		Basioccipital		Prootic		Hyomandibular		Ceratohyal		Lingual plate	
		Length (mm)	Age (days)	Length (mm)	Age (days)	Length (mm)	Age (days)	Length (mm)	Agd (days)	Length (mm)	Age (days)	Length (mm)	Age (days)
C.namaycush	B	24	33	21	20	24	33	22	26	17.5	8	18	18
S.a.alpinus	E	20	81	18	52	20.5	88	18	52	17.5	45	18	52
S.f.fontinalis	I	23	50	18	26	24	68	19	33	16	16	19	33
S.f.timagamiensis	J	23	72	23	72	Not ossified at 23	Not ossified at 72	23	72	23	72	23	72
Salmo clarkii	M	23	-	23	-	23	-	23	-	23	-	23	-

TABLE 44. The minimum length and age of fry of five species of Salmonidae at the beginning of ossification of four selected bony structures.

Species	Locality	Gill raker Length (mm)	Gill raker Age (days)	Hypurals[2] Length (mm)	Hypurals[2] Age (days)	Uroneural one Length (mm)	Uroneural one Age (days)	Epurals Length (mm)	Epurals Age (days)
C.namaycush	B	18	17[1]	21	20	22	26	24	33
S.a.alpinus	E	19.5	73	18	52	20.5	88	20.5	88
S.f.fontinalis	I	23	50	18	26	23	50	23	50
S.f.timagamiensis	J	Not ossified at 23	Not ossified at 72	23	72	23	72	23	72
Salmo clarkii	M	23	-	23	-	23	-	30-32	-

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[1] In C.namaycush, ossification of the gill rakers was first noticed in the 3 - 4 rakers on the lower arm of the branchial arch. Observations were made on the first branchial arch on the left side of the fish.

[2] The ossification of the lower five hypurals (1 - 5) are referred to in this table, the other 2 hypurals ossified later.

arcticus at 35 mm (Norden, 1961).

Frontal. The frontals are a pair of bones. The frontal appears as an ossification around the supraorbital canal. From there it ossifies over the tactum cranii, the taenia marginalis (de Beer, 1937), and the anterior part of the auditory capsules. Ossification continues in all directions until the frontal acquires full size, meeting its corresponding partner from the other side dorsomedially. The frontal first appeared at a much younger age, 20 days (21 mm), in namaycush than in chars (Table 42, and Fig. 5). In Salmo fario fry the frontal ossified at a length of 16 mm (de Beer, 1937) and in Thymallus arcticus fry at 30 - 40 mm (Norden, 1961).

Lachrymal. The lachrymals are a pair of bones. The lachrymal lies anteroventrally to the eye, above the maxilla, and carries the anterior extension of the infraorbital canal. In namaycush it ossified at an earlier age, 49 days (25 mm), than in chars (Table 42). In Salmo fario it appeared at a length of 18 mm.

Preopercle. The preopercles are a pair of bones which carry the preopercular lateral line (sensory) canals. Ossification begins in the region of the canal of the horizontal arm of the preopercle, then spreads posteriorly and upward. In namaycush it ossified at an earlier age, 20 days (21 mm), than in chars. See Fig. 5.

Membrane bones without the canals of the lateral line system. Twenty-two of these bones were studied. These include the bones of the skull proper, the upper jaw, the orbital region, the opercular region, and the branchiostegal rays. Only the supraethmoid and maxilla are included here.

Supraethmoid. In namaycush the supraethmoid appears at the age of 49 days (25 mm) as a fairly broad ossification between the anterior ends of the premaxilla. At first the supraethmoid is deeply notched posteriorly, but in a few days the notch is filled and the bone extends into a narrow point, thus assuming the adult shape. In brook char and cutthroat trout the bone is not pointed caudad. In brook char it ossified at the age of 92 days (30 mm), in cutthroat trout it appeared at a length of 40 mm; and in Arctic char the bone did not appear until the age of 97 days.

Maxilla. The maxillae are a pair of bones. The maxilla ossifies as a thin splint. The ossification then spreads anteriorly and posteriorly. A few teeth appear independently even before the maxilla above the anterior end of that bone. They subsequently become attached to the bone. The number of teeth increases with the age of the fry. In namaycush, brook char, Arctic char, and cutthroat trout the maxilla ossified at 17, 14, 13, and 17 mm, respectively. At all these lengths the fry were only 1 day old.

Membrane bones of the oral cavity. Ten membrane bones of the oral cavity were studied. Only the vomer, lingual plate, and basibranchial plates are presented.

Vomer. In adults of Salmonidae the vomer is a single bone. In fry of namaycush and other species the vomer ossifies intramembranously as 2 distinctly separate small round bones at the anterior end of the ethmoid cartilage. The 2 ossifications later fuse to form a single bone. The vomer appeared at an earlier age, 33 days (24 mm), in namaycush than in chars (Table 43, and Fig. 5). In Salmo fario it ossified at a length of 17 mm (de Beer, 1937).

Lingual plate. In namaycush the lingual plate ossified at an age of 18 days (18 mm) as a spatula on the basihyal cartilage but always remains separate from it. In namaycush and other species as well, the teeth appeared in advance of the plate. In namaycush fry the teeth appeared at an age of 8 days (17.5 mm), were not attached to the bone, and were not developed in any particular pattern. At an age of 49 days (25 mm), 4 - 5 teeth were arranged in two parallel rows on the plate. Each row of teeth was situated on the right and left lateral sides of the plate, respectively. In brook char fry the lingual plate ossified at an age of 33 days (19 mm). In Arctic char it ossified at an age of 52 days (18 mm). In cutthroat trout the plate ossified at 23 mm. See Table 43, and Fig. 5.

Basibranchial plate. In namaycush the basibranchial plates originated as 2 - 3 very narrow, small, independent plates on the basibranchial bones. These plates started to ossify in namaycush at an age of 49 days (24 mm). Later the plates fused together and formed 1 or 2 plates. In namaycush and other species the teeth appeared independently in advance of the plates and afterwards attached to them. In brook char 2 - 3 plates were ossified at an age of 68 days (24 mm). In Arctic char the anterior basibranchial plate made its appearance at an age of 68 days (20.5 mm).

The ages and lengths at the beginning of ossification of several bones in fry of 5 forms of Salmonidae emphasize the fact that in namaycush ossifications commenced at an earlier age than in chars and cutthroat trout, and that namaycush is far separated from them. Aurora char is closer to brook char than to any other species, and in most cases aurora char overlaps it. In cutthroat trout fry ossifications begin at greater lengths than in *Salmo fario*.

Morphology

Percentages of body parts in the total length of fry. In sac fry and advanced fry of namaycush 16.7 - 29.8 mm in length, T and H increase with growth in body length. The distances aD, aV, and aN remain fairly constant (Table 45). In namaycush fry 45 - 49 mm in length the distance aV diminishes a little; the remaining proportions are in accordance with the group above. The general pattern of growth in other species, except Arctic char, is similar to that of namaycush. In Arctic char fry the body proportions are much more constant. This constancy is possibly the result of slow growth.

Head length (T). Arctic char fry have the smallest head, the mean values for the 2 size groups being 17.5 and 20.6. In cutthroat trout the proportional values are slightly higher; the range of means for 4 size groups is 18.2 - 24.1. In fry of the 4 species, 20.0 - 29.9 mm in total length, the value of $\frac{T}{TL}$ % acquires adult proportions. See Tables 45 and 12 - 14.

Maximum depth of body (H). Body depth is minimum in Arctic char. The means of the 2 size groups range 7.8 - 11.4. Body depth is maximum in brook char fry, with the means lying between 9.5 and 16.1. The body depths of the various species do not attain adult proportions in the length groups examined. See Table 45, and Fig. 6.

Predorsal fin length (aD). The predorsal length is minimum in brook char; the means for the 2 length groups are 40.5 and 42.9. The values in Arctic char are similar to those in brook char. The predorsal

TABLE 45. Selected body proportions, expressed as percentages of the total length and head length, in fry of various species of Salmonidae.
Explanations of abbreviations is given under the section "Methods".

Locality	No.	Total length[1] mm	In percentages of total length					Head length mm	In percentages of head length		
			T	H	aD	aV	aN		O	Mx	ma
						C.namaycush					
B	8	16.7-19.5 (17.8)	16.8-20.7 (18.5)	7.5-11.3 (8.3)	42.6-46.8 (44.0)	47.7-51.7 (49.9)	63.6-65.9 (64.8)	2.9- 3.9 (3.3)	41.9-46.7 (44.9)	34.5-40.6 (37.7)	40.0-43.8 (42.2)
	44	20.3-29.8 (23.5)	18.2-23.5 (21.1)	8.8-14.4 (12.3)	41.6-46.0 (43.8)	43.3-50.9 (47.8)	58.4-65.8 (63.5)	3.7- 6.5 (4.9)	31.5-48.8 (41.6)	29.3-43.9 (38.5)	38.1-46.6 (42.6)
C	4	45.0-49.3 (46.6)	22.9-23.5 (23.2)	13.2-13.9 (13.7)	43.1-23.5 (44.4)	45.8-48.1 (46.9)	62.9-64.6 (63.9)	10.3-11.0 (10.7)	36.1-38.8 (37.6)	36.4-38.8 (37.9)	41.7-42.9 (42.3)
						S.a.alpinus					
E	37	12.8-19.9 (17.0)	14.1-22.1 (17.5)	6.8-11.4 (7.8)	40.0-44.3[2] (42.9)	46.1-54.9 (50.9)	57.1-69.7 (63.3)	1.9- 4.3 (2.9)	34.6-55.0 (43.2)	25.0-37.5 (30.3)	31.3-40.5 (36.7)
	7	20.1-22.2 (21.2)	19.9-21.2 (20.6)	10.5-12.2 (11.4)	41.6-43.5 (42.4)	45.0-48.4 (47.5)	59.5-62.8 (61.1)	4.0- 4.6 (4.4)	32.6-43.5 (39.7)	26.1-38.1 (34.5)	39.1-44.4 (41.9)
						S.f.fontinalis					
I	18	12.7-19.6 (17.0)	16.3-21.4 (18.5)	7.1-11.9 (9.5)	40.8-46.5 (42.9)	47.7-52.2 (49.7)	59.7-68.1 (63.4)	2.4- 4.0 (3.2)	37.5-48.6 (43.6)	25.0-42.4 (36.3)	29.2-48.5 (40.9)
	24	20.2-27.7 (24.4)	19.3-23.0 (21.6)	9.9-17.9 (16.1)	37.8-42.1 (40.5)	42.9-48.7 (44.8)	55.3-62.9 (59.5)	3.9- 6.0 (5.3)	36.2-43.8 (40.2)	40.0-44.4 (42.8)	42.2-47.5 (45.1)
						S.f.timagamiensis					
J	20	23.0-25.8 (24.4)	18.5-20.9 (20.1)	10.9-13.1 (12.3)	40.5-43.8 (42.1)	42.9-46.2 (44.5)	56.8-61.2 (59.0)	4.6- 4.9 (4.8)	36.7-43.5 (40.2)	38.3-40.4 (39.2)	40.8-42.9 (42.1)
						Salmo clarkii					
M	3	17.0-19.4 (18.2)	15.9-19.7 (18.2)	9.8-12.9 (10.9)	45.4-48.2 (46.7)	53.3-54.6 (53.9)	63.4-65.6 (64.6)	2.7- 3.7 (3.3)	41.7-44.4 (43.1)	Not measured	
	8	20.4-26.8 (24.4)	20.6-25.4 (23.8)	11.3-14.3 (12.9)	41.5-47.5 (44.4)	43.0-50.0 (46.6)	59.6-66.2 (61.7)	4.4- 6.6 (5.8)	33.3-41.4 (37.1)	31.8-44.6 (40.2)	37.3-46.2 (43.5)
	2	30.0-32.9 (31.5)	23.5-24.8 (24.1)	16.7-17.3 (17.0)	43.5-44.7 (44.1)	46.0-47.4 (46.7)	61.4-61.7 (61.5)	7.6- 8.0 (7.8)	32.5-32.9 (32.7)	40.8-41.3 (41.0)	42.1-42.5 (42.3)
	3	43.8-49.2 (46.3)	22.8-25.5 (23.9)	16.7-18.5 (17.6)	43.4-44.8 (43.8)	47.9-48.8 (48.1)	60.7-62.2 (61.6)	9.3-11.4 (10.5)	30.8-32.3 (31.3)	41.2-42.1 (41.7)	42.1-43.0 (42.4)

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[1] Length groups of 10 mm were considered. The range and mean length of fry within these groups are given.
[2] In length group 10 - 20 mm, 37 fry were observed. The distance a D was measured on 19 fry, 16.0 - 19.9 mm.

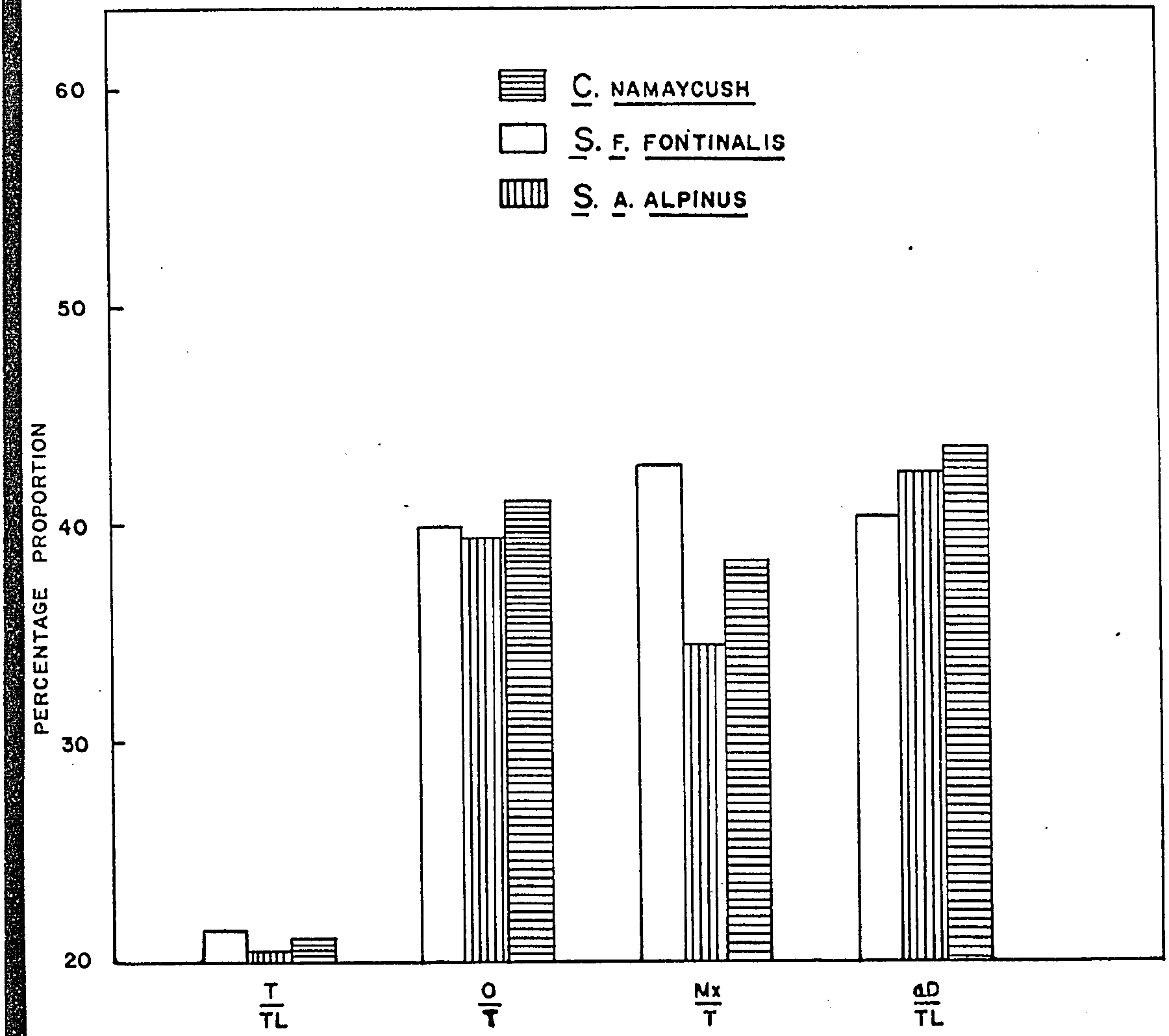

Fig. 6. Histograms showing the body proportions in fry of C.namaycush (44), S.f.fontinalis (24), and S.a.alpinus (7), expressed in percentages of either the total length of fry or head length of fry. The length group of fry considered is 20.0-29.9 mm. The number of fry used is shown in parentheses. For abbreviations see the section "Methods".

length is maximum in namaycush, the mean being about 44. In all the species except namaycush, the expected adult values for this character are attained in fry of about 22 - 25 mm in length. In namaycush mean values of about 47 - 49 are found for adults. See Tables 45 and 12 - 14, and Fig. 6.

Preventral fin length (aV). The preventral distance is slightly shorter in brook char; the range of means is 44.8 - 49.7. The means for the other species range 47 - 54 (Table 45).

Preanus length (aN). The preanus distance is maximum in namaycush, with a range of means 63.9 - 64.8, and minimum in brook and aurora chars, with a range 59 - 63.4 (Table 45).

Percentages of head parts in the total head length. In the several species studied, the lengths of the maxilla and the lower jaw increase and the diameter of the eye reduces with increasing head length. In fry of the various species none of these proportions attain adult values.

Horizontal diameter of eye (O). The values for diameter of the eye are slightly lower in cutthroat trout (range of means 31.3 - 43.1) than in the remaining species (range of means 37.6 - 44.9). See Table 45.

Length of maxilla (Mx). The maxilla is shortest in Arctic char fry (range of means 30.3 - 34.5) and longest in brook char (range of means 36.7 - 41.9). The values for cutthroat trout approach those for brook char (Table 45).

Length of lower jaw (ma). Arctic char fry has the smallest lower jaw (range of means 36.7 - 41.9) and brook char fry has the largest (range of means 40.9 - 45.1). The values for cutthroat trout fry approach those for brook char (Table 45).

Martin (1949) has pointed out that in namaycush fry between the sizes 20 - 30 mm in length, head length, eye diameter, body depth, and body width all increase rapidly with body growth. Beyond 30 mm these body parts more closely approximate isauxesis (Huxley et al 1941). But our observations on the 4 species show that the proportion of the diameter of the eye in the head length decreases with the increase in body length, and characters such as aD and aV approximate isauxesis even before the fry reach 30 mm (Table 45).

In 2 characters, aD and aN, Arctic char and brook char are similar. Brook and aurora chars overlap in many characters (Table 45). In 2 characters, Mx and ma, cutthroat trout fry approach brook char fry. Nevertheless, the 4 forms, namaycush, Arctic char, brook char, and cutthroat trout, can be separated.

Meristic Characters and Colouration

Meristic Characters. Wherever possible the minimum total length in mm and the minimum age in days at the appearance of a character are given. For details Tables 42 - 44 may be consulted.

The gill rakers are discussed under "Osteology".

Pectoral fin rays. In namaycush fry, pectoral fin rays first appeared at a minimum length of 18.8 mm (17 days). The number reached about 13 between 22 and 23 mm and acquired adult complements at about 23 mm. In a single fry of 29.8 mm the number of rays was 15. In Arctic char fry, rays first appeared at 15.5 mm (25 days). At 19.5 mm the number of rays (12 - 13) reached that seen in adults of the species. In brook char fry, rays were first observed at 16.5 mm (18 days). When the brook char fry attained the length of about 22 mm the number of rays was about equal to that of adult fish. Similar observations were obtained for aurora char. In cutthroat trout, rays first appeared at 17 mm. At 23 mm and 33 mm the numbers of rays were 13 and 15, respectively. In adult rainbow trout, another species in the genus Salmo and closely related to the cutthroat trout, the pectoral rays numbered 15 - 17. See Tables 46 and 34, and Fig. 7.

For his stock of brook char fry reared at 5.5°C, Wilder (1952) has given the mean as 12.7. Our mean value of 12.6 is in accordance with his.

Ventral fin rays. In namaycush fry, ventral fin rays first appeared at about 21 mm (20 days) and acquired the number (9 - 10) as seen in the adult at about 23 - 24 mm. In Arctic char the ventral fin rays

TABLE 46. Progressive increase in the number of fin rays, branchiostegal rays, and parr marks with the growth in size of fry of various species of Salmonidae. The following abbreviations are used: P = pectoral fin; V = ventral; A = anal; and Br. = branchiostegal rays

Species	Locality	No. of fry	Total length mm	Fin rays P	Fin rays V	Fin rays A	Br.	Parr marks
<u>C.namaycush</u>	B	8	16.7 - 19.5 (17.8)	5 - 7 (6.0)	- -	5 - 8 (6.0)	- -	- (4.0)
		44	20.3 - 29.8 (23.5)	8 - 15 (11.8)	4 - 10 (7.9)	8 - 13 (10.9)	4 - 12 (8.7)	5 - 9[1] (5.8)
	C	4	45.0 - 49.3 (46.6)	14 - 14 (14.0)	9 - 10 (9.5)	11 - 12 (11.8)	13 - 14 (13.3)	7 - 10 (8.8)
<u>S.a.alpinus</u>	E	37	12.8 - 19.9 (17.0)	4 - 13 (8.7)	3 - 6 (4.9)	3 - 11 (7.9)	1 - 7 (3.6)	- -
		7	20.1 - 22.2 (21.2)	11 - 13[2] (12.4)	4 - 8 (6.3)	10 - 12 (10.6)	5 - 8 (6.9)	Slight impression
<u>S.f.fontinalis</u>	I	18	12.7 - 19.6 (17.0)	3 - 10 (7.7)	3 - 5 (4.2)	3 - 10 (7.9)	1 - 5 (3.5)	- 4[3]
		24	20.2 - 27.7 (24.4)	11 - 13 (12.6)	5 - 8 (7.9)	10 - 13 (11.8)	4 - 11 (8.3)	5 - 8 (6.5)
<u>S.f.timagamiensis</u>	J	20	23.0 - 25.8 (24.4)	11 - 12 (11.4)	7 - 7 (7.0)	10 - 11 (10.9)	5 - 6 (5.6)	6 - 9 (7.4)
<u>S.clarkii</u>	M	3	17.0 - 19.4 (18.2)	7 - 10 (9.0)	- -	11 - 12 (11.7)	- -	- -
		8	20.4 - 26.8 (24.4)	11 - 13 (12.5)	6 - 9 (7.9)	13 - 15 (13.9)	7 - 11 (8.9)	8 - 10[4] (8.8)
		2	30.0 - 32.9 (31.5)	14 - 15 (14.5)	9 - 10 (9.5)	14 - 15 (14.5)	11 - 12 (11.5)	8 - 11 (9.5)
		3	43.8 - 49.2 (46.3)	14 - 15 (14.7)	10 - 10 (10.0)	15 - 16 (15.3)	11 - 12 (11.7)	10 - 11 (10.7)

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[1] Under our conditions the parr marks appeared at a length of 21.4 mm, big black blotches among the parr marks are not included in the count.

[2] Only in 2 fry is the number of pectoral rays found to be 11.

[3] In brook char under our conditions the parr marks first appeared at a length of about 19 mm.

[4] The parr marks are observed at a length of 23 mm.

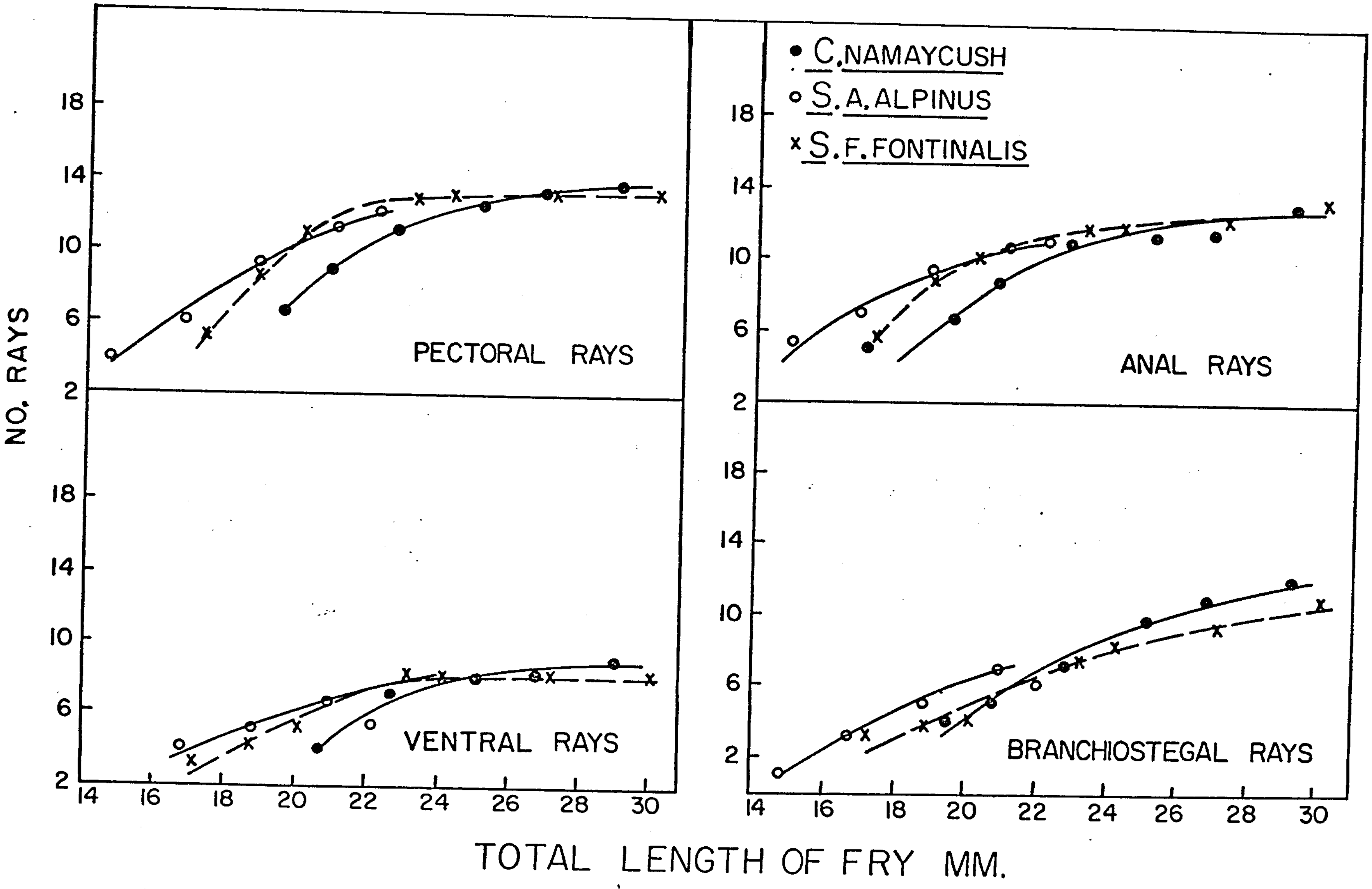


Fig. 7. Increase in the number of rays in various fins and branchiostegal rays with the increase in the total length of fry of C.namaycush, S.a.alpinus, and S.f.fontinalis.

were first observed at 17.4 mm (40 days). The number 7 - 8 was reached at 21 - 22 mm. This was somewhat less than the number usually seen in adults. In brook char fry, rays first appeared at 17.7 mm (20 days). At 23 mm the number increased to 8. The number of ventral fin rays in aurora char was similar to that in brook char. Seven rays were observed in cutthroat trout fry at 20.4 mm. At 25 mm and 30 mm the numbers reached 9 and 10, respectively, which approximated the numbers seen in adult fish. See Tables 46 and 35, and Fig. 7.

In his stock of brook char fry reared at 5.5°C, Wilder (1952) observed a mean number of 8.0 ventral fin rays, close to our mean number of 7.9.

Anal fin rays. Anal fin rays were first observed in namaycush fry at a length of 17.6 mm (8 days). The number of rays reached 12 - 13 at 26 - 27 mm. The range of the number of anal rays in adult namaycush was 13 - 15. In brook char fry, anal fin rays were first seen at 16.5 mm (18 days). The number of rays reached 11 - 13 at 22.8 - 23.9 mm; the range in the adults was 10 - 13. The number of rays in aurora char fry was slightly lower (10 - 11) than that in brook char. In Arctic char fry the rays were first noticed at 14.8 mm (20 days). The number of rays reached 10 - 12 at 20.1 - 22.2 mm; the range in adult Arctic char was 12 - 14. In cutthroat fry the anal rays first appeared at 17 mm. The number reached 14 - 15 at 26.0 - 26.8 mm. In adult rainbow trout the range of the number of anal rays was 12 - 15. See Tables 46 and 33, and Fig. 7.

Wilder's (1952) mean value for the number of anal fin rays in brook char fry was lower (9.8) than ours.

In the several species of Salmonidae the dorsal fin rays appeared at the same minimum lengths and ages as the anal fin rays.

Branchiostegal rays. In namaycush fry the branchiostegal rays first appeared at 19.5 mm (18 days) at the posterior ventral region of the skull. The number reached 12 at 27 - 28 mm and 13 - 14 at 45 - 49 mm. In Arctic char and brook char fry the branchiostegal rays appeared at 14.8 mm and 16.5 mm, respectively. In Arctic char fry the highest number of rays (8) was reached at 21 - 22 mm. This number (8) was the minimum for S. alpinus oquassa. In brook char fry of about 28 mm long the number of branchiostegal rays increased to 10 - 11. The mean for adult brook char was 11.3. The numbers of rays in aurora and brook chars were comparable. In cutthroat trout fry 30 mm long the maximum number of branchiostegal rays was 12. See Tables 46 and 37, and Fig. 7.

For brook char fry Wilder's (1952) mean value was 11.8, which was close to our value for adult brook char.

Parr marks. In namaycush fry, parr marks were seen at 21.4 mm (20 days). The number reached 8 - 9 at 27 - 29 mm and 10 at 49 mm. The anterior-most (near the opercle) 2 - 3 parr marks were oblong and at times were below the lateral line. Parr marks under and beyond the region of the dorsal fin were somewhat circular, less defined, and bisected by the lateral line (Pl. 12, A). In addition to parr marks the namaycush fry (43 - 45 mm) had 3 - 5 black blotches, about half the size of the parr marks, above the lateral line but below the dorsal fin.

In brook char fry, parr marks were noticed at a length of about 19 mm (30 days). In fry at 27 mm the number was 8. Black blotches among the parr marks were present both above and below the lateral line. The parr marks in brook char were about twice the size of those in namaycush (Pl. 12, B). Parr marks of aurora char were comparable to those of brook char.

In Arctic char fry up to a total length of 22 mm no definitive parr marks were noticeable (Pl. 12, C1-2). Larger sized fry were not available.

In cutthroat trout fry, 8 parr marks were enumerated at a length of about 23 mm. The highest number (10 - 11) was attained at about 33 - 49 mm. A few black blotches among the parr marks were present but only above the lateral line.

See Table 46 for parr marks in all the species.

Vladykov (1954) gave the mean number of parr marks as 9, 9.9, 11.7, 12.3, and 12.2 for brook char, namaycush, Sunapee char, Quebec red char, and Arctic char fry, respectively. It is difficult to compare the present findings with his values because he included the incomplete bars in his count. However, his observations showed that Arctic, Quebec red, and Sunapee chars were similar for this character. Bacon (1954) wrote that parr marks in brook char from Montana, U.S.A., were large and pear shaped. Carl et al.(1959) mentioned that brook char fry (species introduced in B.C.) had long brown parr marks. The range of the number of parr marks in Dolly Varden char was reported by Chamberlain (1907) and Carl et al.(1959) to be 7 - 10. In addition, parr marks were reported to be wide and roundish in Dolly Varden char.

Carl et al.(1959) noted about 10 parr marks in very young cutthroat trout and 9 - 13 dark oval parr marks in very small rainbow trout. Chamberlain (1907) noted 9 - 12 parr marks in rainbow trout fry and thought they were indistinguishable from those of cutthroat trout fry.

In fry of the four species of Salmonidae the number of pectoral, ventral, dorsal, and anal fin rays increased with the length of the fry. In various fins the number of rays in fry approached that in adults at lengths of 23, 20, 23, and 23 mm in namaycush, Arctic char, brook char, and cutthroat trout fry, respectively. In practically all the fins the rays appeared at younger ages in namaycush fry.

The branchiostegal rays achieved the numbers seen in the adult at about the same length (28 mm) in namaycush, brook char, and cutthroat trout fry. At a length of 22 mm there were 8 branchiostegal rays in Arctic char, the minimum number for the adult of the species.

For various species in the length groups examined, the near maximum number of parr marks were observed at lengths of about 21, 26, and 33 mm in namaycush, brook char, and cutthroat trout, respectively. Parr marks were absent (or barely seen) in Arctic char up to a length of 22 mm.

Table 46 gives the impression that among chars and namaycush, the highest value of a character is generally seen in namaycush, followed by brook char fry. The values are lowest in Arctic char fry.

For the various species of Salmonidae it can safely be said that at 30 mm the meristic characters attained adult proportions.

Colouration. The eyed eggs of S.a.alpinus, C. namaycush, and S.f. fontinalis were extremely weakly pigmented, lightly pigmented, and strongly pigmented, respectively.

TABLE 47. Description of pigmentation in sac fry and fry of various species of Salmonidae; magnified 10x. The number of fry used for various species is about the same as in Table 46. o = absence of pigmentation; (+)=extremely weak pigmentation; + = weak pigmentation; ++ = moderate pigmentation; +++ = strong pigmentation.

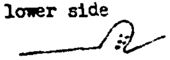
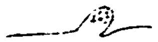
Species	Locality	Total length mm (stage)	Body				Head				Fins		
			Flank	Upper surface of yolk sac	Back ant. to dorsal fin	Pre-dor. fin-fold	Dentary	Chin and isthmus	Floor of the mouth cavity	Bases of gill lamellae	Pectoral	Anal	Adipose[2]
C. namaycush	B	17 (sac fry)	(+)	(+)	(+)	o	o	o	o	o	o	o	 No speckling
		20 - 22 (sac fry)	+	+	+	+	(+) anterior 1/3	(+) chin only	(+)	(+)	o	o	 dark speckling on posterior and lower side
		25 - 29[1] (advanced fry)	++	yolk sac absorbed	++	+	+ more than ant. 1/3	(+)	+	+	(+) only base	o	 dark speckling on posterior and lower side
	C	45 - 49 (advanced fry)	++	absorbed	++	+	+ more than ant. 1/3	(+)	+	+	(+) only base	(+) only ant. edge	 dark speckling on posterior and lower side
S. a. alpinus	E	13 - 15 (sac fry)	(+)	(+)	(+)	o	o	o	o	o	o	o	 no speckling
		19 - 22 (fry)	(+)	absorbed	(+)	o	o	o	o	(+)	o	o	 no speckling
S. f. fontinalis[3]	I	13 - 16 (sac fry)	+	+	+	+	o	o	o	o	o	o	 no speckling
		19 - 21 (sac fry)	++	++	++	++	++ ant. $\frac{1}{2}$	+	++	++	o	o	 dark speckling on upper half of fin
		23 - 27 (advanced fry)	++	absorbed	++	++	+++ ant. $\frac{1}{2}$ symphysis black	+	++	++	o	o	 dark speckling on upper half of fin
S. f. timagamiensis[4]	J	23 - 26 (advanced fry)	++	absorbed	++	++	+++ ant. $\frac{1}{2}$	+	++	++	o	+ base and postero-ventral region	 dark speckling on upper half of fin

Table 47 cont.

Species	Locality	Total length mm (stage)	Body				Head				Fins		
			Flank	Upper surface of yolk sac	Back ant. to dorsal fin	pre-dor. fin-fold	Dentary	Chin and isthmus	Floor of the mouth cavity	Bases of gill lamellae	Pectoral	Anal	Adipose
S.clarkii[5]	L	18 - 21 (sac fry)	+++	+++	+++	+++	++ complete symphysis of dentary not as dark as in brook char	++	++	++	++ complete	++ complete	—2 rim around adipose speckled with 1 or 2 breaks
		24 - 28 (advanced fry)	+++	absorbed	+++	+++	+++ complete symphysis not as dark as in brook char	+++	+++	+++	++ complete also large black spots at the base	++ complete	—2 rim around adipose speckled with 1 or 2 breaks
		43 - 49 (advanced fry)	+++	absorbed	+++ usually fewer than five, often none, dark parr marks ant. to dorsal fin present	+++	+++ symphysis not as dark as in brook char	+++	+++[2]	+++	++ complete also large black spots at the base	++ complete	—2 rim around adipose speckled with 1 or 2 breaks

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[1] Tail starts to fork at about 26 mm. The fin-fold was mostly lost at 29 mm.
[2] Adipose fin was demarcated at about 24 - 25 mm.
[3] Fin-fold posterior to the adipose and anal fins was present in fry of 27 mm long. Definite adipose fin developed at about 23 mm.
[4] Only in S.f.timagamiensis have the extremities of the dorsal and the caudal fins yellowish orange tinge.
[5] Fin-fold was completely lost at about 43 mm. Adipose fin was demarcated at about 24 mm.

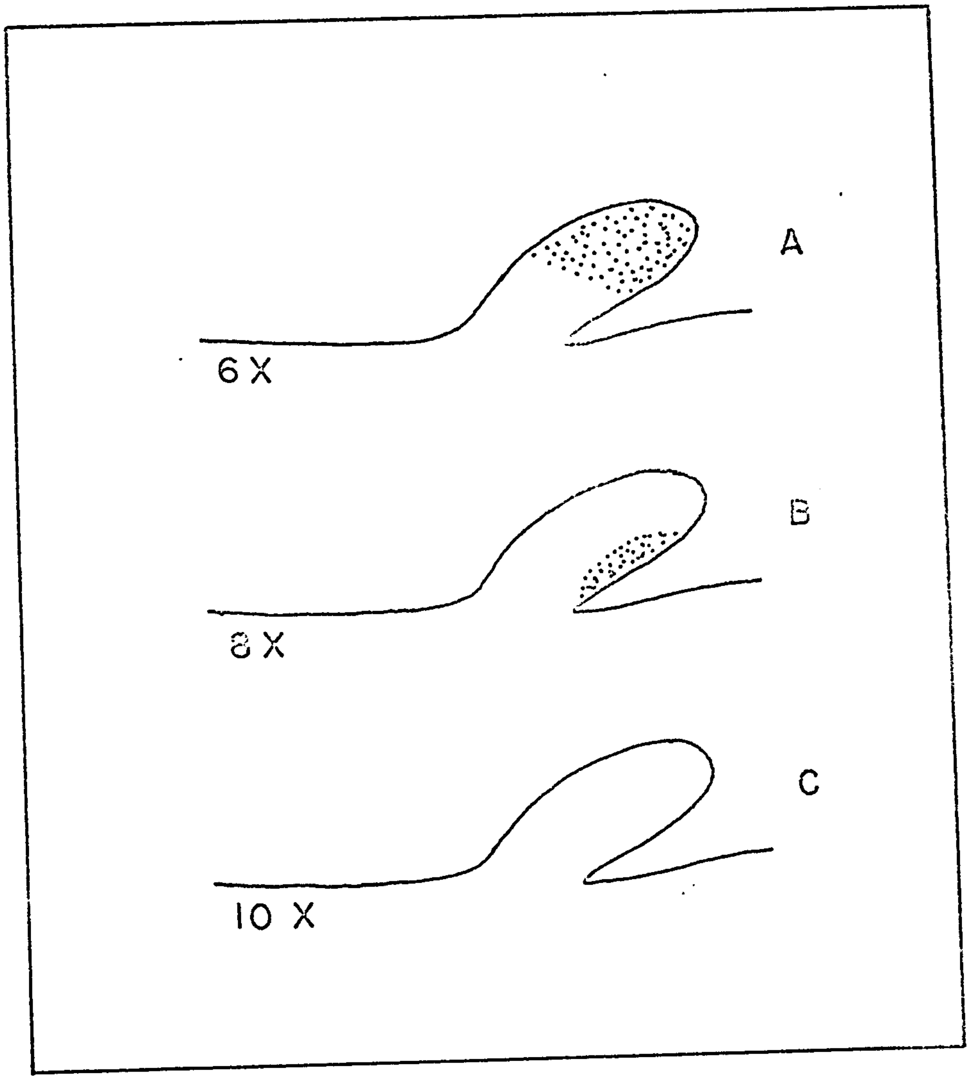

Fig. 8. Schematic drawings of the adipose fins showing the differences in pigmentation. In each case the fry were about 3 months old. A- S.f.fontinalis; B- C.namaycush; C- S.a.alpinus.

Generally, the intensity of the black pigmentation was extremely weak in fry of Arctic char and namaycush, moderate to strong in brook char, and strong in cutthroat trout. The size of the melanophores was largest and star-shaped in namaycush, and smallest and roundish in cutthroat trout. In body pigmentation brook char was closer to cutthroat trout than to the other chars. Usually, the intensity of pigmentation increased with the length of the fry.

Pigmentation on the dentary, mouth cavity, adipose fin, pectoral fin, anal fin, and back of the fry separated the species of Salmonidae (Table 47, and Fig. 8).

Carl _et_ _al_.(1959) described the young of namaycush without a black line on the chin or at most a few scattered brown speckles; our observations were similar. Bacon (1954) mentioned that in brook char, the surface of the abdomen and the chin were immaculate. Carl _et_ _al_. (1959) wrote that brook char young had a blackish line around the tip of the chin, a dark margin on the adipose fin, and a black strip along the front of the dorsal fin. Bacon, and Carl _et_ _al_. used the advanced fry of 1.5 - 2 inches in length. Our observations on the advanced fry of brook char were to a certain extent in accordance with those of Carl _et_ _al_.; however, our specimens were much smaller.

For cutthroat trout our findings were in agreement with those of Carl _et_ _al_. (1959).

DISCUSSION

In appropriate sections our results are already discussed and compared with the findings of earlier workers. In this part I am avoiding detailed discussion of the results and am providing only necessary information. In the light of modern definitions various categories---genera, species, and subspecies---are decided. Moreover, only the scientific names of the fishes are used.

Genera

In Salmonidae the genera Brachymystax, Hucho, Salvelinus, Salmo, and Oncorhynchus are universally accepted. The status of the genera Cristivomer and Salmothymus is still disputed.

Probably no taxonomic category causes as much difficulty as the genus. The definitions of the species and family are relatively stable. The genus lies in between the species and family; therefore the generic boundaries are made to fluctuate a little. However, the genus is a more usable and reliable unit for classification (Simpson, 1961). An objective definition of the genus is rather impossible. A convenient definition of it as proposed by Mayr, Linsley, and Usinger (1953) and accepted here is: "A genus is a systematic category including one species or a group of species of presumably common phylogenetic origin, which is separated from other similar units by a decided gap." The two essential criteria of the genus are morphological distinctness, and the natural occurrence of its species in a well defined ecological niche. Preferably, the genus should be defined on the basis of the combination of characters and not by a single character (Edwards, 1953).

Inger (1958) and Vladykov (1963) suggested that the osteological characters should be preferred to determine the genus, and the morphometric and meristic differences to determine the species ranking. Since the form and structure of an individual are the results of its genetic composition, and physiological and ecological adjustments, therefore, wherever possible, these criteria should also be considered to decide a genus as well as other taxa.

With the recent development of systematics (Huxley, 1940; Mayr, 1942) many of the earlier taxonomic works are evaluated. Presently, we are looking more for lineage and relationships and are not satisfied with merely naming the animal. Revisions or new attempts have been made to assess the systematics of the isospondylous fishes (Gosline, 1960 and 1961) and the family Salmonidae (Vladykov, 1962 and 1963). The genus *Cristivomer* is no exception.

Until 1914 most ichthyologists accepted the genus *Cristivomer* because of the long crest of the vomer. Regan (1914) and Kendall (1914) amalgamated *Cristivomer* and *Salvelinus* and thought that the crest of the vomer in *S. fontinalis* was intermediate between those in *C. namaycush* and *S. alpinus*. Kendall (1919) retracted his judgment and accepted *Cristivomer*. Ten years ago Morton and Miller (1954) synonymized *Cristivomer* and *Salvelinus* and started the controversy over the generic status of *Cristivomer*. They disregarded the long crested vomer and the wide patch of basibranchial teeth in *Cristivomer* as being of generic significance. The position of the dorsal fin, the deeply forked caudal fin, and the higher number of pyloric caeca in *Cristivomer* were considered by them to be specific only. In the same year Vladykov (1954) retrieved *Cristivomer* as a genus because of the shape of the supraethmoid bone, parallel rows of teeth on the lingual plate, and the presence of pearl organs. Recently, Vladykov (1963) and Dymond (1964) accepted the genus *Cristivomer*. In the present study many qualitative as well as quantitative characters are considered in order to retain the genus *Cristivomer*.

The olfactory and frontal cartilaginous areas of the chondrocranium are flat in *Cristivomer* as opposed to the slightly convex condition seen in *Salvelinus*, *Salmo*, or *Oncorhynchus*. The median strip of cartilage (*taenia tecti medialis*) which separates the two dorsal fontanelles is much narrower and longer in *Cristivomer* (Pl. 1, A) than in *Salvelinus* (Pl. 1, F, H, and J1-2), *Salmo* (Pl. 1, K), or *Oncorhynchus*.

The presence of the single orbitosphenoid bone has been considered one of the special features of Salmonidae. In the genera *Cristivomer* and *Salvelinus* the bone is paired. The orbitosphenoid is absent from 30 per cent of the specimens in *Cristivomer* (Pl. 1, B) but always present in the other genera of the family. At present the significance of this bone is not well understood for *Cristivomer*.

In *Cristivomer* the supraethmoid is without a rounded front head (Pl. 4, A), whereas in *Salvelinus* the head is distinct (Pl. 4, C). In *Cristivomer* the mean value of $\frac{L}{L_1}$ per cent is 68.9, while in various species of *Salvelinus* the means ranged between 81.3 and 101.5 (Table 6). Kendall's (1919) and Vladykov's (1963) conviction for the separation of *Cristivomer* from *Salvelinus* by considering the shape of the supraethmoid is confirmed.

In *Cristivomer* the frontals (Pl. 6, A) are long and triangular bones. The caudolateral projection of the frontal which meets the dermal crest of the pterotic is more developed in *Cristivomer* than in *Salvelinus* (Pl. 6, B-H).

In *Cristivomer* the supramaxilla is a thin narrow bone tapered at both ends (Pl. 3, A; Pl. 4, A). In several species of *Salvelinus* and *Salmo gairdnerii* the bone is much wider in the posterior than in the anterior region (Pl. 4, C-G and J). In *Cristivomer* the mean value of $\frac{W}{L}$ per cent is 12.3, whereas in various species of *Salvelinus* (except brook char, mean 10.8) the means ranged from 15.3 to 21.9 (Table 7).

The postorbital 1 is neglected by earlier workers. In *Cristivomer* the bone is thin, plate-like, and does not bear a notch on the posterior margin of its vertical arm(Pl. 4, A). In *Salvelinus* this notch is present and the bone is the longest of the 3 or 4 postorbital bones (Pl. 4, C-I).

The anterior portion and hook-like process of the subopercle are narrow and distinctive of *Cristivomer* (Pl. 6, A). In *Salvelinus* and *Salmo gairdnerii* this process is broad (Pl. 6, B-H; Pl. 6, I).

In earlier studies heavy emphasis was laid on the shape of the vomer and the presence of teeth on the crest or shaft of the vomer (Regan, 1914; Kendall, 1914, 1919; Morton and Miller, 1954). This bone is important in segregating the genera of Salmonidae into 3 groups. In *Brachymystax* and *Hucho* the teeth are located only on the head of the vomer. *Cristivomer* and *Salvelinus* have teeth on the crest of the vomer. Moreover, in *Cristivomer* the crest is usually long and attached to the shaft (Pl. 5, B), contrary to its detached condition in *Salvelinus* (Pl. 5, C-E). *Salmothymus*, *Salmo*, and *Oncorhynchus* have teeth on the shaft of the vomer. In *Cristivomer* the mean value of $\frac{L1}{L}$ per cent is 76.7 against 41.1 - 52.8 for various species of Salvelinus (Table 10).

In our samples of Cristivomer, the teeth on the lingual plate are arranged on the outer edges in two rows parallel to each other, one on each side of the plate (Pl. 5, B). Vladykov (1954) showed the two parallel rows of teeth closer to each other and situated in the middle of the plate. I have checked this condition in his study material. As a result, it seems logical to comment that the position of the rows of teeth is not stable and should be viewed carefully. Besides, a somewhat similar pattern of parallel rows of teeth is observed in some specimens of S. malma (Pl. 5, G). Usually in Salvelinus the teeth on the lingual plate form equal sides of an isosceles triangle (Pl. 5, C-F, and H-I). In Cristivomer the distances between the tooth rows at the anterior and posterior ends of the plate are about equal; in Salvelinus the distance between the tooth rows at the anterior end is considerably shorter than that at the posterior end. See Table 10.

The multiserial arrangement and higher number of basibranchial teeth in Cristivomer were used to separate it from Salvelinus (Stokell, 1951). In the present study the basibranchial teeth in S. a. alpinus are found to be multiserially arranged and higher in number than in Cristivomer (Pl. 8, D). Morton and Miller (1954) and McPhail (1962) have also stated the multiserial condition of teeth in S. alpinus. The basibranchial teeth should not be used to separate Cristivomer from Salvelinus.

Kölliker (1860), Vladykov (1954 and 1962), and Gosline (1960 and

1961) have emphasized the importance of the caudal skeleton for separating salmonid fishes. In the present study it is observed that in Cristivomer the expanded neural and haemal processes are broader proximally and more pointed distally (Pl. 11, A) than those in Salvelinus (Pl. 11, B-G).

In Cristivomer the presence of pearl organs was first reported by Vladykov (1954). In all the other genera of Salmonidae the pearl organs are absent. These organs are found in several families such as Coregonidae and Osmeridae of the order Clupeiformes.

The flank of the body is spotted with white and gray in Cristivomer, whereas in Salvelinus the spots are orange or red. The same observations were made by Morton and Miller (1954) and Vladykov(1954).

Waters (1960), because of serological tests, concluded that "Cristivomer represents a distinct genus, perhaps no more closely related to Salvelinus than the Atlantic salmon."

Females of Cristivomer namaycush never dig a redd (Royce, 1951) during the reproductive period. However, such digging is commonly observed in all other Salmonidae.

The natural distribution of the genus Cristivomer is restricted to the freshwater lakes of North America (Hubbs and Lagler, 1958; Vladykov, 1963). Nevertheless, Dunbar and Hilderbrand (1952) and Walters (1953) have reported stray cases of C. namaycush from the brackish waters of Ungava Bay and from western Arctic America, respectively. Salvelinus is holarctic and naturally distributed in North America, north Asia, and Europe (Dymond and Vladykov, 1934, and Vladykov 1963).

More differentiating characters between *Cristivomer* and *Salvelinus* are discussed with the descriptions of the species.

Having considered the above differences between the genera *Cristivomer* and *Salvelinus*, the genus *Cristivomer* should be maintained. The author joins with Kendall (1919), Stokell (1951), Vladykov (1954 and 1963), Dymond (1964), and many others who consider *Cristivomer* a distinct genus.

The genus *Baione* of DeKay (1842) and Slastenenko (1958) and subgenus of Vladykov (1954) was established on the basis of the following characters: absence of basibranchial teeth; presence of uninterrupted row of vomerine and palatine teeth; square caudal fin in adult; lower fins with a black stripe. This taxon should be synonymized with *Salvelinus* for the reasons that the basibranchial teeth have been observed in both the forms of *S. fontinalis* and their absence has been noticed in *S. a. oquassa*. The uninterrupted row of vomerine and palatine teeth has been observed in *S. alpinus* populations by the author and also by McPhail (1961). The square caudal fin is seen in adults of *S. malma*. The colour patterns which help to characterize *S. fontinalis* should be considered to designate only specific, but not generic or subgeneric, differences. Therefore *S. fontinalis* is included in the genus *Salvelinus* and not *Baione*.

The genus *Salmothymus* was established by Berg in 1908. But Regan (1920) and Norden (1961) synonymized it with *Salmo*. Hadžišče (1960) and Vladykov (1963) retained this genus. I have studied the osteology of *Salmothymus ohridanus* and feel that the genus should be kept. *Salmothymus ohridanus* has a small mouth, and the jaw hinge is situated below the posterior margin of the orbit (Pl. 3, G). The premaxilla is triangular in shape as opposed to the wing-shaped condition seen in Salmo (Pl. 4, J). The head of the maxilla is short as opposed to the long head in Salmo (Pl. 4, J). The supramaxilla is tapered at both ends as opposed to the elliptical shape in Salmo (Pl. 4, J). The vomerine and palatine teeth are not separated in Salmothymus ohridanus, but separation is evident in Salmo. Teeth on the lingual plate of the former are arranged in 4 - 5 rows as opposed to the triangular arrangement in the latter.

It may be added that the genera Salmothymus and Salmo are closely related because of the shape of the supraethmoid, the absence of basibranchial teeth, the presence of teeth on the shaft of the vomer, and the presence of black spots on the body.

Teeth on the lingual plate form equal sides of an isosceles triangle in Salmothymus letnica and Salmothymus obtusirostris. Possibly these two species are closer to Salmo than Salmothymus ohridanus.

Species

The species represent an important level of integration in living nature. The recognition of the species is fundamental to pure as well as to applied biology. Communication of the results of scientific findings depends on the correct identification of the species involved. Three important aspects of species are stressed in modern discussions. Mayr (1963) states that: 1. the species are based on distinctness rather than on difference and therefore are to be defined biologically rather than morphologically; 2. they consist of populations rather than of unconnected individuals; 3. they are more succinctly defined by isolation from non-conspecific populations than by the relation of conspecific individuals to each other. In his words "the crucial species criterion is thus not the fertility of individuals but rather the reproductive isolation of populations".

Meglitsch (1954) distinguishes three species concepts, the phenotypic, genetic, and phylogenetic. Mayr's (1963) basic species concepts are the typological, nondimensional (reproductive gap), and multidimensional (gene flow). The definition of the species in the last 100 years has been based on one or the other of the above concepts. More recently (within the last 30 years), the typological concept of the species has nearly faded away (Simpson, 1951). Most emphasis is now placed on the nondimensional and the multidimensional species concepts. A trend toward acceptance of a synthetic species definition often referred to as biological species definition is gaining momentum (Stresemann, 1919; Rensch, 1929; Du Rietz, 1930). Dobzhansky (1950) defined the species as "the largest and most inclusive reproductive community of sexual and cross fertilizing individuals which share in a common gene pool". Simpson (1961) defined species as "a genetic group of organisms so constituted and so situated in nature that a hereditary character of any one of these organisms may be transmitted to descendants of any other". Mayr (1940 and 1963) defined species as "groups of actually or potentially interbreeding natural populations which are reproductively isolated from other such groups".

Mayr's definition is the one accepted in this paper. The number of species in the genera Cristivomer and Salvelinus are evaluated under the influence of this modern thinking.

The genus Cristivomer is monotypic. However, Slastenenko (1958) attributed C. siscowet to the genus. Hubbs and Lagler (1958) observed one form each from the deeper waters of Lake Superior and Rush Lake and gave them subspecific rank, C. n. siscowet and C. n. huronicus, respectively. We did not have an opportunity to examine these two forms.

The genus Salvelinus is polytypic. According to some authors, in North America these chars fall into three species, the S. alpinus complex, S. malma, and S. fontinalis, and their possible forms (Bailey, et al., 1960; McPhail, 1961). Other authors consider the above three forms plus the following four as distinct species under Salvelinus: S. aureolus, S. marstoni, S. oquassa, and S. timagamiensis (Kendall, 1919; Everhart, 1950a). In our description S. alpinus, which is circumpolar in distribution, refers to a complex of forms, not to a single species (Jordan, Evermann, and Clark, 1930; Walters, 1955). Recently McPhail (1961) considered S. rossii, S. alipes, S. nitidus, S. arcturus, and S. naresii synonymous with S. alpinus.

The question of the distinctness and validity of the species of Salvelinus is an important one and deserves attention.

The shape of the supraethmoid bone in S. a. alpinus is much broader posteriorly (Pl. 4, C) than in S. malma (Pl. 4, G) and S. f. fontinalis (Pl. 4, H).

The frontal bone in S. a. alpinus (Pl. 6, B) is not so long as in S. malma (Pl. 6, F) and S. f. fontinalis (Pl. 6, G).

The shapes of the parasphenoid in S. a. alpinus (Pl. 5, C), S. malma (Pl. 5, G), and S. f. fontinalis (Pl. 5, H) are different.

Slight differences are also observed in the shapes of postorbital 1 in S. a. alpinus (Pl. 4, C), S. malma (Pl. 4, G), and S. f. fontinalis (Pl. 4, H).

In *S. fontinalis* uroneural 1 is broad (Pl. 11, F and G). It is usually crescent-like in *S. alpinus* (Pl. 11, B and C). The second expanded haemal process is broader distally in *S. fontinalis* than in *S. alpinus* and *S. malma*.

Martin (1949), Milne (1948), Wilder (1952), Vladykov (1954), and Hartman (1956) have studied the morphology of Salmonidae and have established the taxonomic status of various groups and forms. We have examined 17 body and head proportions to ascertain differences among several forms. *Cristivomer namaycush* differed from various species of *Salvelinus* in 11 characters.

We have shown in earlier pages that the caudal fin is deeply forked in *C. namaycush* but not in *S. fontinalis*. The forked nature of the fin in *S. alpinus* and *S. malma* is intermediate between these two extremes. See the values of $\frac{TL}{FL}$ per cent in Tables 12 - 14. Also refer to Table 20. Earlier Morton and Miller (1954) and Slastenenko (1958) reported similar observations.

The predorsal fin length (aD) is longest in *C. namaycush* and shortest in *S. a. oquassa* - Floods Pond pop. Consult the values of $\frac{aD}{FL}$ per cent in Tables 12 - 14. See also Table 20. Vladykov's (1954) values for this proportion are higher for spawning males of *S. alpinus*.

The preventral fin length (ma-V) is maximum in *C. namaycush* and minimum in *S. f. fontinalis*. See the values of $\frac{ma\text{-}V}{FL}$ per cent in Tables 12 - 14. Also consult Table 20.

The head is longest in *C. namaycush* and shortest in *S. a. alpinus*. Consult the values of $\frac{T}{FL}$ per cent in Tables 12 - 14. Also see Table 20. Similar observations are reported by Vladykov (1954) and Slastenenko (1958).

The interorbital space (I) in *C. namaycush* is narrower and significantly different from those in various species of *Salvelinus*. The values of $\frac{I}{T}$ per cent may be consulted in Tables 16 - 18. See also Table 20. Kendall (1919) made a similar observation.

The body length (BdL_1) is longest in *S. a. alpinus* and significantly different from those in *C. namaycush*, *S. malma*, and *S. fontinalis*. The values $\frac{BdL_1}{FL}$ per cent may be consulted in Tables 12 - 14. Also refer to Table 20. This proportion signifies that the head is smaller in *S. a. alpinus* from the Canadian Arctic than in the three populations of *S. a. oquassa* (Tables 12 - 13). Martin (1949) and Vladykov (1957) have suggested the same phenomenon is fishes where the heads were shorter in the northern populations of a species than in its southern populations.

In *S. a. alpinus* the distance from the origin of the ventral to the origin of the anal fins (V-A) is longest and significantly different from those in other species. The values of $\frac{V-A}{FL}$ per cent may be seen in Tables 12 - 14. Also consult Table 20.

In *S. a. alpinus* the mean value of $\frac{\text{the head length (T)}}{\text{the body length } (BdL_2)}$ per cent is lowest and significantly different from those in *C. namaycush* and the other species of *Salvelinus* (Table 20).

None of the body proportions of *S. malma* are significantly different from those of other species of the genus *Salvelinus*. However, the proportional values of the distance from the origin of the pectoral fin to the origin of the ventral fin (P-V) and the length of the lower jaw (ma), expressed as percentages of the fork length and the head length, respectively, are lowest. See Tables 12 - 14.

S. fontinalis is not significantly different from other species of

Salvelinus in any body proportion. However, the proportional values of the total length (TL), body length (BdL_2), and preventral fin length (ma-V), expressed as percentages of the fork length, are lowest in S. fontinalis. The lengths of the upper and lower jaws are near maximum in S. f. fontinalis (maximum and significantly different in S. f. timagamiensis). Consult Tables 12 - 14, 16 - 18, and 20.

Meristic characters are extensively used in fish taxonomy (Taning, 1952; Svärdson, 1957; Seymour, 1959). We will very briefly discuss some of these characters.

In S. a. alpinus the mean number of total vertebrae is highest whereas in S. fontinalis it is lowest (Table 21). S. a. alpinus, S. f. fontinalis, and S. f. timagamiensis are significantly different (Table 40). Our values for S. a. alpinus are in accordance with those of Delacy and Morton (1943) and McPhail (1961). Our values for vertebral counts in S. fontinalis correspond well with those of Wilder (1952).

Among the foreign genera Salmothymus ohridanus has the minimum number of vertebrae.

The number of neural arches not fused with the vertebrae is highest in S. a. alpinus and lowest in two forms of S. fontinalis (Table 23). These three fishes are significantly different (Table 40).

The total number of gill rakers is highest in S. a. alpinus and lowest in S. malma. C. namaycush has the intermediate value. The number of gill rakers separates these three fish. Consult Tables 36 and 40. Our values are in accordance with those of McPhail (1961). This character has been considered very stable by McPhail (1961) in S. alpinus and S. malma.

In *S. malma* the mean of the total number of branchiostegal rays is highest and significantly different from those of the other species examined (Tables 37 and 40).

The total number of pyloric caeca is one of the important taxonomic characters to differentiate *Cristivomer* from *Salvelinus*. In *C. namaycush* the mean number of pyloric caeca is highest and significantly different from those of the various species of *Salvelinus* (Tables 38 and 40). Our counts for the several species correspond well with those of Morton and Miller (1954), Vladykov (1954), Carl, Clemens, and Lindsey (1959), and McPhail (1961).

The mean for the total number of pores on lateral line scales is maximum in *S. a. alpinus* and separates this form from the other species (Tables 39 and 40). Our values are in confirmation with those of McPhail (1961).

Information on other meristic characters, as for instance, the number of pectoral fin rays, dorsal fin rays, anal fin rays, and total number of ribs, etc., may be obtained from the section "Meristic Characters" of adult fish.

With respect to colour, *S. fontinalis* is particularly distinct and can be easily segregated from other species of *Salvelinus* and from *Cristivomer namaycush*. In *S. fontinalis* the lower fins have a white edge which is followed by a black stripe.

The developmental history of the fry of *C. namaycush*, *S. a. alpinus*, and *S. f. fontinalis* suggests that ossification in several bones begins at a younger age in *C. namaycush* (Tables 42 - 44 and Fig. 5).

C. namaycush fry can be separated from those of *S. a. alpinus* and

S. f. fontinalis because of the longer predorsal fin length (Table 45 and Fig. 6). *S. fontinalis* fry have a longer upper and lower jaw than fry of *S. a. alpinus* and *C. namaycush* (Table 45 and Fig. 6).

The pigmentation of fry (particularly of the adipose fin) segregates *C. namaycush*, *S. a. alpinus*, and *S. f. fontinalis* (Table 47 and Fig. 8). Also refer to Pl. 12.

The study of the osteology, morphology, and meristic characters of adult fish and fry suggests that *C. namaycush*, *S. alpinus*, *S. malma*, and *S. fontinalis* are distinct species.

This brings us to another difficulty, the subspecific ranking of the various populations of these species.

Subspecies

Mayr (1963) defines a subspecies as follows: "A subspecies is an aggregate of local populations of a species, inhabiting a geographic subdivision of the range of the species, and differing taxonomically from other populations of the species." He also points out that a subspecies may consist of many local populations which vary from each other genetically and phenotypically, and that the range of the species may be discontinuous. Adjacent subspecies interbreed or are potentially capable of doing so if separated by extrinsic barriers. Two misconceptions about the subspecies must be corrected. First, a subspecies is usually not an incipient species of the typologist (Simpson, 1961) and relatively few will ever become species. Second, the subspecies does not express the geographic variation of a character (cline) of a species and is only partially descriptive of that variation.

Most modern taxonomists believe in subspecific nomenclature (Simpson, 1961; Mayr, 1963). Wilson and Brown (1953) and Gosline (1954) are strong opponents of subspecific ranking and trinomial nomenclature. They prefer to describe such populations in a sentence or two.

To qualify as a subspecies an assemblage of populations must be taxonomically different from other subspecies. The differences between the populations must be sufficiently great so that it is possible to identify the majority of specimens without knowledge of their provenance. For that purpose many taxonomists adhere to 75 per cent rule (Hubbs, 1953) and others to 93 per cent rule (Bailey, 1954). To resolve this problem in the present study, coefficient of difference values were calculated. If the value was higher than 1.28 I have considered subspecific separation of two populations. At this value about 90 per cent of one population is different from about 90 per cent of the other population (Mayr, Linsley, and Usinger, 1953).

The three forms, _S. oquassa_ (Girard), _S. aureolus_ (Bean), and _S. marstoni_ (Garman) have been considered distinct species by Kendall (1914). Vladykov (1954) thought that _S. marstoni_ and _S. oquassa_ were conspecific, and that _S. aureolus_ was a distinct species. Dymond (1947) and Legendre (1954) considered _S. marstoni_ a subspecies of _S. alpinus_.

In this study _S. alpinus_ is considered polytypic. Tentatively, two subspecies are assigned to it, _S. alpinus alpinus_ and _S. alpinus oquassa_ (previously called _S. marstoni_). There may be more forms of _S. alpinus_ from the Canadian Arctic and Greenland. The name _S. alpinus oquassa_ is adopted because of its precedence over _S. marstoni_. The other two populations, one each from Pushineer Lake, Maine (previously known as _S. oquassa_) and from Floods Pond, Maine (previously known as

S. aureolus) are synonymized with S. a. oquassa from Quebec. The reasons for accepting the subspecies S. a. oquassa are given below.

The number of basibranchial teeth is usually higher in S. a. alpinus (Pl. 8, D) than in S. a. oquassa (Pl. 8, F). No other consistent osteological difference was observed between S. a. alpinus and S. a. oquassa - Quebec. See Pl. 4, C and D; Pl. 5, C and D; Pl. 6, B and C. McPhail pointed out that there are no osteological differences between the populations of S. alpinus.

The data on morphologic and meristic characters treated by Duncan's test (Tables 20 and 40) did not show any significant differences between S. a. alpinus and S. a. oquassa - Quebec.

Colour differences which have been thought specific between S. a. alpinus and S. a. oquassa - Quebec were found insignificant. In reality freshwater populations of S. a. alpinus from Labrador were very variable in colour and some of them resembled the three populations of S. a. oquassa more than they resembled each other.

The coefficient of difference values for several meristic characters were compared between S. a. alpinus and each of the three populations of S. a. oquassa. Since the values for the three comparisons were similar, only the values for the S. a. oquassa - Quebec pop. are shown in Table 41. It is observed that S. a. alpinus differed from S. a. oquassa - Quebec pop. in several characters, as for instance, total numbers of vertebrae, ribs, gill rakers, and pores on lateral line scales (Table 41). In all cases C.D. values are higher than 1.28 and suggest that S. a. oquassa - Quebec pop. should be designated a subspecies of S. alpinus.

S. a. alpinus is circumpolar in distribution and is found in the

Canadian Arctic, Labrador, Quebec, New Brunswick, and Newfoundland (Vladykov, 1963); it reaches close to but does not overlap the northern limits of the distribution of *S. a. oquassa*. The two subspecies are geographically isolated, a criterion for subspecific differentiation.

The status of *S. oquassa* and of *S. aureolus* is controversial. To decide their nomenclature differences as well as similarities must be found between them. They must also be compared with *S. a. oquassa* - Quebec (nomenclature previously settled).

S. oquassa was originally described by Girard (1854) during what has been referred to as the most retrogressive period in the history of taxonomy. Taxonomists were running out of material for study; consequently there was much unjustified splitting of taxonomic categories. In addition slight phenotypic variations were considered of taxonomic significance.

Girard (1854) gave *S. oquassa* a specific rank because of its small size, small head and mouth, undulated margin of the tail, prominent lateral line, and a bluish tint along the back of the fish. Kendall (1914) accumulated and published all the information available to him but admitted, "Up to the present day, there is very little published information." Kendall (1914) failed to express an opinion on the specific status of *S. oquassa* but did say that no conspicuous external characters except the larger size of *S. aureolus* separated *S. oquassa* and *S. aureolus*. Everhart (1950a and 1950b) distinguished *S. oquassa* from other chars mainly on the basis of colour. Waters (1960) differentiated *S. oquassa* from *S. aureolus* because of the former's small size, morphological and colour differences, higher number of caudal vertebrae, and lower level of dental development, lower number of expanded neural and haemal processes, and serological differences.

Bean (1887) established the species S. aureolus and separated it from S. oquassa because of the former's lower anal fin ray count, larger adult size, and gill rakers shorter, fewer, and almost always curled.

Our observations on the above differentiating characters between S. marstoni, S. oquassa, and S. aureolus point to the fact that the differences were inconsistent and not real.

The supramaxilla and postorbital 1 are slightly broader in S. aureolus (Pl. 4, F) than in S. oquassa (Pl. 4, E). Both these bones are similar in S. oquassa and S. marstoni (Pl. 4, D).

The mean number of expanded neural and haemal processes is slightly higher in S. aureolus than in the other two forms (Table 11).

The differences observed among the three forms for the following structures were inconsistent and overlapped: the dorsal and ventral views of the chondrocrania (Pl. 1, H-K2); the dermal bones (Pl. 4, D-F; Pl. 5, D-F; Pl. 6, C-E); the basibranchial and upper and lower pharyngeal teeth (Pl. 8, F-H); the general shape of the caudal skeleton (Pl.11, C-D2); the number of sensory pores on the dentary, preopercle, and frontal (Table 9); the proportional measurements in several dermal bones (Tables 6 and 7).

The data on several morphologic (Tables 12-13 and 16-17) and meristic (Tables 21-39) characters treated by Duncan's test did not separate the three forms for any character (Tables 20 and 40). Coefficient of difference values for several meristic characters did not distinguish the forms at the subspecific levels (Table 41).

In S. aureolus, only the distance from the anterior end of the lower jaw to the pectoral fin (ma-P) is greater than in S. marstoni and

S. oquassa (Tables 12-13, and 20). Considering the many similarities, I feel that this character should not be given much emphasis.

The mean number of caudal vertebrae in S. oquassa is higher (28) than that in S. aureolus (27). See Table 22. But the means were not significantly different (Table 40).

The total number of gill rakers is slightly lower in S. aureolus than in S. oquassa (Table 36) but the difference is not significant (Table 40). Regarding Bean's (1887) observations on the small size of the gill rakers and their curled nature, I must add that the two conditions are frequently seen in S. oquassa and S. marstoni as well.

The mean number of branchiostegal rays is slightly higher in S. aureolus (Table 37) than in S. oquassa or in S. marstoni. The differences are not significant (Table 40).

It has been reported by Walters (1955), Backus (1957), and McPhail (1961) that anadromous and freshwater populations of S. alpinus have various shades of colours that resemble S. oquassa, S. aureolus, and S. marstoni. Therefore, it is impossible to separate the various forms because of colour only.

The present geographical distributions of S. marstoni in Quebec, S. oquassa in Maine, and S. aureolus in New Hampshire and Maine suggest that the three forms are somewhat separated but not geographically isolated. Backus (1957), in considering the geographical distribution of S. alpinus and S. oquassa and their similarities, concluded that S. oquassa should be considered a population of S. alpinus.

After having considered in this paper morphometric and meristic characters, colour, and geographical distribution, it is obvious that the observed differences among the three forms were negligible and values for most characters overlapped. Table 40 shows that the three forms separated themselves into groups in the number of epineurals and in total number of gill rakers. Table 41 shows no subspecific differences. The slight differentiation observed seemed to be only phenotypic and did not warrant separation of the three forms into distinct species or subspecies. Therefore, they are considered three populations of the subspecies S. a. oquassa: S. a. oquassa - Quebec population, S. a. oquassa - Pushineer Lake, Maine, population, and S. a. aureolus - Floods Pond, Maine, population.

The species S. timagamiensis was first described by Henn and Rinkenbach (1925). MacKay (1963) described the fish under the name S. timagamiensis but did not confirm or deny its species status. Dymond (1947) thought it a subspecies of S. fontinalis. Vladykov (1954) considered it a colour variety of S. fontinalis. Scott (1958) hesitated to give it a species or subspecies name pending further study. I have considered S. f. timagamiensis a subspecies of S. fontinalis. Differences were not observed between the two forms in most morphologic and meristic characters. However, the length of the upper jaw and of the lower jaw as percentages of the head length, and the interorbital space as a percentage of the postorbital distance (O-p) were maximum in S. f. timagamiensis (Tables 18 and 20).

The colour differences which were emphasized by Henn and Rinkenbach (1925) are inconsistent and should not be considered specific.

The C.D. values for several meristic characters showed that S. f. timagamiensis differed from S. f. fontinalis in the numbers of trunk vertebrae, precaudal vertebrae, single neural spines, ribs with strong bifid heads, and total number of epineurals. See Tables 26, 29, and 41.

The populations of S. f. timagamiensis are geographically isolated in some lakes of the Timagami forest, Ontario. In a few lakes where S. f. fontinalis and S. f. timagamiensis occurred together, hybridization was frequent (Sale, P., 1964. Personal communication). The presence of hybridization between the two forms forces us to abandon the belief that S. timagamiensis is a distinct species. Therefore, S. f. timagamiensis is recognized as a subspecies of S. fontinalis.

After having decided the generic status of Cristivomer and Salmothymus, the species status of C. namaycush, S. alpinus, S. malma, and S. fontinalis, and the subspecies ranks of S. a. oquassa (three populations) and S. f. timagamiensis, the discussion leads into the origin, distribution, and relationships of various forms.

ORIGIN, DISTRIBUTION, AND RELATIONSHIPS OF SALMONIDAE

Most naturalists who have studied the Salmonidae have speculated its origin. Some ichthyologists attribute its origin to fresh water (MacFarlane, 1923; Tchernavin, 1939). Others suggest a marine ancestry (Regan, 1911; Meek, 1916). The former viewpoint seems to be more reasonable and is supported by the following basic biological principles.

Many families closely related to Salmonidae, such as Coregonidae and Thymallidae, are mainly freshwater in distribution.

Parallel freshwater forms of the anadromous Oncorhynchus and Salmo are found in almost every case. Possibly the freshwater forms went into the sea during the glacial period due to the low temperature which induced great changes in freshwater life.

All migratory forms of Salmonidae return to spawn in fresh water.

The freshwater distribution of Salmonidae over immense areas of mainland in Asia, Europe, northern Africa, and North America is a proof of their freshwater origin.

The presence of a high number of pyloric caeca and a well developed air bladder suggest the freshwater origin of Salmonidae (Tchernavin, 1939).

The paleontological proof of the freshwater origin of Salmonidae is meagre. However, it has been suggested that Salmonidae and Clupeidae (herring-like fishes) probably came from a common root, a view still maintained (Berg, 1940). Macfarlane (1923) believed that herring evolved in fresh water, and herring-like fishes, possibly through the intermediate freshwater genus *Crossognathus* (extinct), were related to the ancient freshwater family Leptolepidae (extinct) of the primitive order Holostei among the ganoid fishes.

The ancestors of the genus *Clupea* (suborder, Clupeoidei) have been traced as far back as the Upper Cretaceous and Lower Eocene times. It may be that the fishes of the suborder Salmonoidei originated with Clupeoidei in fresh water during the Lower Eocene epoch (Berg, 1940) and from that time onward the salmonids and herrings developed independently.

Cockerell (1919) and David (1946) have described fish scales from the Upper Cretaceous and attributed them to Salmonidae or a closely related family ____ . A fossil salmonid fish *Thaumaturus furcatus* has been described by Voigt (1934, quoted by Berg, 1940) from the Miocene of Bohemia. David (1943) described a fossil possibly belonging to the family Bathylagidae from the Upper Miocene of California. Weiler (1943) described 3 fossils belonging to the family Argentinidae from the Upper Tertiary of Romania. I agree with Norden (1961) who has suggested that Salmonidae separated itself from Argentinidae and other related families at the beginning of the Miocene.

Among truly salmonid fossils should be mentioned the fossils of *Rhabdofario* described by Cope (1870) from the Pleistocene of Idaho and believed by him to be closely related to the genus *Salmo*. Uyneo and Miller (1963) and Vladykov (1963) concluded that the genera *Rhabdofario* and Pacific *Salmo* (subgenus *Parasalmo* of Vladykov, 1963) are identical.

The discovery of some fossil bones of *C. namaycush* from the interglacial deposits of Wisconsin carry back the history of this species to Pleistocene time. Hussakof (1916) compared the fossil bones with the skull bones of modern fish and emphasized the fact that the fossil form cannot be separated even as a variety from the existing species. The age of that particular deposit is estimated between 250,000 and 500,000 years.

The finding of this specimen proves that the genus existed during glacial times in the same region as today (Hussakof, 1916), so that its antecedent history - whether it arose in the same region or wandered into it from somewhere else - dates back to an even earlier time; the riddle still requires explanation.

How *C. namaycush* attained its present distribution is intriguing. Radforth (1944), Wynne-Edwards (1952), and Hubbs and Lagler (1958) believed that *C. namaycush* survived in the northwest North America during the glacial period and extended its range postglacially into central and eastern North America. But their suggestion fails to answer the question of the absence of *C. namaycush* from Siberia. Of the 20 species of freshwater fishes found in Siberia, only the minnow (*Phoxinus phoxinus*) is absent from Alaska, and except for *C. namaycush* every Arctic Alaskan freshwater fish occurs in Siberia. The present writer shares the views of Walters (1955) who suggested that *C. namaycush* lived in central North America south of the Laurentide Ice Sheet during the last glacial period. Through water connections, the species followed the retreating ice border toward the north, west, and east from the Mississippi Refugium, and acquired its present distribution across northern North America.

Rounsefell (1962) suggested that *Cristivomer* developed from *Cristivomer-Salvelinus* ancestry in North America, while *Salvelinus* developed simultaneously in Asia. Later, *Salvelinus* invaded North America over an Asian-North American land-bridge or via the sea. But *Cristivomer* could not make a reciprocal invasion because of its special breeding behaviour, ecological adaptation, and temperature preference.

Due to the morphological similarities, it is reasonable to believe that *S. malma* and *S. alpinus* are derived from a common ancestor. McPhail (1961) suggested that before the first Pleistocene emergence of the Bering Strait land-bridge, the ancestor of *S. malma* and *S. alpinus* was distributed from the North Pacific to the North Atlantic. During the Pleistocene the North Pacific was separated from the Arctic Ocean several times by the land-bridge. During one of these periods of isolation *S. malma* probably evolved to the south of the land-bridge and S. alpinus to the north. It is further suggested that *S. malma* probably survived the last Pleistocene glaciation in 2 regions, one in the unglaciated areas of Alaska and the other south of the ice sheet on the Pacific coast. The latter stock spread widely and provided the present distribution.

In North America *S. alpinus* survived the last Pleistocene glaciation in Alaska and in eastern North America south of the ice sheet. *S. alpinus* acquired its present North American distribution from these 2 centres.

Regarding the distribution of various populations of *S.a. oquassa*, it is suggested that it was the Labrador population of *S. alpinus*, which was displaced southward in Pleistocene times and was anadromous along the New England coast, that undoubtedly provided the stock for the several New England and Quebec lakes and developed some morphological differences.

S. fontinalis naturally occurs in eastern and central North America (Hubbs and Lagler, 1958). It has been suggested by Radforth (1944) that brook char survived the Ice Age in the drainage of the Atlantic coast. With the retreat of the ice sheet dispersal of the species took place through the eastern outlets, the Great Lakes, and over the divides into the Hudson Bay drainage and possibly the upper Mississippi waters.

The subspecies S.f. timagamiensis is distributed in White Pine, Whirligig and Wilderness Lakes in northern Ontario (Mackay, 1963). It is speculated that the fish originated during postglacial times. It seems that some populations of S. fontinalis became isolated in the above mentioned lakes and became morphologically different from the neighbouring parental stock and gave rise to aurora char.

Regarding the origin of Salmo and Oncorhynchus, Mottley (1934) suggested that during the next to last glacial period, the joint ancestors of Salmo and Oncorhynchus were separated into a Pacific and an Atlantic group, the former evolving into Oncorhynchus and the latter into Salmo. During the interglacial periods, Salmo migrated from stream to stream across the continent and reached the Pacific coast. Oncorhynchus, being strongly anadromous, could not make the journey. Neave (1958) speculated that Oncorhynchus evolved from Salmo in the western Pacific. Mottley's view seems to have more appeal.

Salmo is distributed on the Pacific and Atlantic coasts of North America and in eastern Asia. Oncorhynchus is distributed on both coasts of the Pacific Ocean (Dymond and Vladykov, 1934;

Vladykov, 1963).

Available information regarding the origin and dispersal of the Eurassian genera Brachymystax, Hucho, and Salmothymus, is very meagre. Speculations would be futile. However, it may be stated that the process of speciation in Salmonidae in Dalmatia, Lake Ohrid, and in the Transcaucasian area is still in progress (Hadžišče, 1960; Vladykov, 1963) and should be watched with interest.

Brachymystax is distributed in eastern Asia, particularly Siberia (Nikolskii, 1961). Hucho is distributed in the Danube River system, Siberia, and eastern Asia. Salmothymus is distributed in Dalmatia and Lake Ohrid in Europe (Vladykov, 1963).

In conclusion, I agree with Neave (1958), Norden (1961), and Vladykov (1963) who mentioned that the genera and species of Salmonidae are of recent origin, probably appearing during the Pleistocene time.

In the absence of well documented paleontological records to establish the relationships among the salmonid genera and species, the only recourse is to revert to osteological and morphological studies of the present day forms. The detailed accounts of osteology and of morphology which have been provided in previous pages are summarized now.

Table 48 lists the presence or absence of 16 characters, possibly of generic importance, for 7 genera of Salmonidae. The number of differences in 16 characters (from Table 48) is summarized in Table 49. Fig. 9, A, shows the hypothetical phylogeny of the genera of Salmonidae. The actual number of differences between the genera from Table 49 is hard to represent in a simplified dendrogram. However, an effort is made to give a general idea of the relationships

TABLE 48. Comparison of certain generic Characters in Salmonidae (Data taken from the present study and also from Norden 1961; Rounsefell, 1962; Vladykov, 1963)

Character	Brachymystax	Hucho	Salmothymus	Cristivomer	Salvelinus	Salmo	Oncorhynchus
Mouth:							
Small	A		A				
Large		B	B	B	B	B	B
Jaw hinge:							
Below orbit	C						
Behind orbit		D	D	D	D	D	D
Palatine and vomerine teeth:							
In Continuous ∩-shaped band	E	E	E				
generally narrowly seperated			F	F	F	F	
generally widely seperated							G
Jaw teeth:							
Small, fine	H						
Strong		I	I	I	I	I	I
Shaft of vomer:							
Short, toothless	J	J					
Long, toothless				K	K		
Long, toothed			L			L	L
Postorbitals contact preopercle:							
No	M	M	M	M	M	M	
Yes							N
Supraethmoid:							
Long and narrow	O	O		O			
Rounded front head and broad posteriorly					P		
Pointed head and broad posteriorly with a notch			Q			Q	
Pointed head and deeply bifurcated at the posterior end							R
Premaxilla:							
Triangular	S	S	S	S	S		
Wing-shaped						T	
Band-shaped							U
Maxilla:							
Head of Maxilla short	V	V	V				
Head of Maxilla long and not in line with the body of maxilla				W	W		
Head of maxilla long and in a straight line with the body of maxilla						X	X
Supramaxilla:							
Elongated and tapered at either end	Y	Y	Y	Y			
Elliptic-shaped						Z	Z
Intermediate between the above two					a		
Teeth on lingual plate:							
Arranged in two parallel rows				b			
Arranged in a triangle	c	c			c	c	c
In four to five series			d (*S. ohridanus*)				
Epurals:							
Two				e	e	e	e
Three	f	f	f			f	f
Ova:							
Small	g		g				
Medium		h		h	h		
Large						i	
Very large							j
Anadromy:							
Fresh water	k	k	k	k			
Slightly anadromous					l		
More anadromous						m	
Most anadromous							n
Colour of flank:							
Black spots on light background	o	o	o			o	o
Light spots on dark background				p	p		
Breeding behaviour:							
Redd digging present	q	q	q		q	q	q
Redd digging absent				r			

TABLE 49. Number of certain characters differing between the genera of Salmonidae
(Characters from Table 48)

	Brachymystax	Hucho	Salmothymus	Cristivomer	Salvelinus	Salmo	Oncorhynchus
Brachymystax	–	4	5	11	12	11	12
Hucho	4	-	4	7	8	8	9
Salmothymus	5	4	-	7	9	6	9
Cristivomer	11	7	7	-	5	10	12
Salvelinus	12	8	9	5	-	8	10
Salmo	11	8	6	10	8	-	6
Oncorhynchus	12	9	9	12	10	6	-

among the genera of Salmonidae. As a good paleontological record is unavailable for the genera, a time scale is not included in the dendrogram. The relationships between the families Coregonidae, Thymallidae and Salmonidae, as shown in Fig. 9, A, are suggested by Norden (1961).

It is evident that Brachymystax is the most generalized because of the following characters: a small coregonine type of mouth, palatine and vomerine teeth in a continuous ∩- shaped band, teeth on the jaws small and fine, the jaw hinge below the orbit of the eye, the supraethmoid long and narrow, the premaxilla triangular, and small ova. The genus is freshwater in distribution. See Table 48. In Brachymystax the absence of sexual dimorphism during the breeding period is another generalized feature. From a Brachymystax-like ancestor the evolution of various genera of Salmonidae can be visualized by the jaws becoming large and more strongly toothed, the jaw hinge moving back to a position behind the orbit of the eye, increased sexual dimorphism in breeding populations, and developed anadromous habits. It seems that Oncorhynchus is the most specialized genus. Hucho and Salmothymus are closer to each other and to Brachymystax than to Salvelinus or Salmo. Salmo is nearer to Oncorhynchus.

Salmothymus has been synonymized with Salmo by earlier workers (Regan, 1920) because of the presence of teeth on the shaft of the vomer and the shape of the supraethmoid bone. I have maintained the generic status of Salmothymus because of the differences in the shapes of the premaxilla, the maxilla, the supramaxilla, and the teeth on the lingual plate, and also because of its freshwater occurrence.

Cristivomer and *Salvelinus* are closely related but represent a split from the main stem because of the shape of the vomer, the shape of the maxilla, specialized scales, and the flank of the body with a distinctive colour pattern of light spots on a dark background. But *Cristivomer* differs from *Salvelinus* because of the shapes of the supraethmoid, supermaxilla, preopercle, postorbital 1, and subopercle, plus the absence of the redd digging behaviour of spawning females, and the presence of pearl organs.

Cristivomer is nearer to *Brachymystax* and *Hucho* because of the shapes of the supraethmoid and supramaxilla, its freshwater occurrence, and the absence of sexual dimorphism in breeding fish.

Tables 50 and 51 (summarized in the fashion of Tables 48 and 49), and Fig. 9, B, show the relationships among the species and subspecies of the genera *Cristivomer* and *Salvelinus*. Between *C. namaycush* and the various species of *Salvelinus*, the former is considered more generalized because of the higher number of sensory pores on the dentary and the preopercle bones, usually a high number of basibranchial teeth, a high number of pyloric caeca, a deeply forked caudal fin, and the occurrence of *C. namaycush* in fresh water.

It is readily seen (Tables 50 and 51, and Fig. 9, B) that *S. namaycush* is far separated from *S. alpinus*, *S. malma*, and *S. fontinalis*. *S.a. alpinus* is much closer to *S.a. oquassa* (3 pop.) than to any other form. *S.f. fontinalis* is closely associated with *S.f. timagamiensis*.

Tables 51 and 41 show that *S.a. alpinus* and *S.a. oquassa* - Quebec pop. are very close but still distinguishable in the total

Morton and Miller, 1954; Rounsefell, 1962; Vladykov, 1954 and 1963)

Character	C. namaycush	S.a.alpinus	S.a. oquassa			S.malma	S.f.fontinalis	S.f.timagamiensis	Salmo gairdnerii
			Quebec	From Pushineer Lake	Floods Pond				
Morphological Characters									
Head:									
Long and pointed	A								
Intermediate						B	B	B	B
Small		C	C	C	C				
Interorbital width:									
Maximum									D
Intermediate		E	E	E	E	E	E	E	
Minimum	F								
Upper and lower jaws:									
Long							G	G	
Short	H	H	H	H	H	H			H
Distance between insertion of dorsal and origin of adipose fins:									
Long		L	L	L	L		L		
Intermediate	M					M		M	
Short									N
Distance ventral to anal fins:									
Long		O							
Intermediate			P	P	P	P	P		P
Short	Q							Q	
Tail:									
Deeply forked	R								
Intermediate		S	S	S	S	S			S
Not forked							T	T	
Meristic Characters									
No. of basibranchial teeth:									
High	a								
Several to high		b	b	b	b				
None to several						c	c	c	c
No. of sensory pores on dentary:									
Mean, 8.0	d								
Means, 6.6-7.0						e	e	e	e
Means, 4.5-5.7		f	f	f	f				
No. of sensory pores on preopercle:									
Mean, 8.0	g								
Means, 7.1-7.6							h		h
Means, 5.8-6.6		i	i	i	i	i		i	
No. of vertebrae:									
High, mean, 67.4		j							
Intermediate means, 63.7-64.7	k		k	k	k	k			k
Low, means 59.5-60.5							l	l	
No. of gill rakers:									
High, mean, 27.8		m							
Intermediate means, 20.7-22.4	n		n	n	n				
Low, means 16.8-19.3						o	o	o	o
No. of branchiostegal rays:									
High, mean, 13.6						p			
Intermediate, means, 11.3-12.3	q	q					q	q	q
Low, means, 9.6-10.6			r	r	r				
No. of pyloric caeca:									
High, mean, 138.5	s								
Intermediate, means, 35.9-46.9		t	t	t	t		t	t	t
Low, mean, 23.9						u			
Colouration									
Red spots on flank							v	v	
Orange spots on flank		w	w	w	w	w			
White spots on flank	x								
Black spots on flank									x'
Vermiculation on back:									
Present	y				y		y		
Absent		y'	y'	y'		y'		y'	y'
Black stripe on lower fins:									
Present							z	z	
Absent	z'	z'	z'	z'	z'	z'			z'
Distribution in N. America:									
Northern N. America	Aa								
Artic N. America, northeastern N. America		Bb							
Northeastern N. America			Cc	Cc	Cc				
Eastern and central N. America							Dd	Dd	
Pacific coast above 40° latitude						Ee			
Pacific coast above 21° latitude									

TABLE 51. Number of certain characters differing between the forms of Salmonidae
(Characters from Table 50)

	C.namaycush	S.a.alpinus	S.a.oquassa Quebec	S.a.oquassa Pushineer Lake	S.a.oquassa Floods Pond	S.malma	S.f.fontinalis	S.f.timagamiensis	Salmo gairdenerii
C.namaycush	--	15	14	14	13	14	16	15	14
S.a.alpinus	15	--	6	6	7	11	14	13	11
S.a.oquassa Quebec	14	6	--	0	1	8	13	14	11
S.a.oquassa Pushineer Lake, Maine	14	6	0	--	1	8	13	14	11
S.a.oquassa Floods Pond Maine	13	7	1	1	--	9	12	15	12
S.malma	14	11	8	8	9	--	11	10	8
S.f.fontinalis	16	14	13	13	12	11	--	5	10
S.f.timagamiensis	15	13	14	14	15	10	5	--	10
Salmo gairdnerii	14	11	11	11	12	8	10	10	--

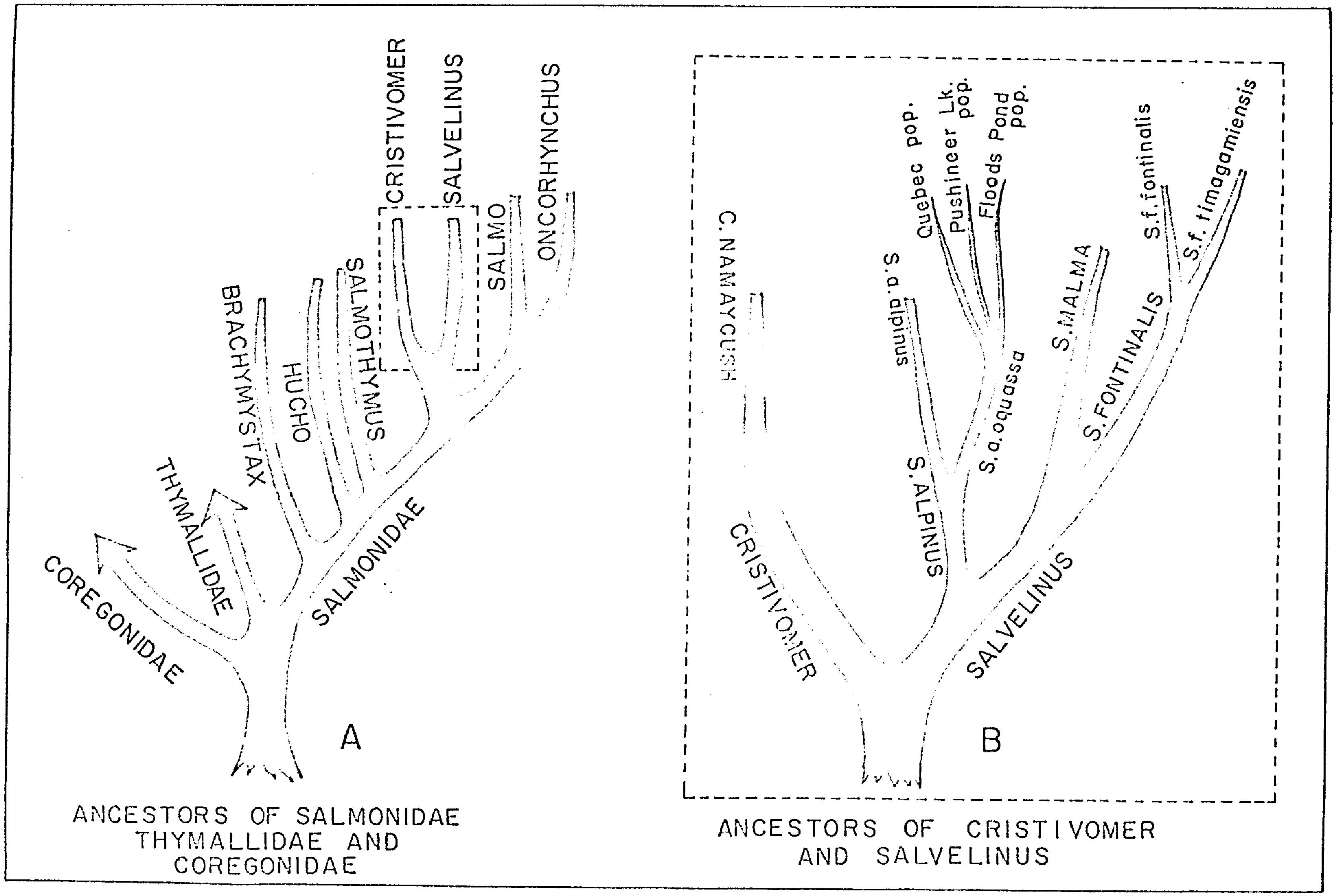

Fig. 9. Hypothetical phylogeny of the genera (A) and some species (B) of Salmonidae.

numbers of vertebrae, ribs, and gill rakers, and some morphological characters.

The 3 populations of *S.a. oquassa* are very similar. The differences which have been observed by Vladykov (1954, Waters (1960), and during this study, are attributed to environmental influences, as for instance, in the total numbers of ribs, epineurals, dorsal fin rays, gill rakers, and branchiostegal rays. See Tables 28, 29, 31, 36, and 37, respectively. In addition, the 3 forms are not significantly different in any character (Tables 20 and 41). *S.a. oquassa*-Floods Pond pop. differs from the other chars in prepectoral fin length; this does not demand a taxonomic status for the population. In the total numbers of epineurals and gill rakers, the 3 populations group together (Table 40).

S. malma is an intermediate group between *S. alpinus* and *S. fontinalis*.

The 2 forms *S.f. fontinalis* and *S.f. timagamiensis* are similar in many characters, such as the total number of vertebrae, ribs, and gill rakers, thus forming a group (Tables 40 and 50). These 2 subspecies are separable in some characters, as for instance the numbers of trunk vertebrae and precaudal vertebrae (Table 41).

Another impression gathered from Tables 50 and 51 is that *Salmo gairdnerii* is closer to *S. malma* and *S. fontinalis* than to *C. namaycush*.

SYNOPSIS OF THE GENERA AND SPECIES OF SALMONIDAE

The synopsis is based on the present study and also on the works of the following authors: Kendall (1914), Tchernavin (1937, 1938a, 1938b), Delacy and Morton (1943), Berg (1908, 1940, 1948), Hikita (1954), Morton and Miller (1954), Hadžišče (1960), Waters (1960), McPhail (1961), Norden (1961), Rounsefell (1962), Svetina (1962), and Vladykov (1954, 1962, 1963).

Genera

Brachymystax Günther, 1866. The fish in this genus have a small mouth; jaw hinge below posterior margin of orbit of eye; hypethmoid absent; orbitosphenoid present; sphenotic not projecting laterally; opisthotic not touching prootic; supraethmoid without rounded front head and pointed posteriorly; frontal much longer than broad; premaxilla triangular with small weak teeth and intermediate-sized ascending process; head of maxilla short and knob-like, body of maxilla short and broad with weak teeth; supramaxilla pointed at both ends and slightly broadened in the middle; postorbital 1 long; notch on posterior margin absent; postorbitals 1 - 3 not extending to preopercle; anterior end and hook-like process of subopercle narrow; teeth on head of vomer only; continuous ⋂ - shaped band of palatine and vomerine teeth; moderate sized teeth on lingual plate form equal sides of an isosceles triangle; basibranchial teeth absent; dorsal fontanelles present in both young and adult; first uroneural thin and crescent-like; flank of body pigmented with black; small ova, in remaining genera ova comparatively large; exclusively freshwater; distributed in eastern part of Asia, particularly Siberia; 1 species only in the genus.

Hucho Günther, 1866. Our osteological study is mainly based on *Hucho hucho*. The fish in this genus have a large mouth; jaw hinge well behind orbit of eye; hypethmoid absent; orbitosphenoid present; sphenotic not laterally projected; opisthotic not touching prootic; supraethmoid without rounded front head and not broad posteriorly; frontal much longer than broad; premaxilla triangular with strong large teeth and intermediate-sized ascending process; head of maxilla short, body of maxilla long, broad posteriorly, and slightly bent upward, with strong, well developed teeth; postorbital 1 without a notch on posterior margin; postorbitals 1 – 3 not extending to preopercle; anterior end and hook-like process of subopercle narrow; teeth on head of vomer only; continuous ∩- shaped band of palatine and vomerine teeth; strong teeth on lingual plate form equal sides of an isosceles triangle; basibranchial teeth usually absent (present in *Hucho perryi*); uroneural 1 thin and crescent-like; flank of body pigmented with black; dorsal fontanelles present in both young and adult; freshwater and anadromous; distributed in Danube River system, Siberia, and eastern Asia; possibly 3 species.

Salmothymus Berg, 1908. Our osteological description for the genus is particularly based on *Salmothymus ohridanus* unless stated otherwise. The fish in this genus have a small to large mouth; jaw hinge below posterior margin of orbit of eye; hypethmoid present in *Salmothymus obtusirostris* but absent in other species; orbitosphenoid present;

sphenotic not projecting laterally; opisthotic not touching prootic; supraethmoid without a rounded front head, posteriorly not broad and with a slight notch; frontal much longer than broad; parietal very small as compared to those of other genera; premaxilla triangular with strong teeth; intermediate-sized ascending process of premaxilla; head of maxilla short, body of maxilla wider at posterior end than at anterior end; crescent-like depression in upper margin of posterior half of maxilla; supramaxilla broad in central region and pointed at both ends; postorbital 1 slightly notched at upper posterior margin; postorbital 3 very small as compared to those in other genera; postorbitals 1 - 3 not extending to preopercle; anterior end and hook-like process of subopercle broad; shaft of vomer long with teeth in 2 rows; vomerine and palatine teeth not separated in Salmothymus ohridanus but narrowly separated in Salmothymus obtusirostris and Salmothymus letnica; teeth on lingual plate in 2 rows in Salmothymus obtusirostris and Salmothymus letnica, and in 4 - 5 rows in Salmothymus ohridanus; basibranchial teeth absent; uroneural 1 thin and crescent-like; dorsal fontanelles present in both young and adults; flank of body pigmented with black; exclusively freshwater; distributed in Dalmatia and Lake Ohrid in Europe; possibly 3 species.

Cristivomer Gill and Jordan, 1878. The fish in this genus have a large mouth; jaw hinge well behind orbit of eye; hypethmoid absent; orbitosphenoid present or absent; sphenotic projecting laterally, opisthotic not touching prootic; supraethmoid long, narrow, without a rounded front head, pointed posteriorly, and without a notch; frontal much longer than broad; premaxilla triangular with moderate to strong teeth, ascending process of premaxilla well developed; head of maxilla long, not knob-like, upturned, body of maxilla straight, not broad posteriorly, and with strong teeth; supramaxilla long, narrow, pointed at both ends, and of about the same width throughout; postorbital 1 short and broad, notch absent on posterior margin; postorbitals 1 - 3 not extending to preopercle; anterior end and hook-like process of subopercle very narrow, distinctive of Cristivomer; crest of vomer long, usually joined to shaft; teeth on crest of vomer only; vomerine and palatine teeth narrowly separated; strong teeth on lingual plate in 2 parallel rows; basibranchial teeth strong and numerous; dorsal fontanelles present in both young and adult; rostrum broad in front and usually without a notch; caudal fin deeply forked; pre-dorsal, pre-pectoral, and pre-ventral fin lengths greater in C. namaycush than in chars and rainbow trout; interorbital space narrower than in chars and rainbow trout; pyloric caeca range from about 100 - 170; pearl organs present; colour not bright but spotted with grey; in fry of Cristivomer, ossification of bones begins at an earlier age than in Salvelinus; adipose fin in fry densely pigmented posteroventrally; lacustrine; distributed in northern North America; only 1 species.

Salvelinus Richardson, 1836. The fish in this genus have a large mouth; jaw hinge well behind orbit of eye; hypethmoid usually absent (often present in S.f. fontinalis and S.f. timagamiensis); orbitosphenoid present; sphenotic not projecting laterally; opisthotic not touching prootic; supraethmoid with rounded front head, posteriorly very broad and without a notch; frontal longer than broad; premaxilla triangular with moderate to strong teeth, ascending process of premaxilla well developed; head of maxilla long, not knob-like, upturned; body of maxilla straight (in S.f. timagamiensis it is bent upward), not broad posteriorly, with moderate to strong teeth; supramaxilla long, usually pointed anteriorly, and broad posteriorly; postorbital 1 long, narrow or broad, with notch on posterior margin; postorbitals 1 - 3 not extending to preopercle; anterior end and hook-like process of subopercle broad; crest of vomer usually short and not joined to shaft; teeth on crest of vomer only; vomerine and palatine teeth moderate, interrupted or uninterrupted; strong teeth on lingual plate form equal side of an isosceles triangle; basibranchial teeth none to numerous; uroneural 1 from crescent-like to broad fan-like; dorsal fontanelles present both in young and adult; rostrum broad in front and with feeble to developed notch; caudal fin from very little to deeply forked; in fry of Salvelinus ossification of bones begins at later age than in Cristivomer; pyloric caeca 20 - 64; pearl organs absent; brightly coloured in fresh water; flank of body spotted with yellow, pink, or red; lower fins usually brightly coloured; adfluvial, fluvial, or optionally anadromous, distributed across northern Europe, Asia and North America; numerous ill-defined species; contemporary authors deal with 3 - 6 forms in North America.

Salmo (Pacific trouts, subgenus Parasalmo of Vladykov, 1963) Linnaeus, 1758. Unless otherwise stated, the description is for Salmo gairdnerii. The fish in the genus Salmo have a large mouth; jaw hinge behind orbit of eye; hypethmoid usually absent (present in Salmo trutta); orbitosphenoid present; sphenotic not projecting laterally;

opisthotic not touching prootic; supraethmoid without a rounded front head and notched posteriorly; frontal slightly longer than broad; premaxilla wing-shaped, ascending process of premaxilla small, teeth on premaxilla strong; head of maxilla long, not knob-like, straight, and in line with body of maxilla, maxilla not bent and not broad posteriorly, teeth on maxilla strong; supramaxilla long, pointed anteriorly and broad posteriorly; postorbital 1 long but without a notch on its posterior margin; postorbitals 1 - 3 not extending to preopercle; anterior end and hook-like process of subopercle broad; teeth on shaft of vomer only; vomerine and palatine teeth narrowly separated; strong teeth on lingual plate form equal sides of an isosceles triangle; basibranchial teeth absent (present in _Salmo clarkii_); dorsal fontanelles present both in young and adult; in adult rostrum broad at anterior edge and notched; distance from insertion of dorsal to adipose fin shorter in _Salmo gairdnerii_ than in namaycush and chars; interorbital width maximum in _Salmo gairdnerii_ as compared with namaycush and chars; caudal fin not deeply forked; number of pyloric caeca not very high (range 27 - 80); pearl organs absent; black spots on flank in adults; in fry of cutthroat trout (_Salmo clarkii_) ossifcation begins at about same lengths as in brook char; anadromous or freshwater; _Parasalmo_ distributed in North Pacific region and has at least 4 species; _Salmo_ distributed in Atlantic, Mediterranean, and Ponto-Aral regions and has at least 4 species.

Oncorhynchus Suckley, 1860. The fish in this genus have a large mouth; jaw hinge behind orbit of eye; hypethmoid absent; orbitosphenoid present; sphenotic not projecting laterally; opisthotic touching prootic; supraethmoid deeply notched posteriorly and butterfly-shaped without a rounded front head; frontal slightly longer than broad; premaxilla band-shaped with very strong teeth in spawning males, no ascending process of premaxilla; head of maxilla long, not knob-like, straight, and in line with body of maxilla; body of maxilla straight, slightly or strongly curved upward, not broad posteriorly, with strong teeth in spawning individuals; supramaxilla short, very broad posteriorly, and slightly pointed anteriorly; postorbital 1 thin, long, without notch on its posterior margin; postorbitals 1 - 3 extending to preopercle; anterior end and hook-like process of subopercle broad; teeth on shaft of vomer only; vomerine and palatine teeth widely separated; strong teeth on lingual plate form equal sides of an isosceles triangle; basibranchial teeth absent, dorsal fontanelles present in young but greatly reduced in adults of _O. keta_, _O. kisutch_, and _O. nerka_, rostrum pointed anteriorly without rostral notch; uroneural 1 long and crescent-shaped to broad; number of pyloric caeca high (range 55 - 249); pearl organs absent; black spots on flank at all stages (breeding colour present); anadromy obligatory or adaptive; distributed in North Pacific region from Formosa to the Bering Sea; 7 species.

Species

Descriptions of _C. namaycush_ and _Salmo gairdnerii_ are given with the genera _Cristivomer_ and _Salmo_, respectively. Under this section, only the species and subspecies of the genus _Salvelinus_ are described. Descriptions of the species of the genera _Salmo_ and

Oncorhynchus are beyond the scope of this paper.

In the genus Salvelinus, 3 species and 2 subspecies are tentatively recognized.

S. alpinus is polytypic; exact number of the subspecies is hard to determine until an exhaustive work is undertaken in the North American Arctic. However, 2 subspecies are recognized.

Two subspecies are recognized in S. fontinalis.

Salvelinus alpinus alpinus (Linnaeus). Supraethmoid with a rounded front head and very broad caudad; frontal not as long as in brook and Dolly Varden chars; maxilla short and either projected or not projected behind orbit of eye; supramaxilla broad posteriorly and pointed anteriorly; postorbital 1 notched near upper posterior margin; uroneural 1 crescent-like to broad; distances from anterior upper end of opercle to fork of tail, from origin of ventral to anal fin, and also length of head are shorter than and significantly different from those in other chars; total number of vertebrae (66 - 69); ribs (39 - 42); gill rakers (26 - 31); and pores on lateral line scales (139 - 146) higher than those in other chars; branchiostegal rays (10 - 13); basibranchial teeth, several to many; pectoral fin rays (13 - 15); in fry of Arctic char, ossification of bones begins at a later age than in brook char fry; in fry (up to 21 mm) general pigmentation of body is weak, and adipose fin is without pigmentation; distributed in the Canadian Arctic, Newfoundland, Quebec and New Brunswick.

S. alpinus oquassa (Girard). Various populations from Quebec, Canada, Maine and New Hampshire, U.S.A. are included in this subspecies.

Supraethmoid with rounded front head, not as broad posteriorly as in Arctic char; maxilla projected or not projected behind orbit of eye; supramaxilla not as broad posteriorly as in *S.a. alpinus*; in *S.a. oquassa*, uroneural 1 is usually thin and crescent-like; coefficient of difference (C.D.) values for the following meristic characters between *S.a. alpinus* and various populations of *S.a. oquassa* are higher than 1.28, suggesting that the 3 forms be included in a single subspecies (*S.a. oquassa*): total number of vertebrae (60 - 66); total number of ribs (34 - 39); number of ribs with weak single heads (7 - 11); total number of gill rakers (19 - 24); total number of pores on lateral line scales (118 - 150); pectoral fin rays (12 - 15); branchiostegal rays (8 - 11); basibranchial teeth from none to several; colouration in the 3 populations similar to that of various landlocked populations of *S.a. alpinus*.

The 3 species *S. marstoni*, *S. oquassa*, and *S. aureolus* of earlier workers (Kendall, 1914, Everhart, 1950a; Vladykov, 1954; Waters, 1960) are considered synonymous in this study and are treated as a single subspecies *S.a. oquassa*; distributed in Quebec, Maine and New Hampshire.

S. malma (Walbaum). Dolly Varden char has been considered a distinct species. Supraethmoid without a rounded front head, differently shaped than that of Arctic and brook chars and broad caudad; frontal longer than in Arctic char; maxilla projected behind orbit of eye; supramaxilla broad posteriorly and pointed anteriorly; postorbital 1 notched at about the middle of posterior margin; parasphenoid differently shaped than in chars and namaycush; uroneural 1 long and broad; statistically no morphological differences were observed between Dolly Varden and the other chars, namaycush, and trout; number of branchiostegal rays higher (13 - 14) and total number of gill rakers lower (15 - 19) and both these values statistically different from those in chars and trout; ranges for other meristic characters: total number of vertebrae (63 - 66); ribs (36 - 39); pectoral fin rays (14 - 15); basibranchial teeth none to several; pyloric caeca (20 - 31); pores on lateral line scales (122 - 128); vermiculation on back absent or faint; no black stripe on lower fin; spots on flank orange or red but without blue borders; tail in adult square; distributed on both sides of the Pacific; along the American side from Alaska to northern California, Yukon, Alberta, Saskatchewan, Montana and Nevada.

S.f. fontinalis (Mitchell). S. fontinalis (brook char) has been considered a distinct species with 2 subspecies (S.f. fontinalis; S.f timagamiensis). The description and distinguishing characteristics of the brook char are as follows: supraethmoid with a rounded front head, broad caudad; maxilla projected well behind orbit of eye; supramaxilla not broad posteriorly; postorbital 1 differently shaped than that of Arctic and Dolly Varden chars, notched at about middle of posterior margin; uroneural 1 distinctly broad and short; morphologically similar to aurora char (S.f. timagamiensis); the following meristic characters are lower in count and statistically different from those in other chars: total number of vertebrae (58 - 61); number of neural arches not fused with vertebrae (26 - 30); total number of single neural spines (21 - 29); total number of ribs (32 - 36); ranges for other meristic characters are: total number of gill rakers (15 - 20); number of branchiostegal rays (10 - 12); basibranchial teeth from none to a few; pyloric caeca (32 - 47); pores on lateral line scales (112 - 123); in adults, back with vermiculations, lower fins strong with white front edge followed by a black stripe; tip of lower jaw black, some pink or red lateral spots with blue halos around them; roof of mouth black; tail in adult square; in brook char fry ossification of bones begins at an earlier age than in Arctic char; in fry, upper half of adipose fin densely pigmented, general pigmentation strong; optionally anadromous, adfluvial, or lacustrine; distributed in eastern North America including Newfoundland.

S.f timagiensis, Henn and Rinkenbach. Supraethmoid, postorbital 1, frontal, basibranchial teeth, and caudal skeleton similar to those of *S.f. fontinalis*; maxilla bent upward and projected far behind orbit of eye; supramaxilla and interopercle slightly different from those in other chars, namaycush, and rainbow trout; lower jaw longest (brook char nearer to aurora char) as compared to other species; interorbital width greater than in other chars; coefficient of difference values for following meristic characters higher than 1.28 between *S.f. fontinalis* and *S.f. timagamiensis*: aurora char has higher number of trunk vertebrae (29 - 31); precaudal vertebrae (4 - 6); single neural spines (27 - 32); ribs with strong bifid heads (27 - 30); total number of epineurals (34 - 42); range for other meristic characters are: total number of ribs (33 - 36); total number of vertebrae (60 - 61); total number of pectoral fin rays (13 - 14); number of branchiostegal rays (11 - 14); total number of gill rakers (17 - 20); basibranchial teeth from none to a few; pyloric caeca (31 - 40); pores on lateral line scales (112 - 128); colour slightly different from that of brook char; in fry ossification of bones begins at about the same length as in brook char; general pigmentation of body of fry is strong; distributed in Timagami forest region of Ontario.

CONCLUSIONS

1. In this study the family Salmonidae includes only namaycush, char , trout , and Pacific salmon, and not whitefishes and grayling.

2. The genera Brachymystax, Hucho, Salmothymus, Cristivomer, Salvelinus, Salmo, and Oncorhynchus are included in Salmonidae.

3. The genus Cristivomer is separated from Salvelinus because of the former's long and narrow supraethmoid; long frontal; supramaxilla long and tapered at both ends; postorbital 1 short and broad, without a notch on its posterior margin; anterior end and hook-like process of subopercle very narrow; crest of vomer long and joined to shaft; sensory pores on dentary and preopercle numerous; interorbital space narrow; caudal fin deeply forked; predorsal fin length long; number of pyloric caeca high; pearl organs present; ossification of bones in fry at an earlier age than in Salvelinus; distribution in freshwater lakes of North America only. Cristivomer namaycush is the only species in the genus.

4. The genus or subgenus Baione, established because of the absence of basibranchial teeth, uninterrupted row of vomerine and palatine teeth, and square tail, is dropped because these features are also observed in various species of the genus Salvelinus.

5. The genus Salmothymus is separated from Salmo because of the former's small mouth; jaw hinge below posterior margin of orbit of eye; triangular premaxilla; crescent-like shape of maxilla; teeth on lingual plate in 4 - 5 rows; exclusively freshwater distribution. The description of this genus is based on Salmothymus ohridanus.

6. *S. alpinus* is considered polytypic. Two subspecies, *S. alpinus alpinus* and *S. alpinus oquassa*, are recognized in this paper:

S. a. alpinus is distinguished from other species and subspecies of chars because of its small head; shape of supraethmoid; short maxilla; high number of vertebrae; high number of ribs; high number of gill rakers; high number of basibranchial teeth; later ossification of bones in fry than in *S. f. fontinalis*.

The subspecies *S. a. oquassa* includes three populations, which previously were considered distinct species---*S. marstoni*, *S. oquassa*, and *S. aureolus*. The subspecies is distinguished from *S. a. alpinus* because of the former's low number of vertebrae; low number of ribs; low number of gill rakers. No consistent osteological and morphological differences were observed between the two subspecies, which are geographically isolated.

7. *S. malma* is separable from other chars because of the shape of its supraethmoid; parasphenoid; low number of gill rakers; high number of branchiostegal rays.

8. *S. fontinalis* is considered polytypic. Two subspecies, *S. f. fontinalis* and *S. f. timagamiensis*, are recognized:

S. f. fontinalis is distinguished from other species of chars on the basis of the shape of postorbital 1; broad uroneural 1; long maxilla; square tail; lowest number of vertebrae; lowest number of ribs; lower fins strong with white front edge followed by a black stripe; earlier ossification of bones in fry than for *S. a. alpinus*; fry strongly pigmented.

In most characters, *S. f. timagamiensis* is similar to *S. f. fontinalis*. However, it differs from *S. f. fontinalis* in the shape of its maxilla; longer upper and lower jaw; higher number of trunk and precaudal vertebrae; higher number of ribs with strong bifid heads. It is geographically isolated from S. f. fontinalis.

9. Morphometric, meristic, and colour studies of fry of Salmonidae show specific differences.

10. Brachymystax is most generalized, whereas Oncorhynchus is most specialized. Hucho, Salmothymus, and Salmo are intermediate between the two extremes. Cristivomer is more generalized than Salvelinus.

11. Fossil material should be collected to establish true relationships in Salmonidae.

12. Detailed osteological studies are recommended for the genera Brachymystax, Hucho, Salmothymus, and possibly Salmo.

13. In Dalmatia and Lake Ohrid, speciation among Salmonidae is still in progress (Vladykov, 1963) and should be studied carefully.

14. There should be closer co-operation between taxonomists in North America and Eurasia to decide the taxonomy of the family Salmonidae. This is necessary because closely related forms occur in the three continents.

BIBLIOGRAPHY

Agassiz, Louis. 1850. Lake Superior. Its physical character, vegetation and animals compared with those of other and similar regions. Boston.

Andrews, C.W., and Lear, E. 1956. The biology of Arctic char (*Salvelinus alpinus*) in northern Labrador: *J. Fish. Res. Bd. Can.*, 13 (6): 843-60.

Backus, R.H. 1957. The fishes of Labrador. *Bull. Am. Mus. Nat. Hist.*, 113 (4): 273-338.

Bacon, E.H. 1954. Field characters of prolarvae and alevins of brook, brown, and rainbow trout in Michigan. *Copeia*, no. 3, p.232.

Bailey, R.M., Winn, H.E., and Smith, C.L. 1954. Fishes from the Escambia River, Alabama and Florida, with ecological and taxonomic notes. *Proc. Acad. Nat. Sci. Philadelphia*, 106: 109-164.

Bailey, R.M., Lachner, E.A., Lindsey, C.C., Robins, C., Roedel, P., Scott, W., and Woods, F. 1960. A list of common and scientific names of fishes from the United States and Canada. *Am. Fish. Soc.*, special publication no. 2, 2nd ed., pp. 1-102.

Bean, T.H. 1887. Description of a supposed new species of char (*Salvelinus aureolus*) from Sunapee Lake, New Hampshire. *Proc. U.S. Nat. Mus.*, 10: 628-30.

Berg, L.S. 1908. Vorlaufige Bemerkungen über die europaisch - asiatischen Salmoniden, insbesondere die Gattung *Thymallus*. *Ann. Mus. Imper. Sci. St. Petersbourg*, 12: 500-14.

——— 1940. Classification of fishes, both recent and fossil. *Trav. Inst. Zool. Acad. Sci. U. R. S. S.*, vol. 5(2): 87-517 (Russian with English translation lithoprinted, 1947, by J.W. Edwards, Ann Arbor, Michigan).

——— 1948. Les poissons des eaux douces de l' U. R. S. S. et des pays limitrophes, vol. 1. Leningrad, 4th ed.

Böker, H. 1913. Der Schädel von *Salmo salar*. Ein Beitrag zur Entwicklung des Teleostierschädels. Anat. Hefte, 49 (1): 359-97.

Boulenger, A. 1895. Remarks on some cranial characters of the salmonids. *Proc. Zool. Soc. London* , pp. 299-302.

Bruch, C. 1861. Vergleichende Osteologie des Rheinlachses (*Salmo salar*) mit besonderer Berücksichtigung der Myologie nebst einleitenden Bemerkungen über die skelettbildenen Gewebe der Wirbelthiere (Mainz).

Carl, G.C. and Clemens, W.A. 1953. The freshwater fishes of British Columbia. *British Columbia Prov. Mus. Handbook* No. 5, 2nd ed.

Carl, G.C., Clemens, W.A., and Lindsey, C.C. 1959. The freshwater fishes of British Columbia. *British Columbia Prov. Mus. Handbook* No. 5, 3rd ed.

Chamberlain, F.M. 1907. Some observations on salmon and trout in Alaska. *Rept. of the U. S. Comm. Fish.*, 1906, Document 627, p. 1-112.

Chapman, W.M. 1941a. The osteology and relationships of the isospondylous fish *Plecoglossus altivelis* Temminck and Schliegel. *J. Morphol.*, 68 (3): 425-55.

________ 1941b. The osteology and relationships of the osmerid fishes. *J. Morphol.*, 69 (2): 279-301.

________ 1942. The osteology and relationships of the Argentinidae, a family of oceanic fishes. *J. Wash. Acad. Sci.*, 32(4): 104-17.

________ 1948. The osteology and relationships of the Microstomidae, a family of oceanic fishes. *Proc. California Acad. Sci.* 26 (4): 1-22.

Clemens, W.A. 1935. The Pacific salmon in British Columbia waters. *Rept. British Columbia Comm. Fish.*, 1934, pp. K103-5.

Cockerell, T.D. 1919. Some American cretaceous fish scales, with notes on the classification and distribution of cretaceous fishes. *U. S. Geol. Surv. Prof. Pap.*, 120: 165-188.

Cope, E.D. 1870. On the fishes of a freshwater tertiary in Idaho. Discovered by Capt. Clarence King. *Proc. Amer. Philos. Soc.*, 11: 538-47.

David, L.R. 1943. Miocene fishes of southern California. *Geol. Soc. Amer. Spec. Pap.*, 43: 1-103.

________ 1946 . Upper cretaceous fish remains from western border of the San Joaquin Valley, California. *Carnegie Inst. Wash.*, pub. 557: 85-112.

de Beer, G.R. 1927. The early development of the chondrocranium of *Salmo fario*. *Quart. J. Microscop. Sci.*, 71 (2): 259-312.

________ 1937. The development of the vertebrate skull. Oxford Univ. Press.

Dekay, J.E. 1842. Zoology of New York or the New York Fauna: IV. Fishes. Albany, N.Y.

Delacy, A.C. and Morton, W.M. 1943. Taxonomy and habits of the charrs, *Salvelinus malma* and *Salvelinus alpinus*, of the Karluk Drainage System. *Trans. Am. Fish. Soc.*, 72: 79-92.

Dineen, C.F. and Stokely, P.S. 1954. Osteology of the central mudminnow, *Umbra limi*. *Copeia*, pp. 169-79.

Dobzhansky, T. 1950. Mendelian populations and their evolution. *Amer. Nat.*, 84: 401-18.

Du Rietz, G.E. 1930. The fundamental units of botanical taxonomy. *Svensk. Bot. Tidsskr.*, 24: 333-428.

Dunbar, M.J. and Hilderbrand, H.H. 1952. Contribution to the study of the fishes of Ungava Bay. *J. Fish. Res. Bd. Can.*, 9 (2): 83-128.

Duncan, D.B. 1955. Multiple range and multiple F tests. *Biometrics*, 11: 1-42.

Dymond, J.R. 1936. Some fresh-water fishes of British Columbia. *Rept. Comm. Fish. B. C.*, 1935, pp. 60-73.

________ 1947. A list of the freshwater fishes of Canada east of the Rocky Mountains. *Roy. Ont. Mus. Zool.*, Miscellaneous Pub. No.1: 1-36.

________ 1964. A history of ichthyology in Canada. *Copeia*, No. 1: 2-33.

Dymond, J.R. and Vladykov, V.D. 1934. The distribution and relationship of the salmonid fishes of North America and north Asia. *Proc. Fifth Pac. Sci. Congr.* (Vancouver, B.C.), pp. 3741-50.

Edwards, F.W. 1953. Genera and subgenera. *Syst. Zool.*, 2: 135.

Everhart, W.H. 1950a. Fishes of Maine. Maine Dept. Inland Fisheries and Game (Augusta).

________ 1950b. The blueback trout, *Salvelinus oquassa* (Girard), in Maine. *Copeia*, p. 242.

Fabricius, E. and Gustafson, K.J. 1954. Further aquarium observations on the spawning behaviour of the char, Salmo alpinus L. Inst. Freshwater Res., Drottningholm, Rept., 35: 58-104.

Ford, E. 1937. Vertebral variation in teleostean fishes. J. Marine Biol. Assoc., N.S. 22: 1-60.

Garman, S. 1885. The American salmon and trout, including introduced species. 19th Rept. Mass. Comm. Inland Fish. (Boston).

________ 1893. The lac de Marbre Trout, a new species. Science, 22: p. 23.

Gill and Jordan. 1878. See Jordan, Evermann, and Clark, 1930.

Girard, C. 1854. Salmo oquassa Girard. Proc. Boston Soc. Nat. Hist., 4: 262-3.

Goodrich, E. S. 1909. Vertebrate craniata. In Treatise on Zoology, by R. Lankester (London).

________ 1930. Studies in the structure and development of vertebrates. London, MacMillan and Co. Ltd., pp. 1 - 837.

Gosline, W. A. 1954. Further thoughts on subspecies and trinomials. Syst. Zool., 3, 92-94.

__________ 1960. Contributions toward a classification of modern Isospondylous fishes. Bull. Brit. Mus. (Nat. Hist.), 6 (6): 327-65.

__________ 1961. Some osteological features of modern lower teleostean fishes. Smith. Misc. Coll., 142 (3).

Green, C. W. and Green, C. H. 1913. The skeletal musculature of the king salmon. Bull. U. S. Bur. Fish., 33: 21-60.

Gregory, W. K. 1933. Fish skulls: A study of the evolution of natural mechanism. Am. Phil. Soc. (Philadelphia), No. 23.

Günther, A. 1866. See Jordan, Evermann, and Clark, 1930.

Hadžišče, S. 1960. Zur Kenntnis der Gattung Salmothymus Berg, zugleich ein Beitrag zur Systematik des Familie der Salmoniden (Pisces). Publ. Zaveda za riberstvo NRM-Skopje, 3 (2): 39-50.

Hartman, G. F. 1956. A taxonomic study of cutthroat trout Salmo clarki clarki Richardson, rainbow trout Salmo gairdneri Richardson and reciprocal hybrids. MA thesis, Univ. of British Columbia.

Henn, A. W. and Rinkenbach, W. H. 1925. Description of the aurora trout (*Salvelinus timagamiensis*), a new species from Ontario. *Ann. Carnegie Mus.*, 16: 131-41.

Hikita, T. 1954. On the common names of the salmonoid fishes and their related forms found in northern Japan and its adjacent waters. *Sci. Rept. Hokkaido Fish Hatchery*, 9 (1-2): 137-45.

_________ 1962. Ecological and morphological studies of the genus *Oncorhynchus* (Salmonidae) with particular consideration on philogeny. *Sci. Rept. Hokkaido Fish Hatchery*, No. 17: 1-97.

Hilderbrand, H. 1948. Marine fishes of Arctic Canada. MS thesis, McGill Univ.

Hollister, G. 1936. Caudal skeleton of Bermuda shallow water fishes. II. Order Isospondyli. *Zoologica*, 21: 257-90.

Hubbs, C. L. 1919. A comparative study of the bones forming the opercular series of fishes. *J. Morphol.*, 33 (1): 61-71.

_________ 1953. An improved graphical analysis and comparison of series of samples. *Syst. Zool.*, 2 (2): 49-56.

Hubbs, C. L. and Lagler, K. F. 1958. Fishes of the Great Lakes. *Cranbrook Inst. Sc. Bull.* 26.

Hussakof, L. 1916. Discovery of the great lake trout, *Cristivomer namaycush*, in the Pleistocene of Wisconsin. *Jour. Geol.*, 24: 685-9.

Huxley, J. S. 1940. The new systematics. Oxford, Clarendon Press (London).

Huxley, J., Needham, J., and Lerner, I. M. 1941. Terminology of relative growth rates. *Nature*, 148: 225.

Inger, R. F. 1958. Comments on the definition of Genera. *Evolution*, 12: 370-84.

Jordan, D. S. 1923. A classification of fishes, including families and genera as far as known. *Stanford Univ. Publ. Biol. Sci.* III (2): 124-5.

Jordan, D. S. and Evermann, B. W. 1896. The fishes of North America and Middle America. Part I. *Bull. U. S. Nat. Mus.*, 47 (1): i - ix, 1-1240.

Jordan, D. S., Evermann, B. W. and Clark, H. W. 1930. Check list of the fishes of North and Middle America. *Rept. U. S. Comm. Fish.*, 1928 (Reprint 1955): 54-61.

Jordan, D. S. and Gilbert, C. H. 1883. Synopsis of the fishes of North America. *U. S. Nat. Mus. Bull.* 12: 1-95.

Kendall, W.C. 1914. The fishes of New England. The salmon family: I. The trout or chars. *Mem. Boston Soc. Nat. Hist.*, 8: 1-103.

——— 1919. Concerning the generic name *Cristivomer* vs. *Salvelinus* for the great lakes trout or namaycush. *Copeia*, 74: 79-81.

Kölliker, A. 1860. Untersuchungen über das Ende der Wirbelsäule der lebenden Ganoiden und einiger Teleostier. Gratulationsschrift zur 400 Jähr Jubiläumsfeier der Universität Basel (Leipzig).

Kramer, C.Y. 1956. Extension of multiple range tests to group means with unequal numbers of replications. *Biometrics*, 12: 307-10.

Legendre, V. 1954. Key to game and commercial fishes of the province of Quebec. The freshwater fishes. Game and Fish Dept., Quebec, 1: 1-180.

Lekander, B. 1949. The sensory line system and the cranial bones in the head of some osteriophysi. *Acta Zoologica*, Haft 1 - 2, Arg. 30: 1-131.

Lindsey, C.C. 1956. Distribution and taxonomy of fishes in the MacKenzie drainage of British Columbia. *J. Fish. Res. Bd. Can.*, 13 (6): 759-789.

Linnaeus. 1758. See Jordan, Evermann, and Clark, 1930.

MacFarlane, J.M. 1923. The evolution and distribution of fishes. The Macmillan Co. of Canada Ltd., London.

MacKay, H.H. 1963. Fishes of Ontario. Dept. of Lands and Forests.

McAllister, D.E. 1964. The evolution of branchiostegal rays in teleostome fishes. PhD thesis, Univ. of British Columbia.

McPhail, J.D. 1961. A systematic study of the *Salvelinus alpinus* complex in North America. *J. Fish. Res. Bd. Can.*, 18 (5): 793-816.

Maär, A. 1949. Fertility of char (*Salmo alpinus L.*) in the Faxälven water system, Sweden. *Swedish Inst. Freshwater Res.*, Rep. No. 29, pp. 115-22.

Martin, N.V. 1940. The Arctic char of North America. MA thesis, Univ. of Toronto.

——— 1949. The mechanics of environmental control of body form in fishes. *Univ. of Toronto Studies*, *Biol. Ser.*, No. 58; *Publ. Ontario Fish. Res. Lab.*, No. 70.

Mayr, E. 1940. Speciation phenomena in birds. Am. Naturalist, 74: 249-78.

_______ 1942. Systematics and the origin of species. Columbia Univ. Press, New York.

_______ 1963. Animal species and evolution. The Belknap Press of Harvard University.

Mayr, E., Linsley, E. G., and Usinger, R. L. 1953. Methods and Principles of systematic zoology. McGraw - Hill Book Co., New York.

Meek, A. 1916. The migration of fishes. Edward Arnold, London.

Meglitsch, P. A. 1954. On the nature of the species. Syst. Zool., 3, 49-65.

Milne, D. J. 1948. The growth, morphology and relationship of the species of Pacific salmon and the steelhead trout. PhD thesis, McGill Univ.

Mitchill, S. L. 1814. See Jordan, Evermann, and Clark, 1930.

_____________ 1818. See Jordan, Evermann, and Clark, 1930.

Morton, W. M. and Miller, R. R. 1954. Systematic position of the lake trout, Salvelinus namaycush. Copeia, pp. 116-24.

Mottley, C. M. 1934. The origin and relations of the rainbow trout. Trans. Am. Fish. Soc., 64: 323-7.

Neave, F. 1958. The origin and speciation of Oncorhynchus. Trans. Roy. Soc. Canada, Series III, sec. 5, vol. 52: 25-39.

Needham, P. R. and Gard, R. 1959. Rainbow trout in Mexico and California with notes on the cutthroat series. Univ. of California Pub. Zool., 67 (1): 1-124.

Nikol'skii, G. V. 1961. Special ichthyology (Chastnaya ikhtiologiya). Published for the National Foundation, Washington, D. C., and the Smithsonian Institution by the Israel Program for Scientific Translations, Jerusalem.

Nomura, M. 1954. On the taxonomic characters in the mouth cavity of salmonid fishes. II. Pacific salmons. Japanese J. Ichthyol., 3 (6): 232-37.

Norden, C. R. 1961. Comparative osteology of representative salmonid fishes, with particular reference to the grayling (Thymallus arcticus) and its phylogeny. J. Fish. Res. Bd. Can., 18 (5): 679-791.

Pennant, - 1792. See Jordan, Evermann, and Clark, 1930.

Pfaff, J.R. 1937. Fishes. In *Report of the Fifth Thule Expedition*, Rasmussen, Knud (ed.) (Copenhagen), 2 (7): 1-29.

Radforth, I. 1944. Some considerations on the distribution of fishes in Ontario. *Contrib. Roy. Ont. Mus. Zool.* No. 25.

Rafinesque - 1817. See Jordan, Evermann, and Clark, 1930.

Regan, C.T. 1909. The classification of teleostean fishes. *Ann. Mag. Nat. Hist.*, 8 (3): 75-86.

——— 1910. The caudal fin of the Elopidae and of some other teleostean fishes. *Ann. Mag. Nat. Hist.*, ser. 8, 5: 354-8.

——— 1911. The fresh water fishes of British Isles, XXV + 287 pp. Metheun and Co. Ltd., London.

——— 1913. The Antarctic fishes of the Scottish National Expedition. *Trans. Roy. Soc. Edinburgh*, 49 (2): 229-92.

——— 1914. The systematic arrangement of the fishes of the family Salmonidae. *Ann. Mag. Nat. Hist.*, 13 (8): 405-8.

——— 1920. The geographical distribution of salmon and trout. *Salmon and Trout Mag.*, 22: 25-35.

Rensch, B. 1929. Das Prinzip geographischer Rassenkreise und das Problem der Artbildung. Bornträger Verl., Berlin.

Richardson, J. 1836. Fauna Boreali Americana III. Fishes (London).

Ridewood, W. G. 1904 . On the cranial osteology of the fishes of the families Elopidae and Albulidae. *Proc. Zool. Soc.* London, 2: 35-81.

Rounsefell, G.A. 1962. Relationships among North American Salmonidae. *U. S. Fish and Wildlife Service, Fish Bull.* No. 209 (62): 235-70.

Royce, W.F. 1951. Breeding habits of lake trout in New York. *U. S. Fish and Wildlife Serv., Fish Bull.*, 59 (52): 59-76 .

Saunderson, E.C. 1935. The early development of the chondrocranium of *Salmo salar*. *Proc. Nova Scotian Inst. Sci.*, 19 (1): 121-47.

Schleip, W. 1904. Development of bony skull in *Salmo*. *Anat. Hefte*, 23: p. 331.

Scott, W.B. 1958. A checklist of the freshwater fishes of Canada and Alaska. *Roy. Ontario Mus.*

Seymour, Allyn. 1959. Effects of temperature on the formation of vertebrae and fin rays in young chinook salmon. *Trans. Am. Fish. Soc.*, 88: 58-69.

Simpson, G.G. 1951. The species concept. *Evolution*, 5: 285-98.

________ 1961. Principles of animal taxonomy. Columbia Univ. Press (New York).

Sisson, E.F. 1950. Lake Sunapee's golden trout. *Natl. Geo. Mag.*, 98: 529-36.

Slastenenko, E.F. 1958. The freshwater fishes of Canada. Kiev Printers, Toronto.

Steel, B.G. and Torrey, J.H. 1960. Principles and procedures of statistics. McGraw - Hill.

Stokell, G. 1951. The American lake char (*Cristivomer namaycush*). *Trans. Roy. Soc. New Zealand*, 79: 213-7.

Stresemann, E. 1919. Uber die europaischen Baumläufer. *Verhandl. Orn. Ges. Bayern*, 14: 39-74.

Suckley, G. 1860. Description of several new species of Salmonidae from the northwest coast of America. *Ann. N. Y. Lyceum Nat. Hist.*, 7: 1-10.

Svärdson, G. 1957. The coregonoid problem. VI. The palearctic species and their intergrades. *Rept. Swedish State Inst. Freshwater Fish* Res., 23: 1-151 (Drottningholm).

Svetina, M. 1962. Etude synoptique sur la biologie du Huchon, *Hucho hucho* (Linné), 1758. *FOA Fish. Biol. Synopsis* (Rome), No. 22.

Taning, A.V. 1952. Experimental study of meristic characters in fishes. *Biol. Revs.*, 27: 169-93.

Tchernavin, V.V. 1923. An attempt towards a systematic arrangement of certain Salmonoidei, based on osteological characters. *Izv. Inst. Opytnoi Agronomii*, 1: 103-6.

________ 1937. Skulls of salmon and trout. *Salmon and Trout Mag.*, 88: 235-42.

________ 1938a. Changes in the salmon skull. *Trans. Zool. Soc. London*, 24 (2): 103-84.

________ 1938b. Notes on the chondocranium and branchial skeleton of *Salmo*. *Proc. Zool. Soc. London, Ser. B.*, 108: 347-64.

________ 1939. The origin of salmon. Is its ancestry marine or freshwater? *Salmon and Trout Mag.*, 95: 120-40.

Uyneo, T. and Miller, R.R. 1963. "Summary of late Cenozoic freshwater fish records from North America", *Occ. Papers Mus. Zool. Univ. Mich.*, No. 631: 1-34.

Vladykov, V.D. 1934. Environment and taxonomic characters of fishes. *Trans. Roy. Can. Inst.*, 20: 99-140.

__________ 1954. Taxonomic characters of the eastern North American chars (*Salvelinus* and *Cristivomer*). *J. Fish. Res. Bd. Can.*, 11 (6): 904-32.

__________ 1957. Les formes locales de la truite rouge due Quebec (*Salvelinus marstoni*). *Nat. Canadian*, 84 (12): 233-48.

__________ 1962. Osteological studies on Pacific salmon of the genus *Oncorhynchus*. *Fish. Res. Bd. Can. Bull.* 136: 1-172.

__________ 1963. A review of Salmonid genera and their broad geographical distribution. *Trans. Roy. Soc. Can. Series IV*, Vol. I: 459-504.

Walbaum, J.J. 1792. Petri Artedi renovati partes (Ichthyologia). Pt. 3, Genera piscum. A.F. Roese, Grypeswaldiae: P. 66.

Walters, V. 1953. The fishes collected by the Canadian Arctic Expedition, 1913-18, with additional notes on the Ichthyofauna of western Arctic Canada. *Bull. Nat. Mus. Can.* No. 128: 1-18.

__________ 1955. Fishes of western Arctic America and eastern Siberia. *Am. Mus. Nat. Hist.*, 106 (5): 259-368.

Waters, C.A. 1960. A study of the life history and taxonomic position of the blueback trout, *Salvelinus oquassa* (Girard). MS thesis, Univ. of Maine.

Weiler, W. 1943. Die Otolithen aus dem Jungertiär Sud-Rumäniens. 1. *Buglow and -Sarmat*, *Senckenbergiana*, 26: 87-115.

Westoll, T.S. 1937. On the cheekbones in teleostome fishes. *J. Anat.*, 71: 362-82.

Wilder, D.G. 1952. A comparative study of anadromous and freshwater populations of brook trout (*Salvelinus fontinalis* Mitchill). *J. Fish. Res. Bd. Can.* 9 (4): 169-203.

Wilson, E.O. and Brown, W.L. 1953. The subspecies concept. *Syst. Zool.*, 2, 97-111.

Wynne-Edwards, V.C. 1952. Freshwater vertebrates of the Arctic and subarctic. *Bull. Fish. Res. Bd. Can.*, 94.

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PLATE 7 269

PLATE 8 271

PLATE 9 281

PLATE 10 285

PLATE 11 287

PLATE 12 295

TABLE: 52. Sizes of the adults of the various species of Salmonidae used for photographing the skeletal elements

Species	Locality	Date of Capture	Tag no.	Fork length mm	Total head length mm	Structures photographed
Cristivomer namaycush	A_2	Oct.1961	A-11094	547	134	Median fins
	A_4	May 1962	4819	435	108	Chondrocranium, and dermal skull bones and caudal skeleton
	"	" "	A-11363	464	121	Chondrocranium
	"	" "	4829	475	119	Dorsal and lateral views of skull
	"	" "	4830	535	128	Branchial skeleton
	"	" "	A-11365	572	134	Pectoral and ventral fins
Salvelinus alpinus alpinus	B_1	July 1962	5248	476	84	Dorsal and lateral views of skull
	"	" "	5252	642	122	Caudal skeleton
	"	" "	5235	685	143	Dermal skull bones
	"	" "	5232	700	133	Chondrocranium and basibranchial teeth
	"	" "	5237	722	147	Pectoral and ventral fins
Salvelinus alpinus oquassa - Quebec	C_5	June 1962	A-12131	291	63	Chondrocranium and dermal skull bones
Salvelinus alpinus oquassa- Pushineer Lake, Maine	D_1	June 1962	6741	204	40	Supraethmoid
	"	" "	6779	245	50	Chondrocranium and dermal skull bones and caudal skeleton
Salvelinus alpinus oquassa - Floods Pond, Maine	E_1	June 1962	6837	251	54	Chondrocranium dermal skull bones and caudal skeleton
Salvelinus malma	F_4	Dec. 1962	5053	465	106	Dorsal and lateral skulls, basibranchial and pharyngeal plates and caudal skeleton
	"	" "	5043	663	157	Chondrocranium and dermal skull bones
Salvelinus fontinalis fontinalis	G_1	May 1962	A-11827	337	69	Pharyngeal plates.
	"	" "	A-11824	392	81.5	Chondrocranium and dermal skull bones and caudal skeleton.
	"	" "	A-11832	432	89.5	Dorsal and lateral skull views
	G_2	Aug. 1962	A-11845	270	53	Basibranchial teeth
Salvelinus fontinalis timagamiensis	H_1	Nov. 1961	A-11934-5	418	98	Chondrocranium and dermal skull bones
Salmo gairdnerii	I_1	Feb. 1961	A-11022	700	141	Caudal skeleton
	"	Jan. 1961	A-11045	788	172	Chondrocranium and dermal skull bones
Salmothymus ohridanus (F)	J_1	Oct. 1929	5218	250	51.5	Lateral skull view and caudal skeleton
Hucho hucho (F)	K_3	Dec. 1888	5410	365	85.5	Lateral skull view and caudal skeleton
Brachymystax lenok (F) [1]	–	– –	5226	132	—	Dorsal and lateral skull bones
	L_1	– –	5195	280	60	Dermal skull bones

[1] Information on date of capture for Brachymystax lenok is lacking. Instead of fork length, standard length is given. The head length is not given as the head bones were detached previously.

PLATE 1(A - S)

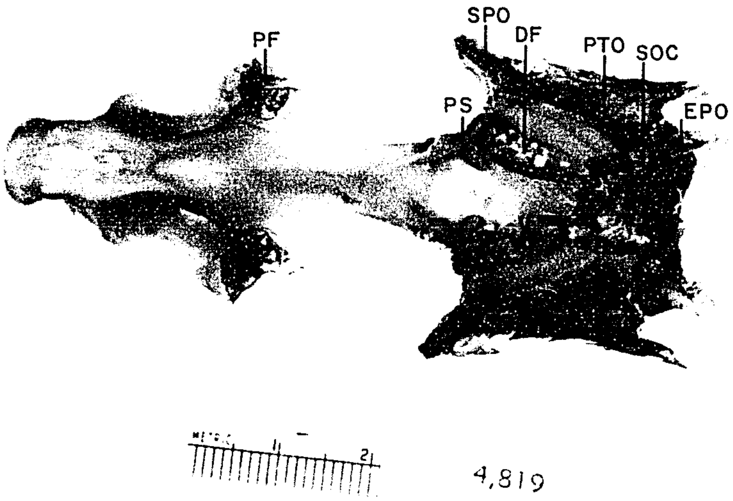
Dorsal, ventral, lateral, and posterior views of Chondrocrania of Salmonidae

The opisthotic and basisphenoid bones are easily detached and are not shown in most cases

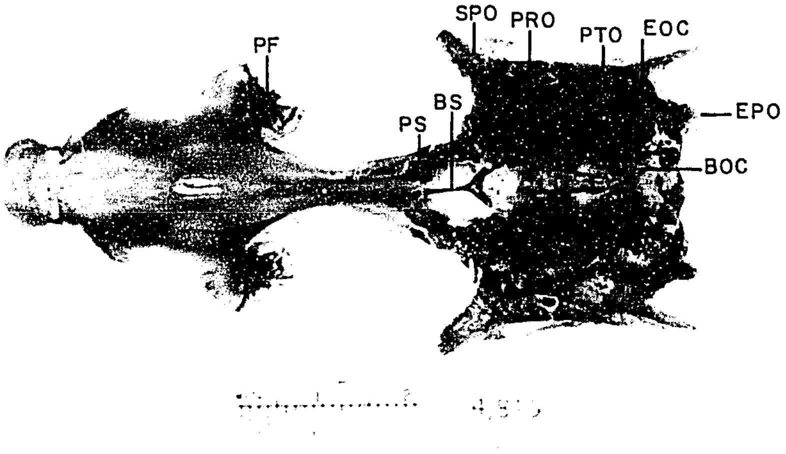
- A. Dorsal view of *Cristivomer namaycush*
- B. Ventral view of *Cristivomer namaycush*, orbitosphenoid bone absent
- C. Ventral view of *Cristivomer namaycush*, orbitosphenoid bone present
- D. Lateral view of *Cristivomer namaycush*
- E. Posterior view of *Cristivomer namaycush*
- F. Dorsal view of *Salvelinus alpinus alpinus*
- G. Ventral view of *Salvelinus alpinus alpinus*
- H. Dorsal view of *Salvelinus alpinus oquassa* - Quebec
- I. Ventral view of *Salvelinus alpinus oquassa* - Quebec
- J(1). Dorsal view of *Salvelinus alpinus oquassa* - Pushineer Lake, Maine
- J(2). Dorsal view of *Salvelinus alpinus oquassa* - Floods Pond, Maine
- K(1). Ventral view of *Salvelinus alpinus oquassa* - Pushineer Lake, Maine
- K(2). Ventral view of *Salvelinus alpinus oquassa* - Floods Pond, Maine
- L. Dorsal view of *Salvelinus malma*
- M. Ventral view of *Salvelinus malma*
- N. Dorsal view of *Salvelinus fontinalis fontinalis*
- O. Ventral view of *Salvelinus fontinalis fontinalis*
- P. Dorsal view of *Salvelinus fontinalis timagamiensis*
- Q. Ventral view of *Salvelinus fontinalis timagamiensis*
- R. Dorsal view of *Salmo gairdnerii*
- S. Ventral view of *Salmo gairdnerii*

Abbreviations: BOC, basioccipital; EOC, exoccipital; EPO, epiotic; FM, foramen magnum; PRO, prootic; PS, pterosphenoid; PTO, pterotic; SOC, supraoccipital; SPO, sphenotic; HE, hypethmoid.

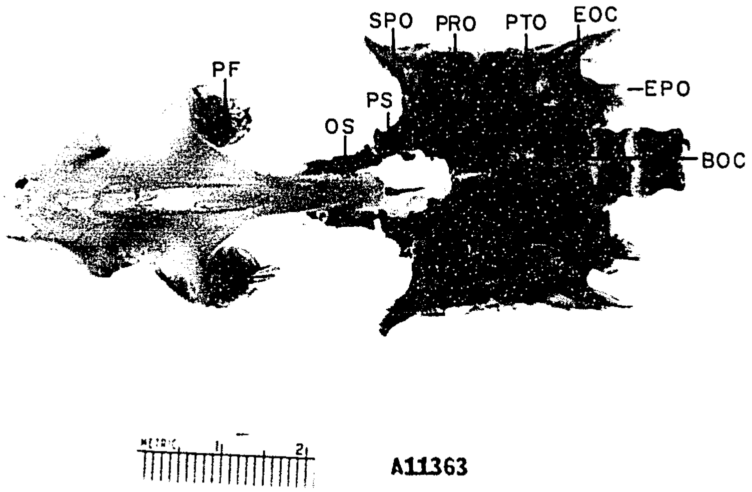
A


SPO
DF
PTO
SOC
PF
PS
EPO
METRIC 1 2
4,819

B

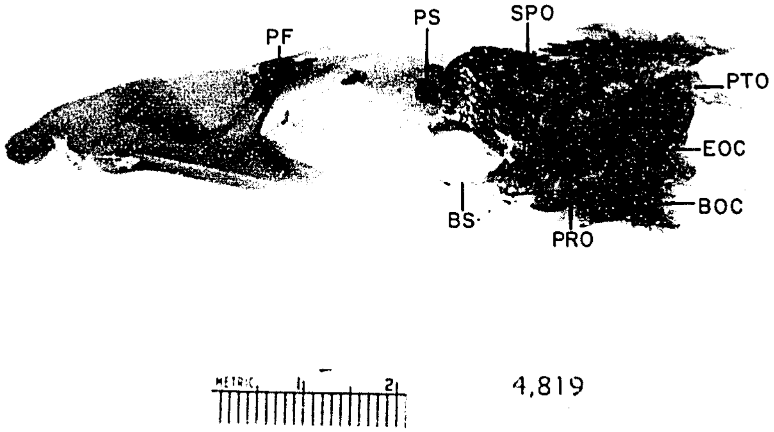

SPO
PRO
PTO
EOC
PF
BS
PS
EPO
BOC
4,819

C



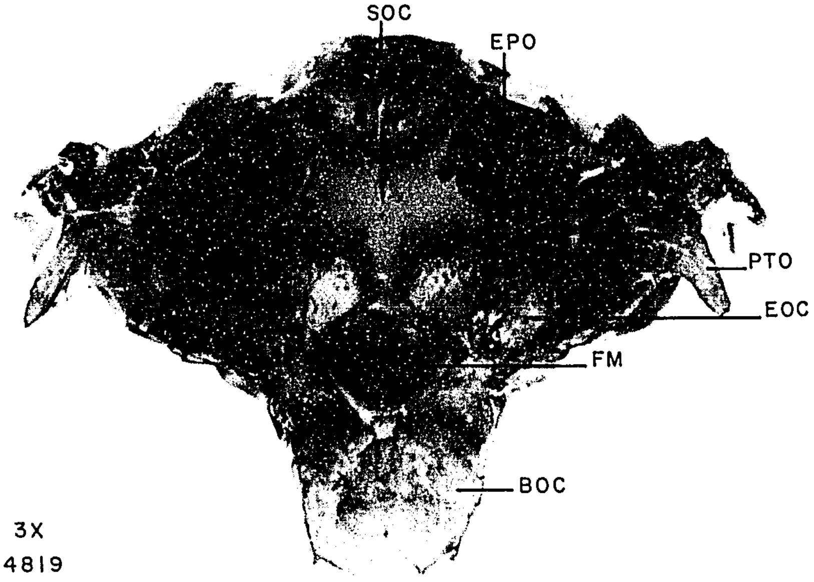
A11363

D



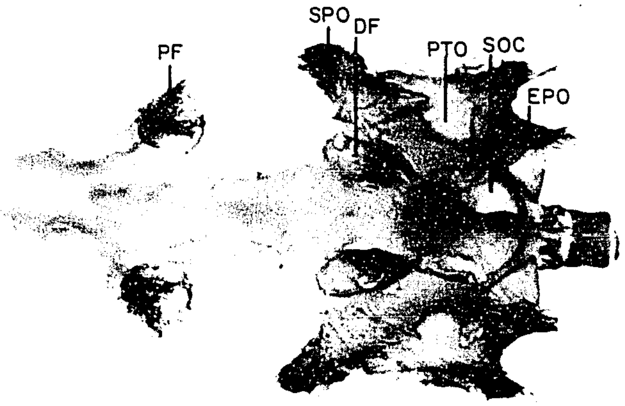
4,819

E



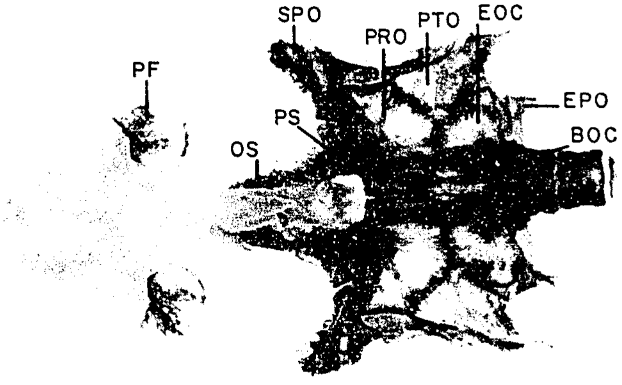
3X
4819

F



5232

G



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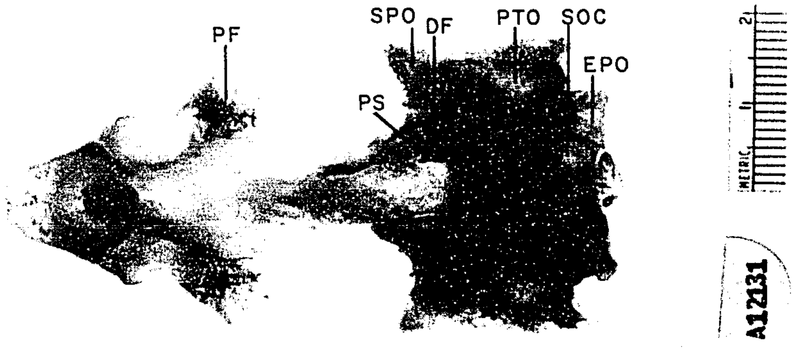
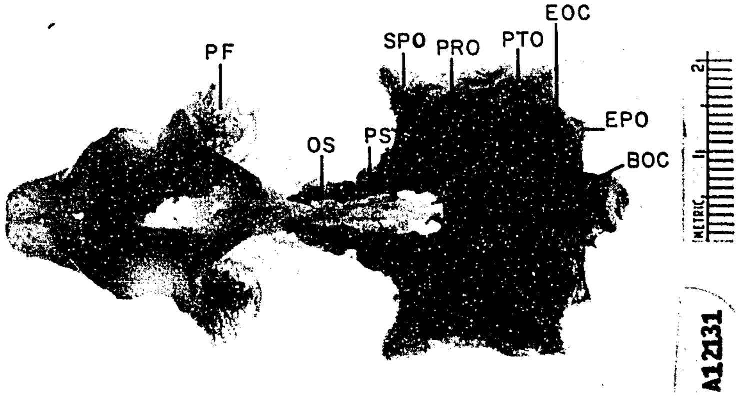
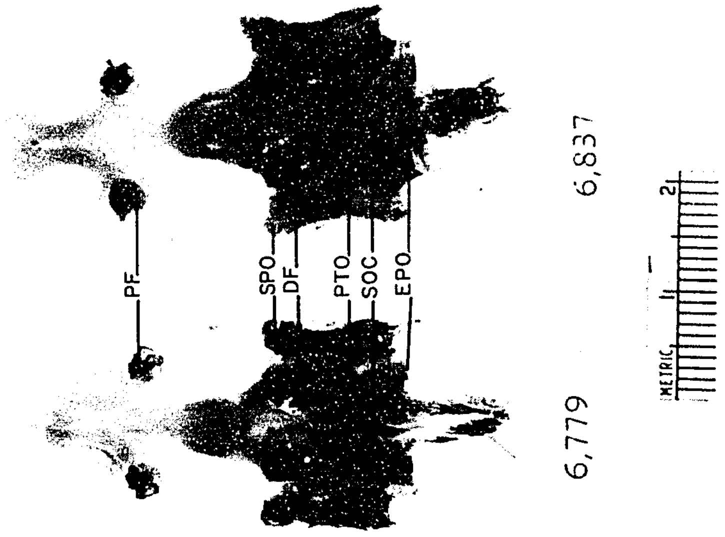

PF
SPO
DF
PTO
SOC
EPO
PS
METRIC
1
2
A12131

I


PF
SPO
PRO
PTO
EOC
EPO
BOC
OS
PS
METRIC
1
2
A12131

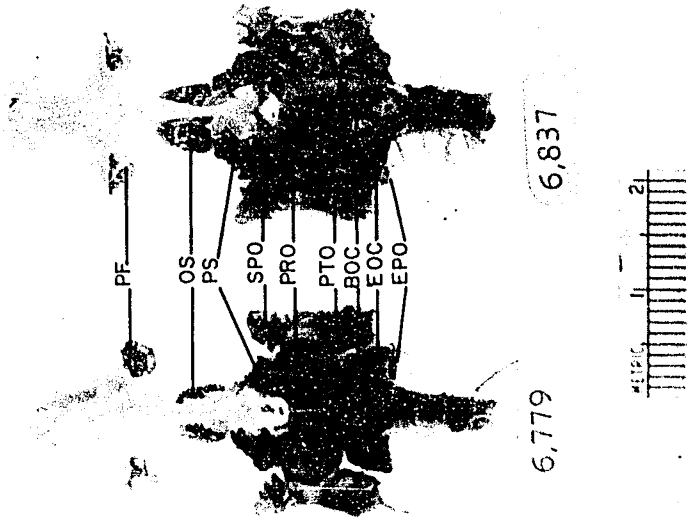
J-2

J-1

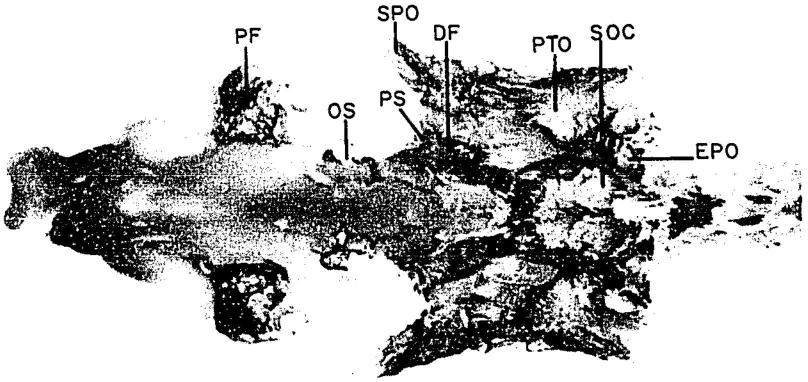

PF
SPO
DF
PTO
SOC
EPO
6,837
6,779
METRIC
1
2

K-2

K-1


PF
OS
PS
SPO
PRO
PTO
BOC
EOC
EPO
6,837
6,779
METRIC
1
2

L



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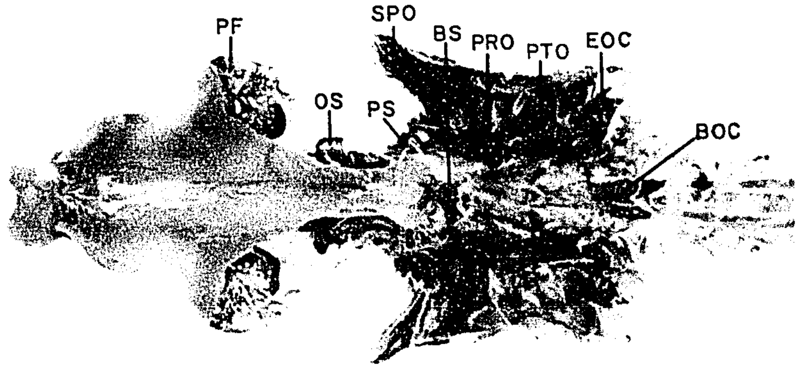

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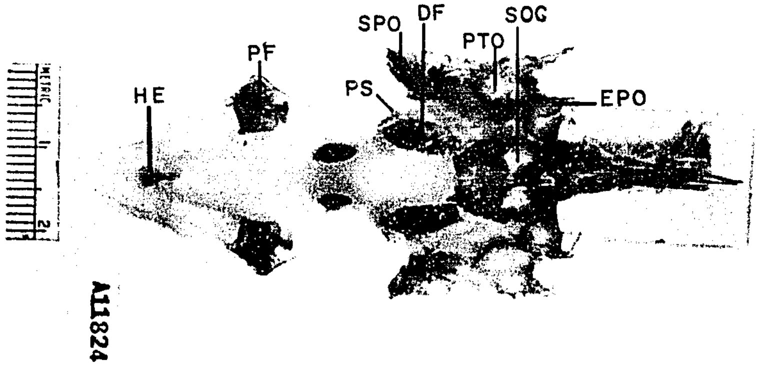
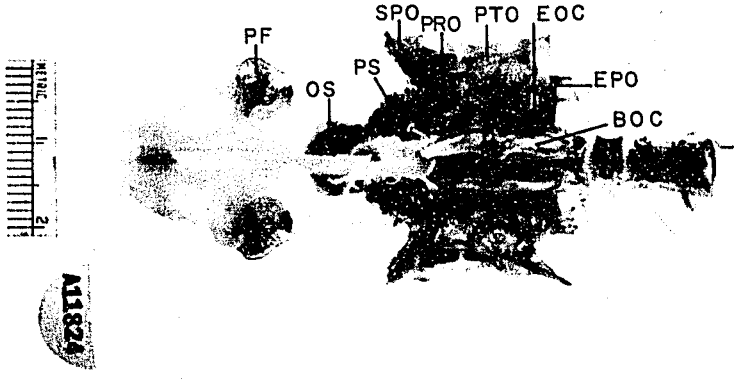
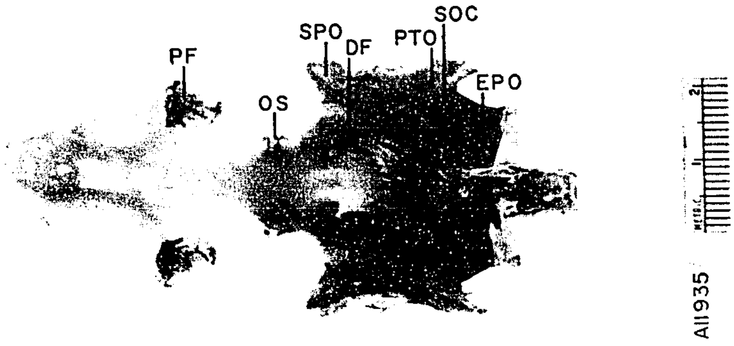

METRIC
1
2
HE
PF
SPO
DF
PTO
SOC
PS
EPO
A11824

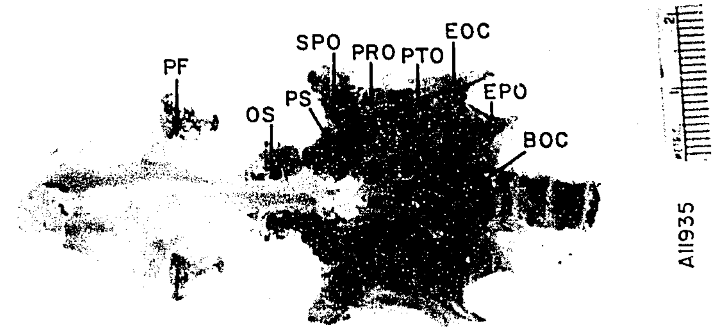
O


METRIC
1
2
PF
SPO
PRO
PTO
EOC
PS
OS
EPO
BOC
A11824

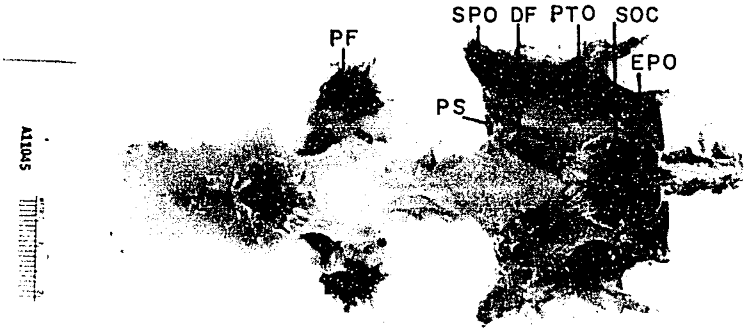
P


PF
SPO
DF
PTO
SOC
EPO
OS
1
2
A11935

Q


PF
SPO
PRO
PTO
EOC
EPO
OS
PS
BOC
1
2
A11935

R


A1045
PF
SPO
DF
PTO
SOC
EPO
PS

S

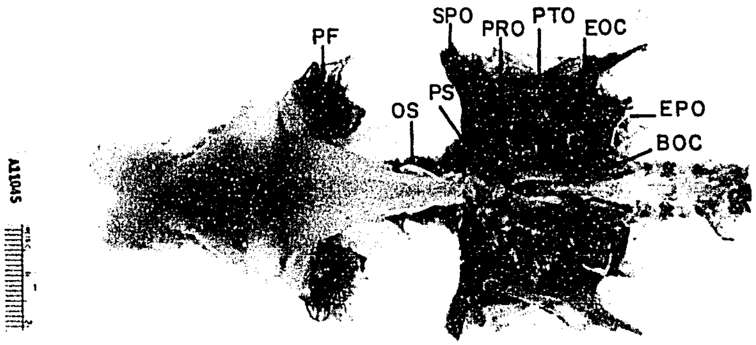
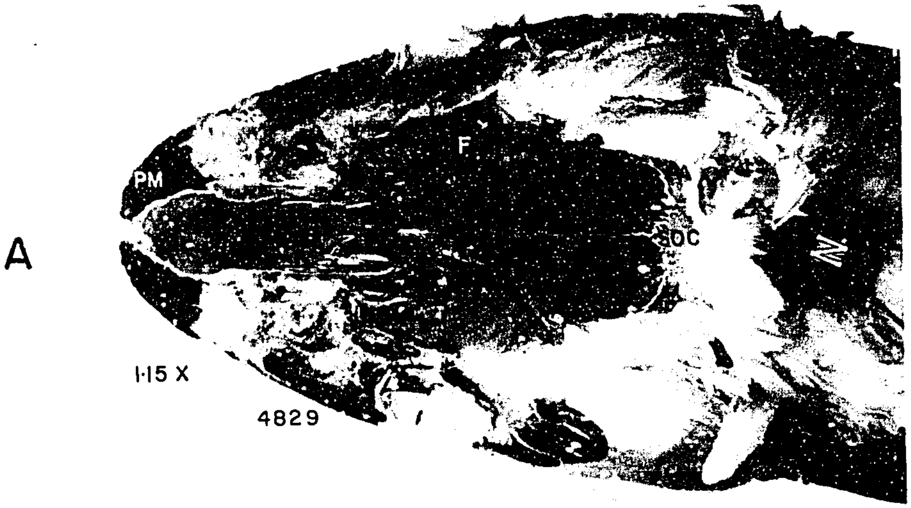

A1045
PF
SPO
PRO
PTO
EOC
PS
OS
EPO
BOC

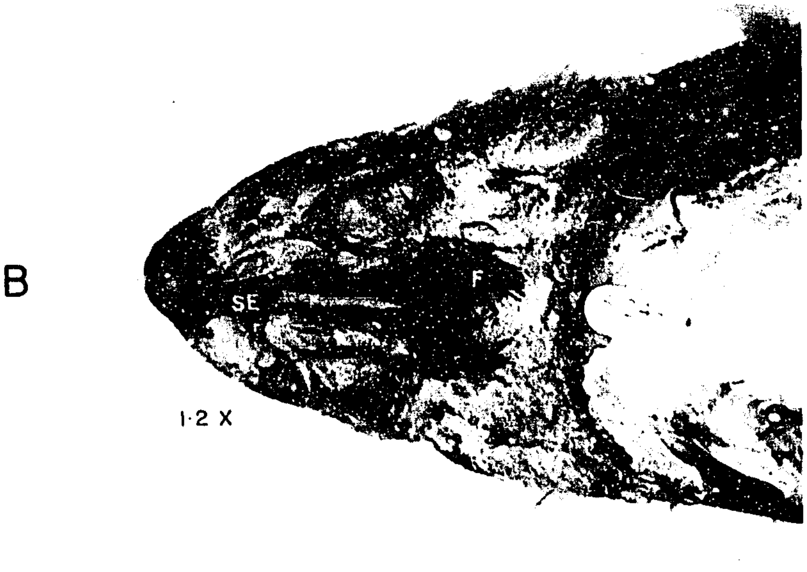
PLATE 2(A - E)

Dorsal views of skulls of Salmonidae

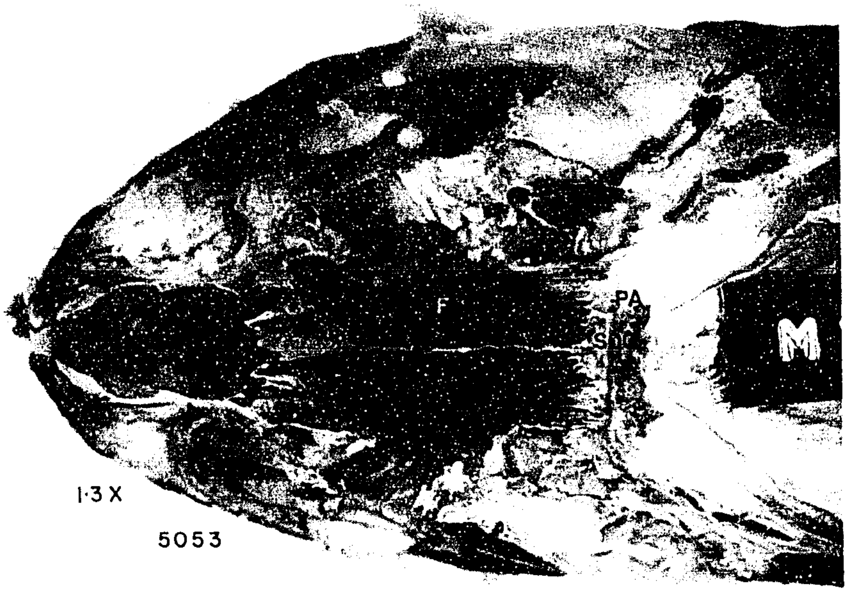
A. *Cristivomer namaycush*
B. *Salvelinus alpinus alpinus*
C. *Salvelinus malma*
D. *Salvelinus fontinalis fontinalis*
E. *Brachymystax lenok*

Abbreviations: [illegible], frontal; [illegible], parietal; SE, supraethmoid; [illegible], supraoccipital.


A
PM
F
SOC
1·15 X
4829


B
SE
F
1·2 X

C



D

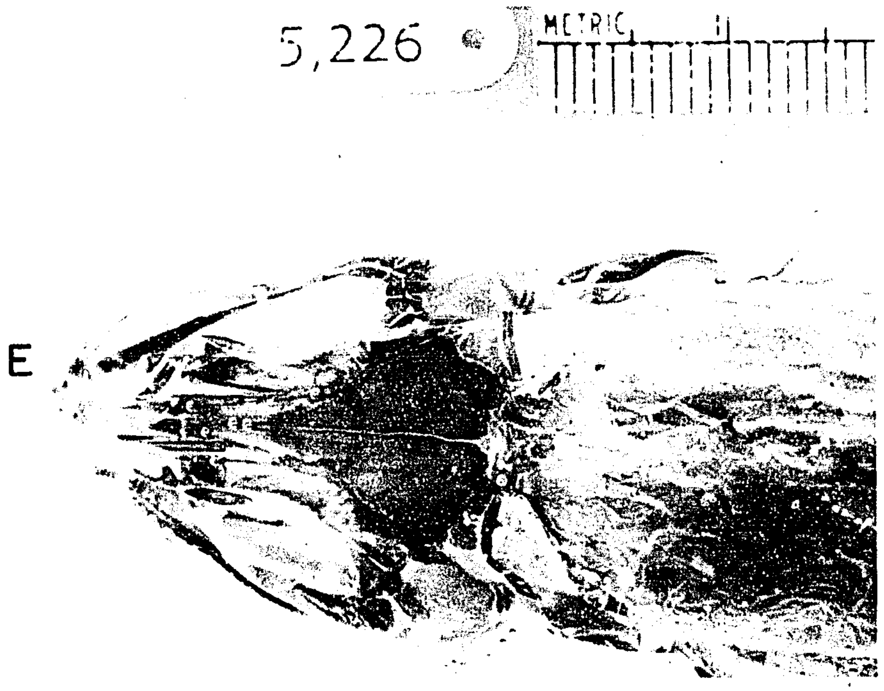

5,226
METRIC
E

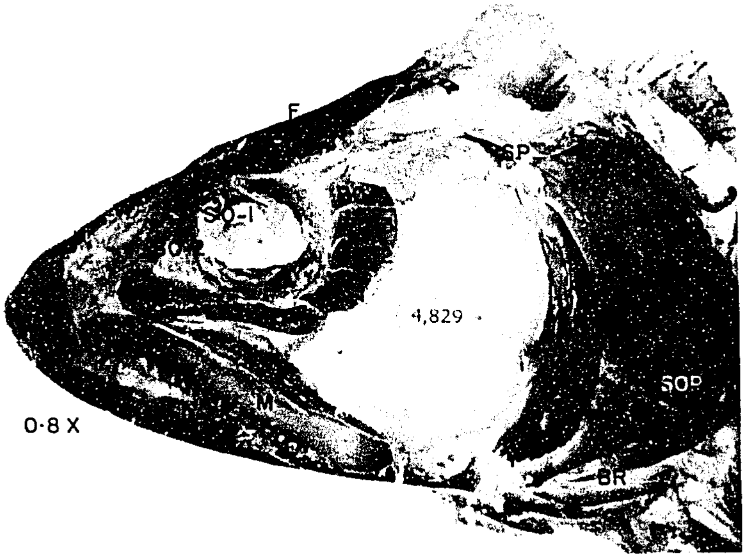
PLATE 3(A - G)

Lateral views of skulls of Salmonidae

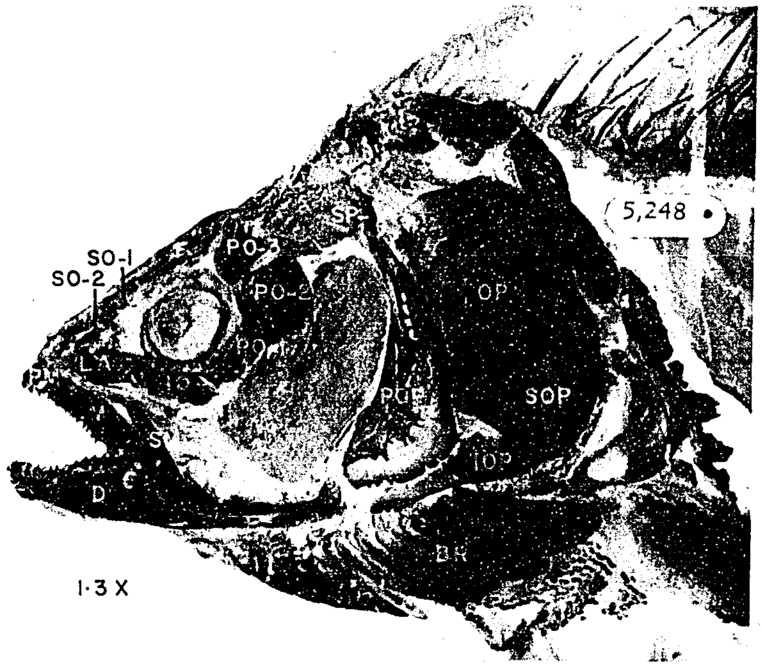
A. *Cristivomer namaycush*
B. *Salvelinus alpinus alpinus*
C. *Salvelinus malma*
D. *Salvelinus fontinalis fontinalis*
E. *Salmothymus ohridanus*
F. *Hucho hucho*
G. *Brachymystax lenok*

Abbreviations: A, angular; BR, branchiostegal ray; D, dentary; F, frontal; IO, infraorbital; IOP, interopercle; LA, lachrymal; M, maxilla; OP, opercle; PM, premaxilla; PO 1-4, postorbitals; POP, preopercle; SM, supramaxilla; SO 1-2, supraorbitals; SOP, subopercle; SP, suprapreopercle.

A



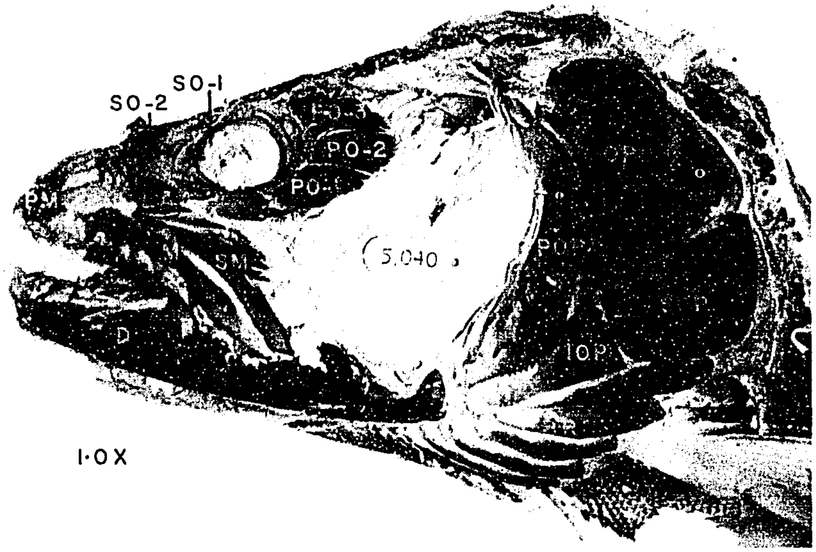
B



SO-1
SO-2
PM
LA
PO-3
PO-2
PO-1
SP
OP
SOP
POP
IOP
S
D
BR
5,248

1·3X

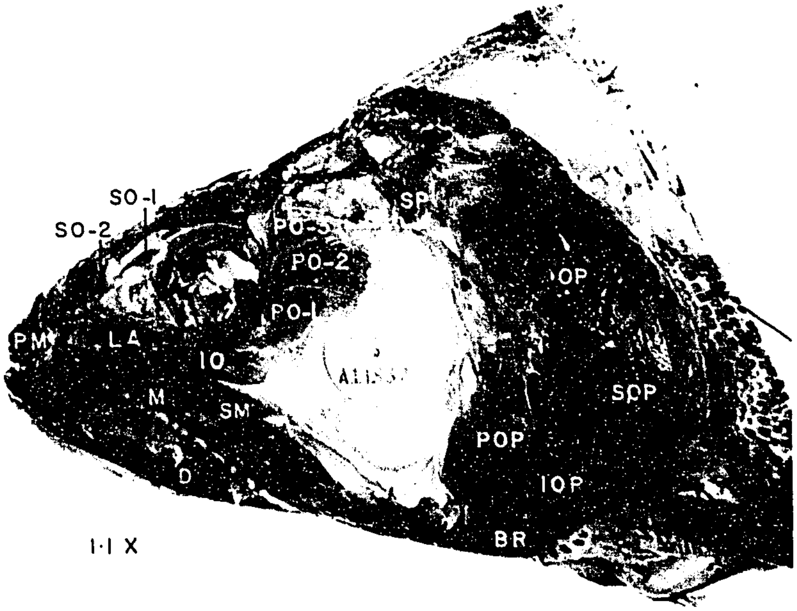
C



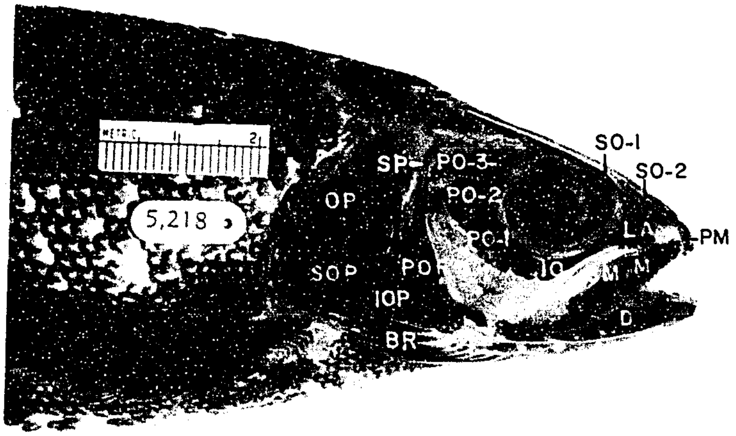
SO-2
SO-1
PO-3
PO-2
PO-1
PM
SM
D
5,040
OP
POP
IOP

1·0X

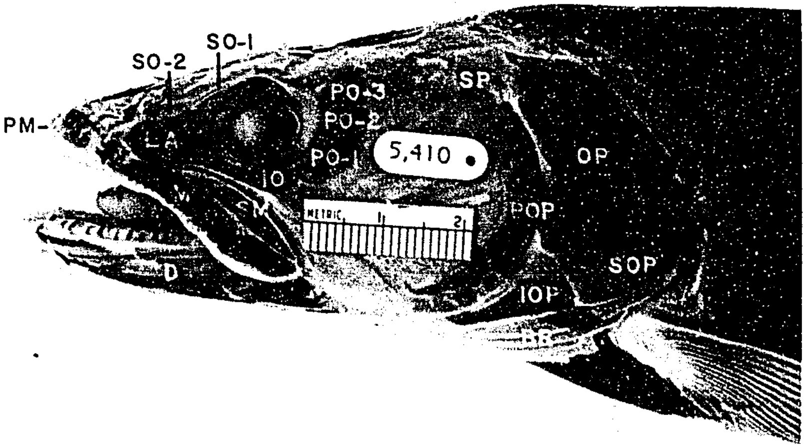
D



E


METRIC
1
2
5,218
SO-1
SO-2
SP
PO-3
PO-2
PO-1
OP
LA
PM
SOP
POP
IO
M
IOP
D
BR

F


SO-1
SO-2
PO-3
SP
PM
PO-2
LA
5,410
PO-1
OP
IO
M
SM
METRIC
1
2
POP
D
SOP
IOP
BR

G

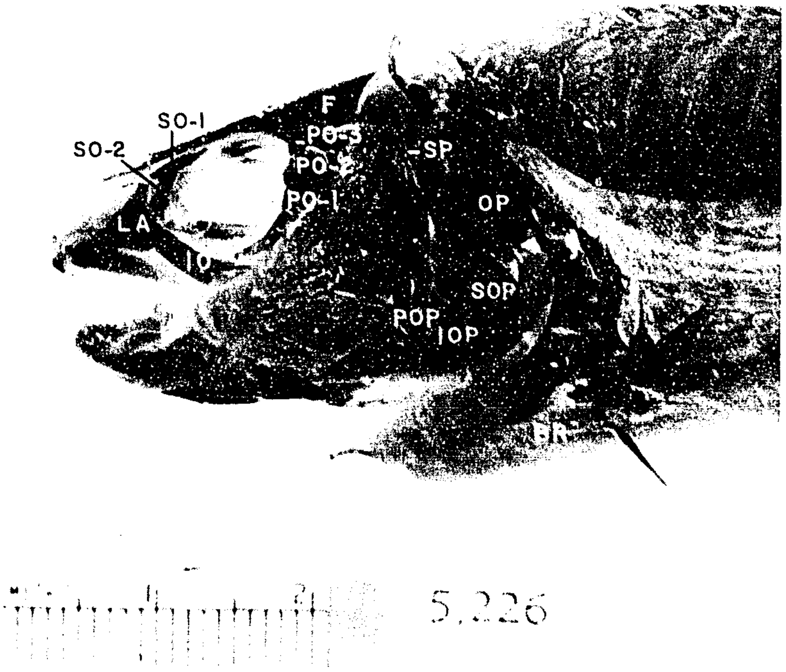
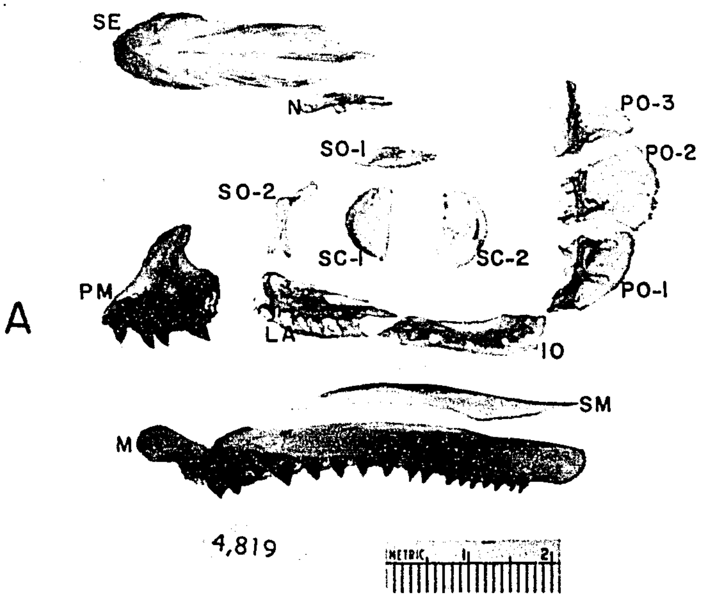

F
SO-1
PO-3
SO-2
PO-2
SP
PO-1
OP
LA
IO
SOP
POP
IOP
BR
1
2
5,226

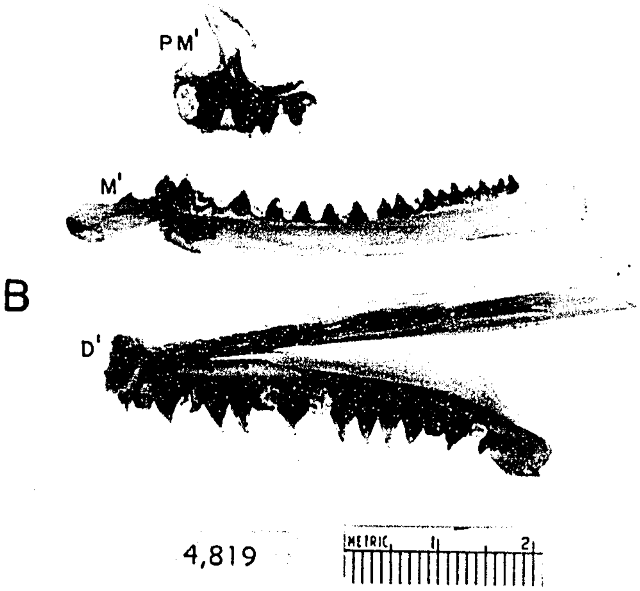
PLATE 4(A - K)

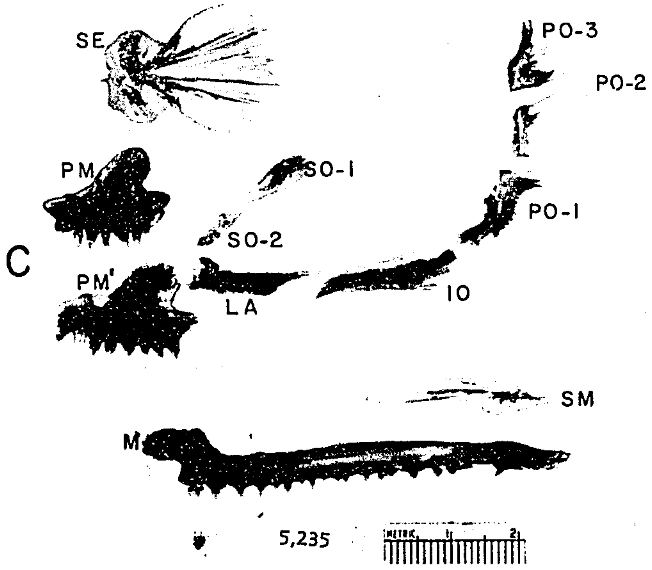
Selected dermal skull bones of Salmonidae.

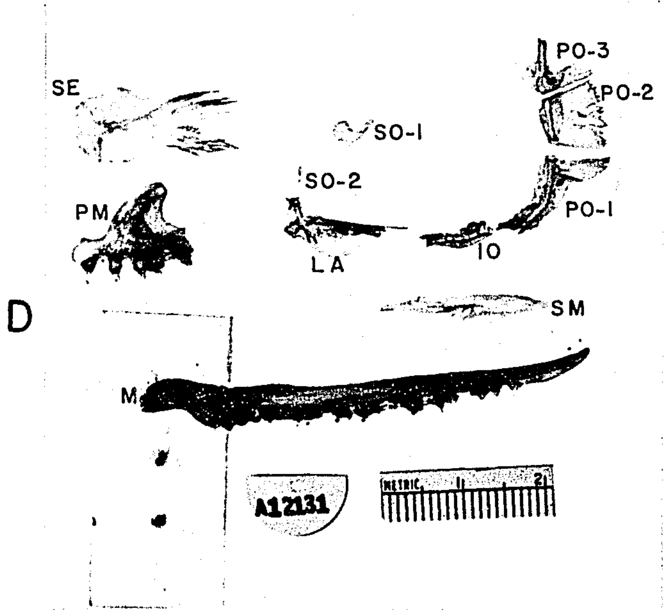
A. *Cristivomer namaycush*
B. *Cristivomer namaycush*
C. *Salvelinus alpinus* [illegible]
D. *Salvelinus alpinus oquassa* - [illegible]
E. *Salvelinus alpinus oquassa* - Pushineer Lake, Maine
F. *Salvelinus alpinus oquassa* - Floods Pond, Maine
G. *Salvelinus malma*
H. *Salvelinus fontinalis fontinalis*
I. *Salvelinus fontinalis timagamiensis*
J. *Salmo gairdnerii*
K. *Brachymystax lenok*

Abbreviations: D', dentary (internal view; IO, infraorbital; LA, lachrymal; M, maxilla (M' internal view); N, nasal; PM, premaxilla (PM', internal view); PO 1-4, postorbitals; SC 1-2, sclerotics; SE, supraethmoid; SM, supramaxilla; SO 1-2, supraorbitals.

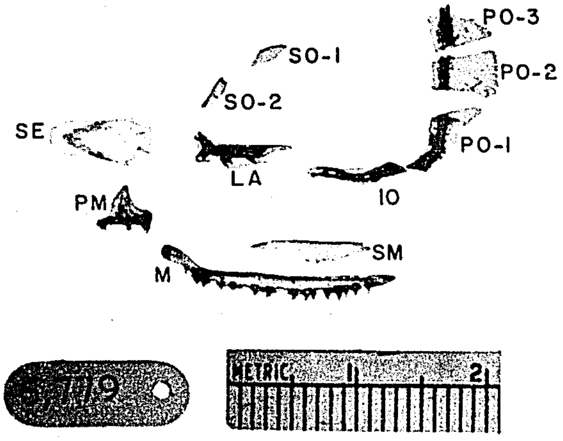

SE
N
PO-3
SO-1
PO-2
SO-2
SC-1
SC-2
PM
PO-1
A
LA
IO
SM
M
4,819
METRIC 1 2


PM'
M'
B
D'
4,819
METRIC 1 2

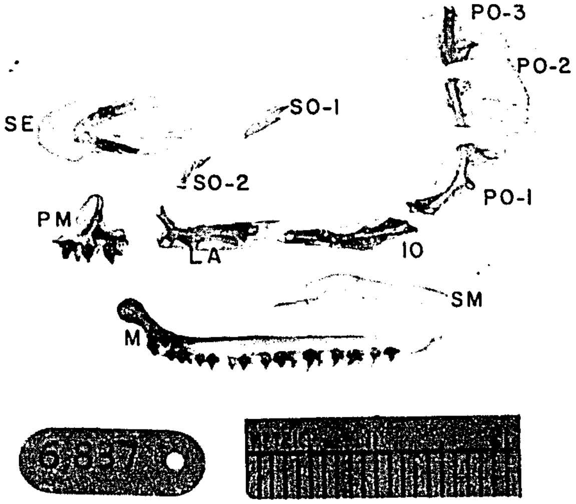

SE
PO-3
PO-2
PM
SO-1
PO-1
SO-2
C
PM'
LA
IO
SM
M
5,235
METRIC 1 2


SE
PO-3
PO-2
SO-1
SO-2
PM
PO-1
LA
IO
D
SM
M
A12131
METRIC 1 2

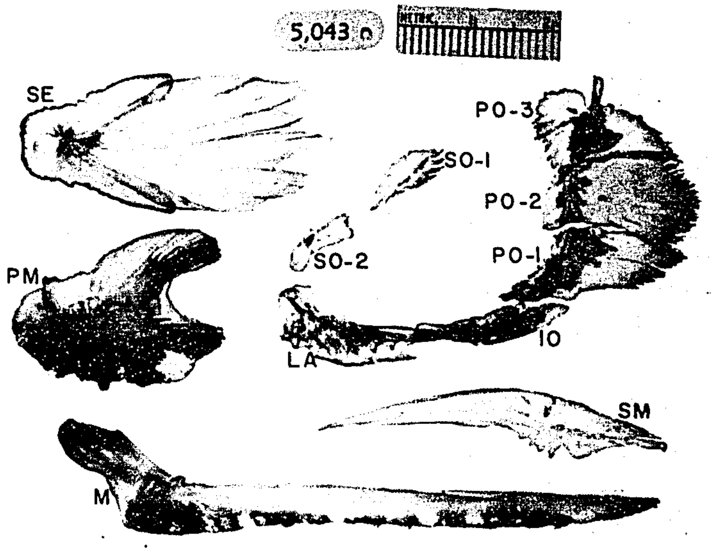
E


PO-3
SO-1
PO-2
SO-2
SE
PO-1
LA
10
PM
SM
M
5719
METRIC
1
2

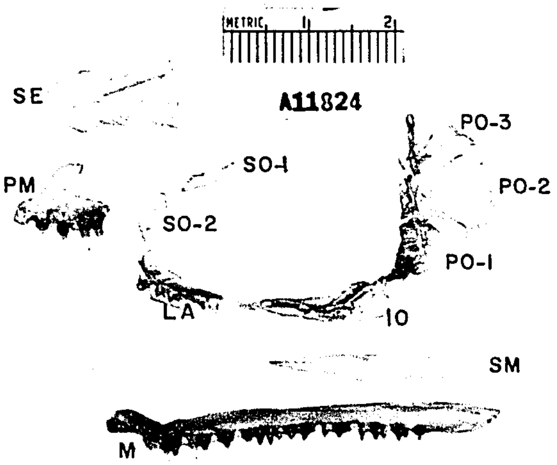
F


PO-3
PO-2
SO-1
SE
SO-2
PO-1
PM
LA
10
SM
M
6887

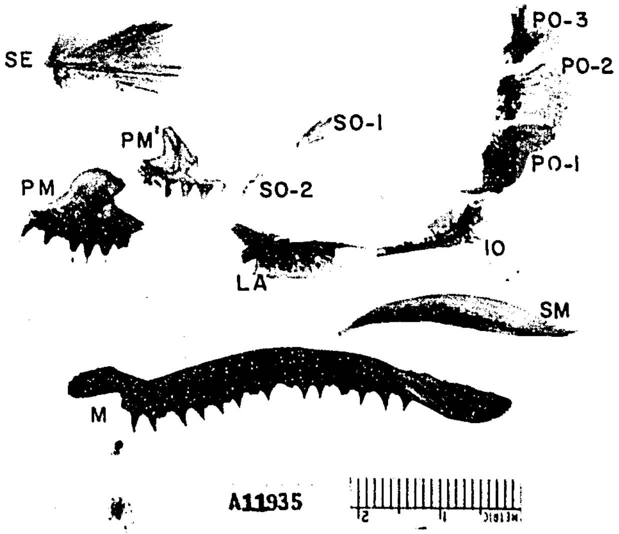
G



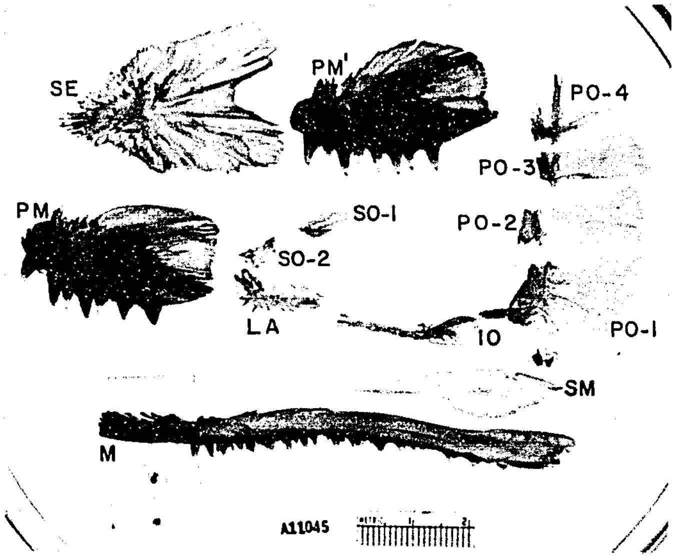
H


METRIC
1
2
A11824
SE
PM
SO-1
SO-2
PO-3
PO-2
PO-1
LA
IO
SM
M

I.


SE
PO-3
PO-2
PM'
SO-1
PM
SO-2
PO-1
LA
IO
SM
M
A11935
2
1
METRIC

J


SE
PM'
PO-4
PO-3
PM
SO-1
PO-2
SO-2
LA
IO
PO-1
SM
M
A11045

K

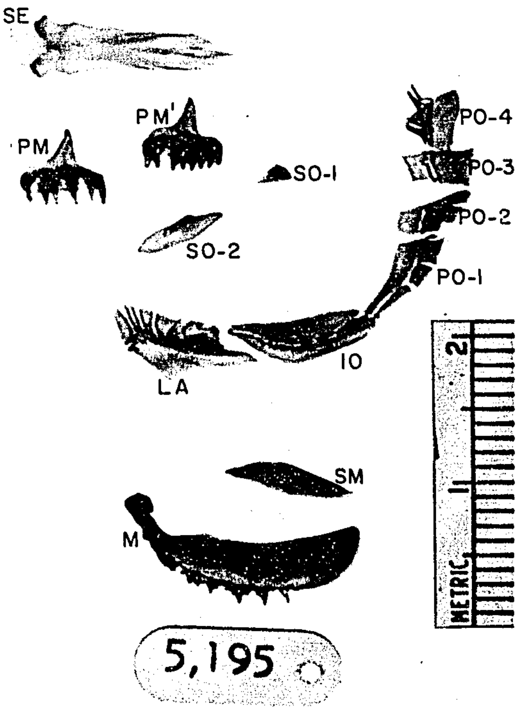

SE
PM'
PO-4
PM
SO-1
PO-3
PO-2
SO-2
PO-1
LA
IO
2
SM
1
M
METRIC
5,195

PLATE 5(A - L)

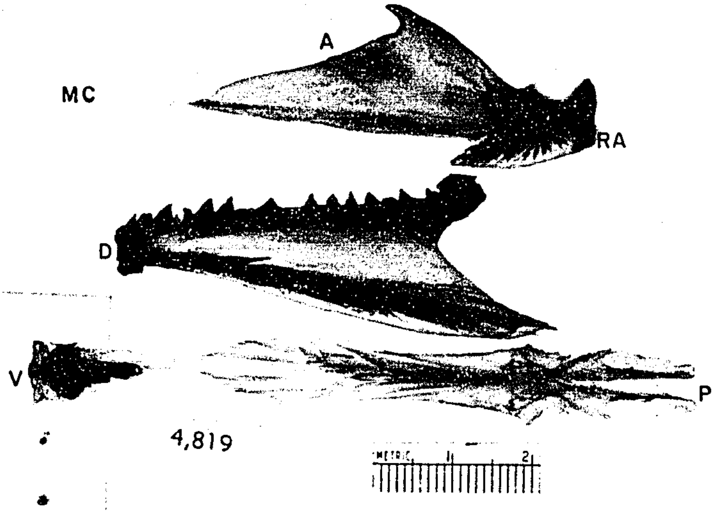
Selected dermal skull bones of Salmonidae

The coronomeckelian and retroarticular bones and Meckel's cartilage are marked on the photographs in rare cases.

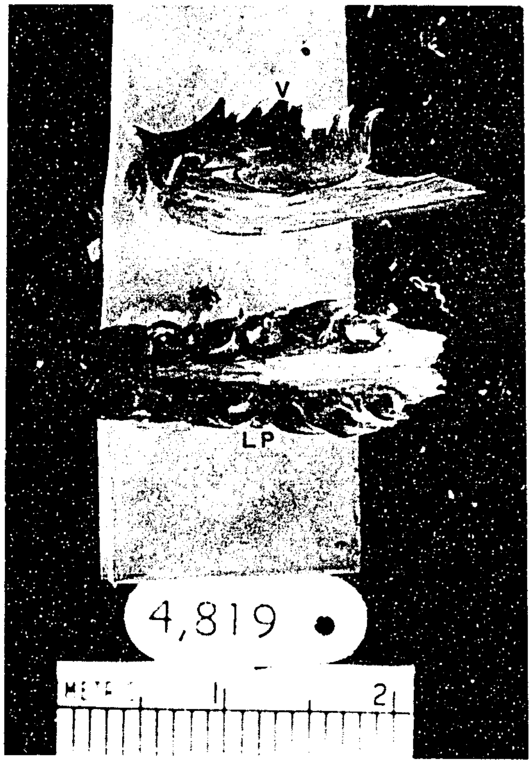
- A. *Cristivomer namaycush*.
- B. *Cristivomer namaycush*, lingual plate and vomer much enlarged to show the teeth, and also the attachment of the crest of the vomer on the shaft.
- C. *Salvelinus alpinus alpinus*
- D. *Salvelinus alpinus oquassa* - Quebec
- E. *Salvelinus alpinus oquassa* - Pushineer Lake, Maine
- F. *Salvelinus alpinus oquassa* - Floods Pond, Maine
- G. *Salvelinus malma*
- H. *Salvelinus fontinalis fontinalis*
- I. *Salvelinus fontinalis timagamiensis*
- J. *Salmo gairdnerii*
- K. *Brachymystax lenok*
- L. *Brachymystax lenok*, vomer much magnified to show the arrangement of the teeth on the head of the vomer

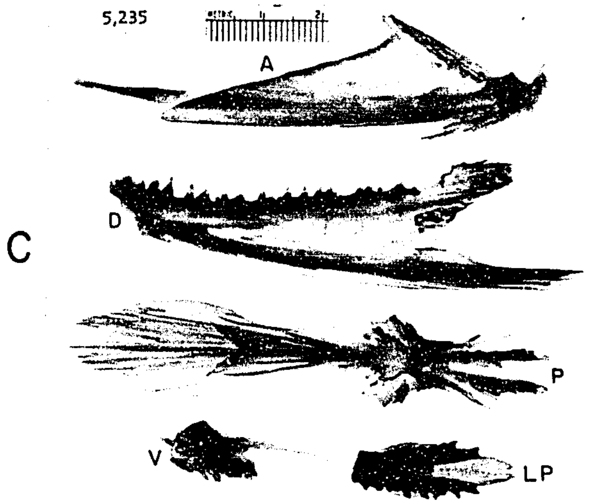
Abbreviations: A, angular; D, dentary; LP, lingual plate; P, parasphenoid; RA, retroarticular; V, vomer.

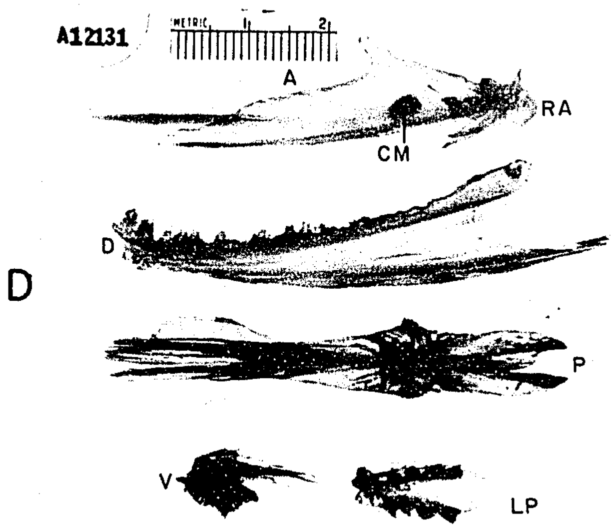
A



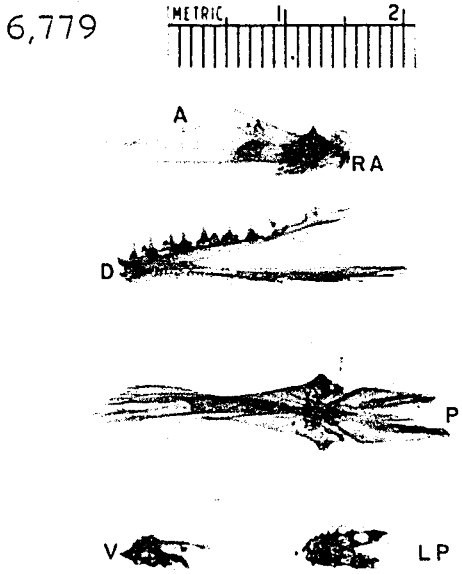
B



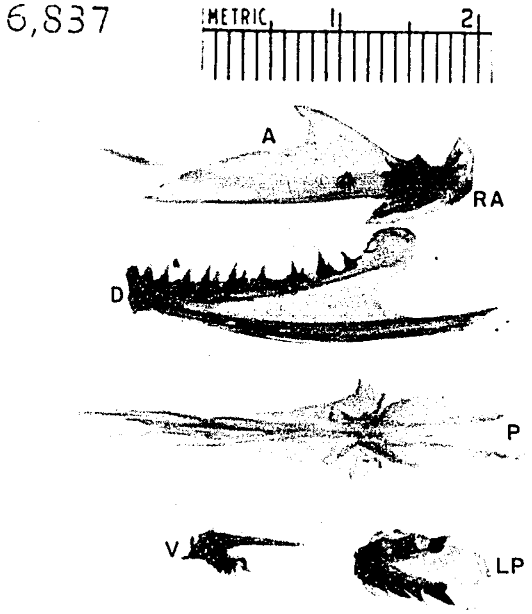

5,235
METRIC
1
2
A
D
C
P
V
LP


A12131
METRIC
1
2
A
RA
CM
D
D
P
V
LP

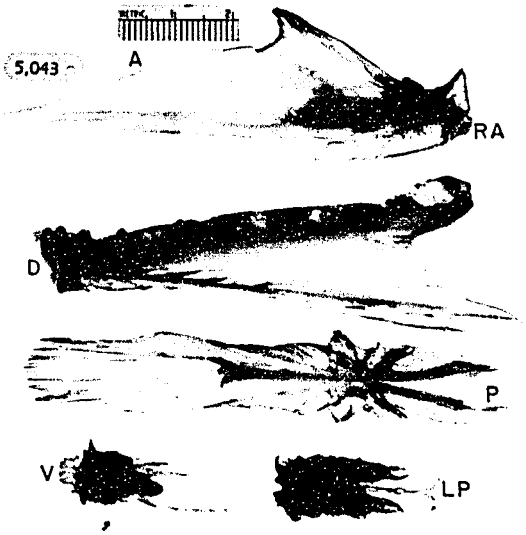
E



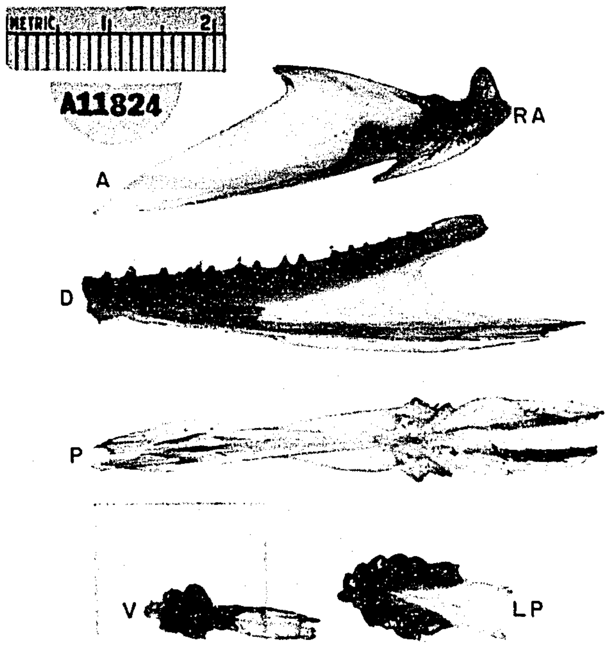
F



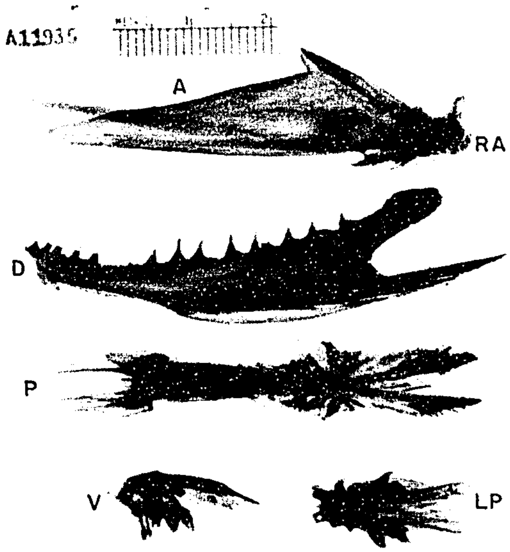
G

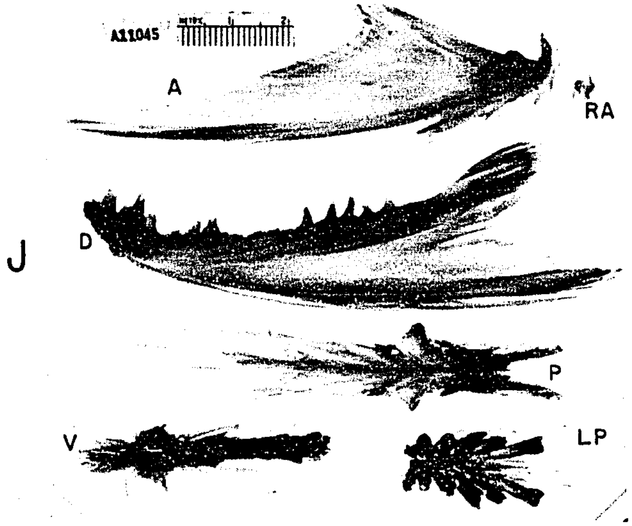


H

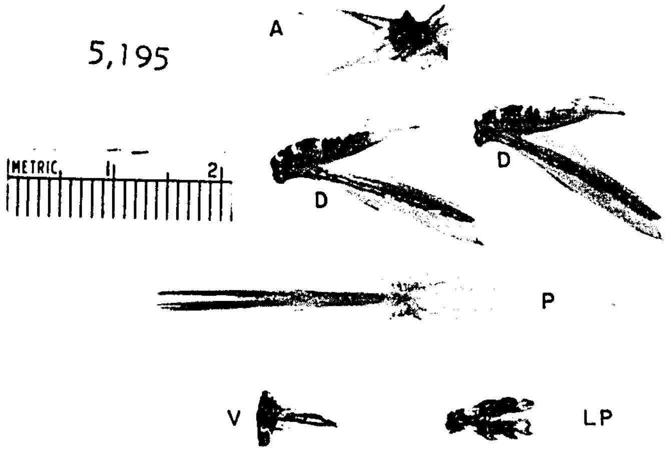


I




A11045
metric
1
2
A
RA
J
D
P
V
LP

K



L

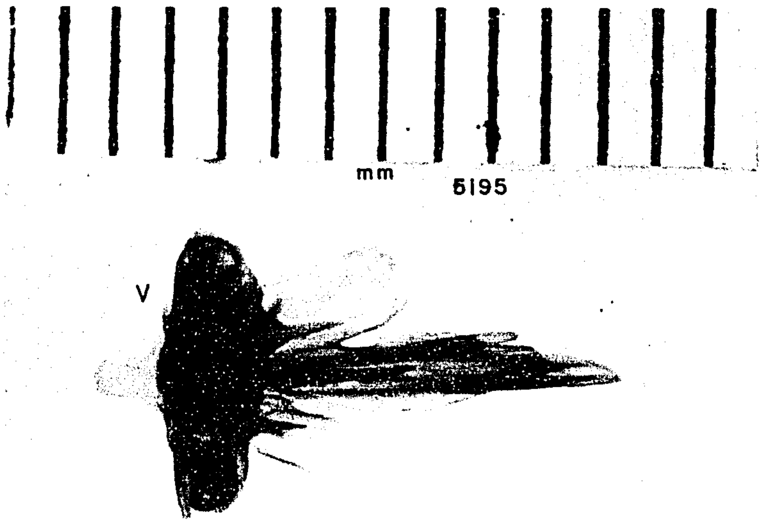
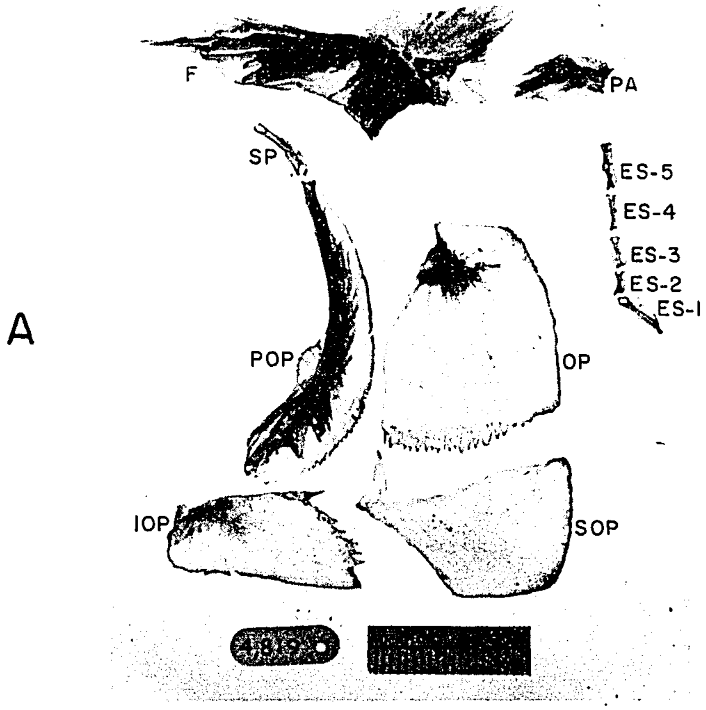


PLATE 6(A - J)

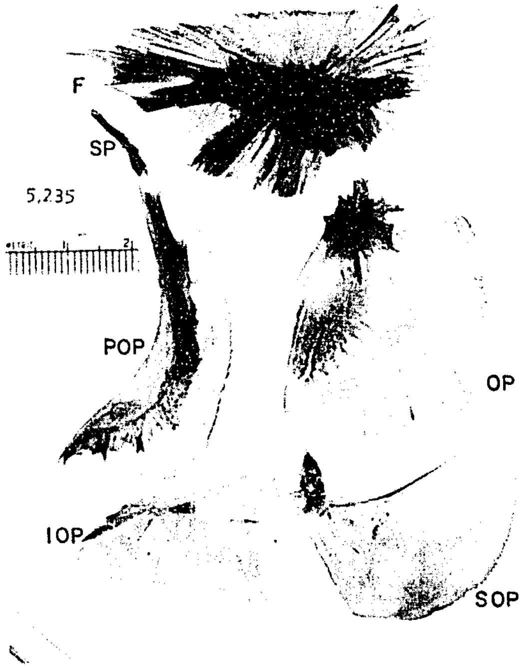
Selected dermal skull bones of Salmonidae

A. *Cristivomer namaycush*
B. *Salvelinus alpinus alpinus*
C. *Salvelinus alpinus oquassa* - Quebec
D. *Salvelinus alpinus oquassa* - Pushineer Lake, Maine
E. *Salvelinus alpinus oquassa* - Floods Pond, Maine
F. *Salvelinus malma*
G. *Salvelinus fontinalis fontinalis*
H. *Salvelinus fontinalis timagamiensis*
I. *Salmo gairdneri*
J. *Brachymystax lenok*

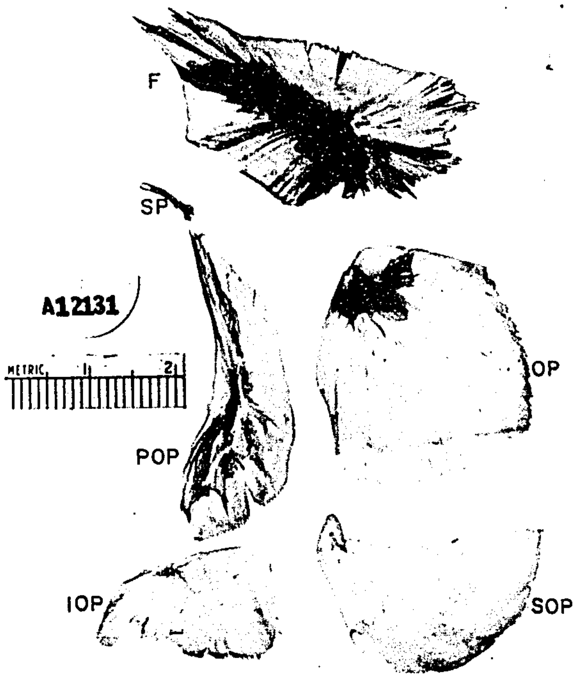
Abbreviations: ES 1-5, extrascapulars; F, frontal; IOP, interopercle; OP, opercle; PA, parietal; POP, preopercle; SOP, subopercle; SP, suprapreopercle.


A
F
PA
SP
ES-5
ES-4
ES-3
ES-2
ES-1
POP
OP
IOP
SOP

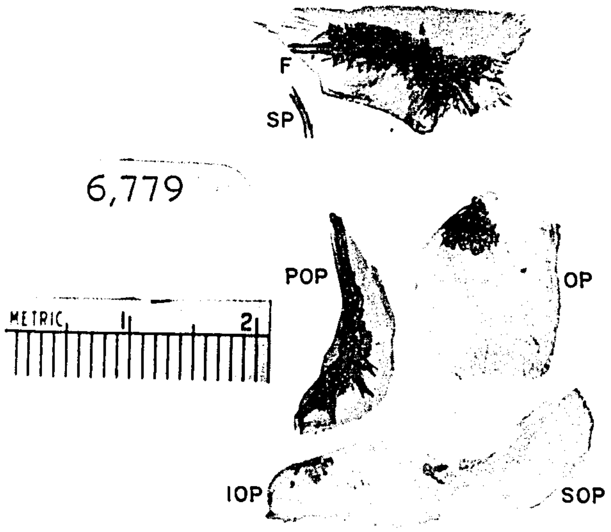
B


F
SP
5,235
METRIC 1 2
POP
OP
IOP
SOP

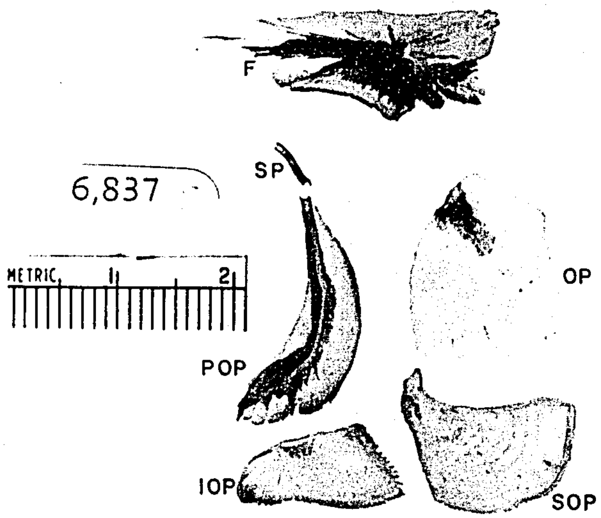
C

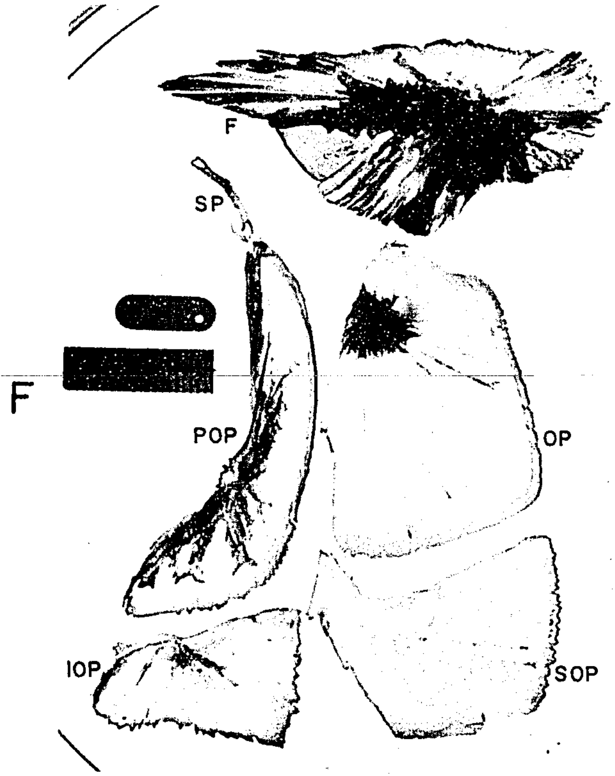

F
SP
A12131
METRIC 1 2
OP
POP
IOP
SOP

D

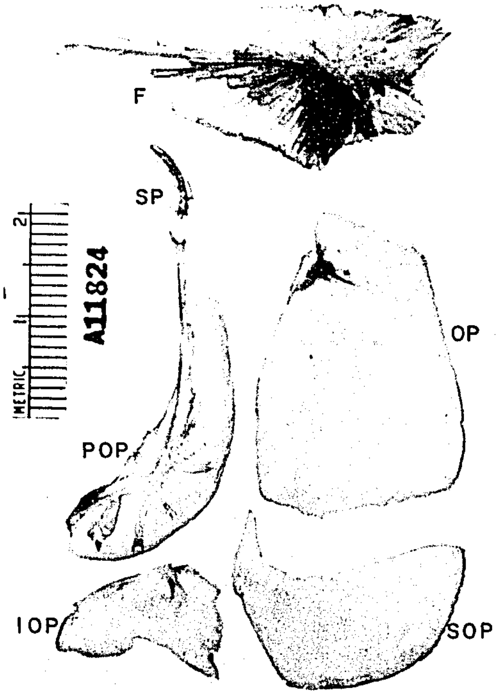

F
SP
6,779
POP
OP
METRIC 1 2
IOP
SOP

E

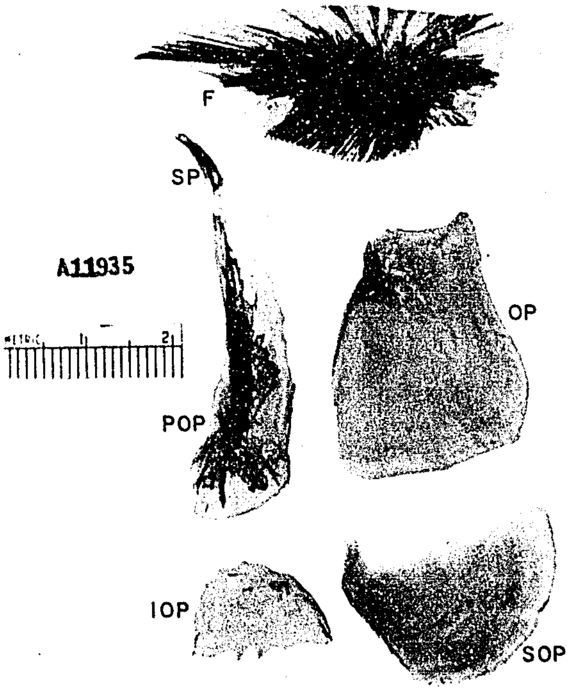

F
SP
6,837
METRIC 1 2
OP
POP
IOP
SOP


F
F
SP
POP
OP
IOP
SOP

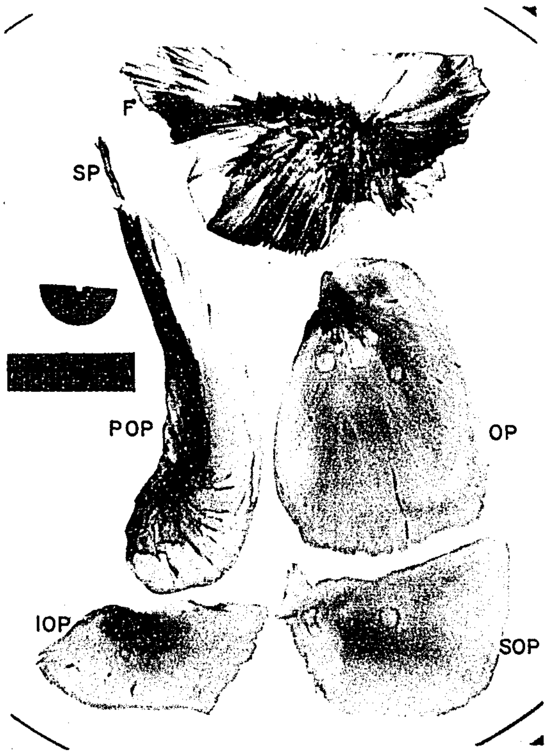
G


F
SP
A11824
METRIC
1
2
OP
POP
IOP
SOP

H


F
SP
A11935
METRIC
1
2
OP
POP
IOP
SOP

I



J

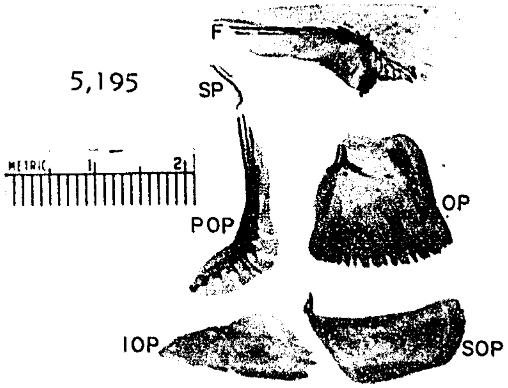


PLATE 7(A - C)

Hyoid arch and associated structures of *Cristivomer namaycush*

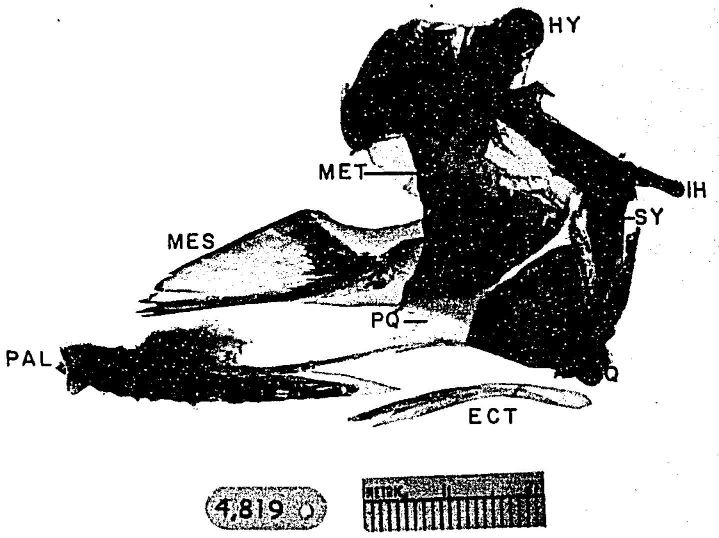
A. *Cristivomer namaycush*, showing the arrangement of hyomandiburlar, mesopterygoid, metapterygoid, and other bones.

B. *Cristivomer namaycush*, showing the arrangement of basibranchial and hypohyal bones.

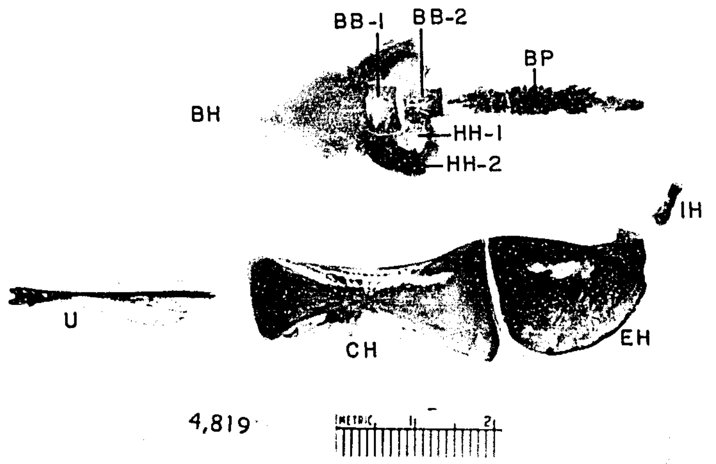
C. *Cristivomer namaycush*, showing the attachment of the branchiostegal rays to the ceratohyal and epihyal.

Abbreviations: BB 1-2, basibranchials; BH, basihyal; BP, basibranchial plate; ECT, ectopterygoid; EH, epihyal; HH 1-2, hypohyals; HY, hyomandibular; IH, interhyal; MES, mesopterygoid; [illegible], metapterygoid; PAL, palatine; PQ, palatoquadrate cartilage; [illegible], quadrate; SY, symplectic; U, urohyal.

A


HY
MET
IH
MES
SY
PQ
PAL
Q
ECT
4,819
METRIC
1

B


BB-1
BB-2
BP
BH
HH-1
HH-2
IH
U
CH
EH
4,819
METRIC
1
2

C

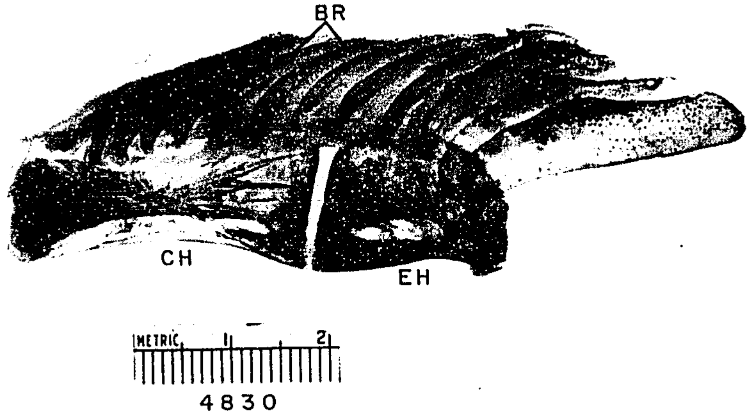
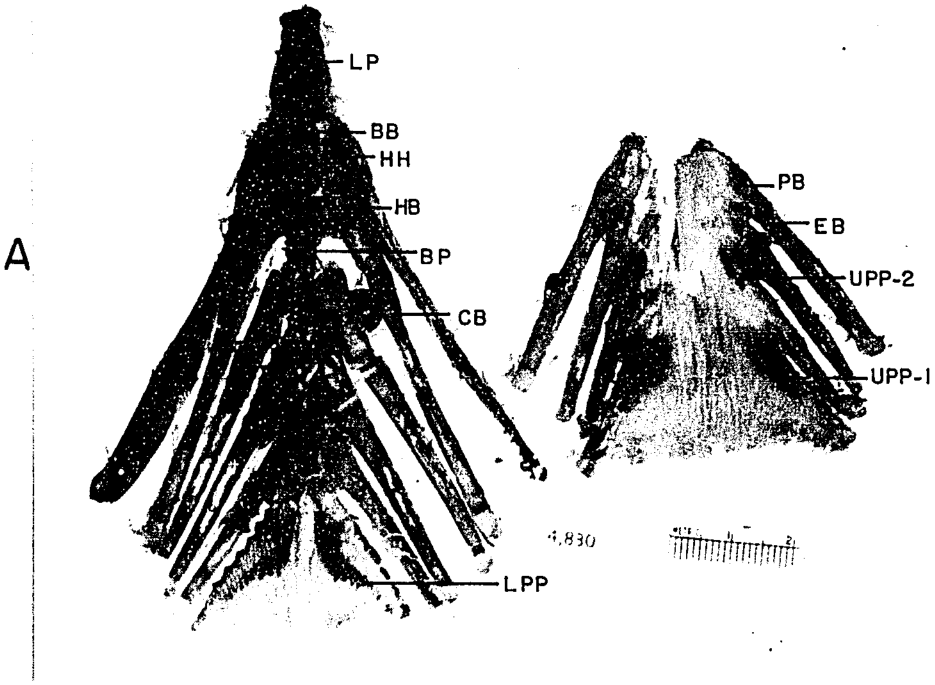

BR
CH
EH
METRIC
1
2
4830

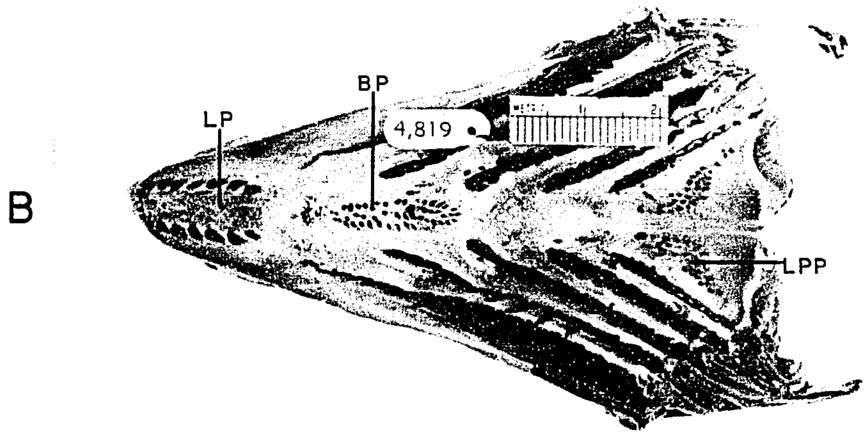
PLATE 8(A - M).

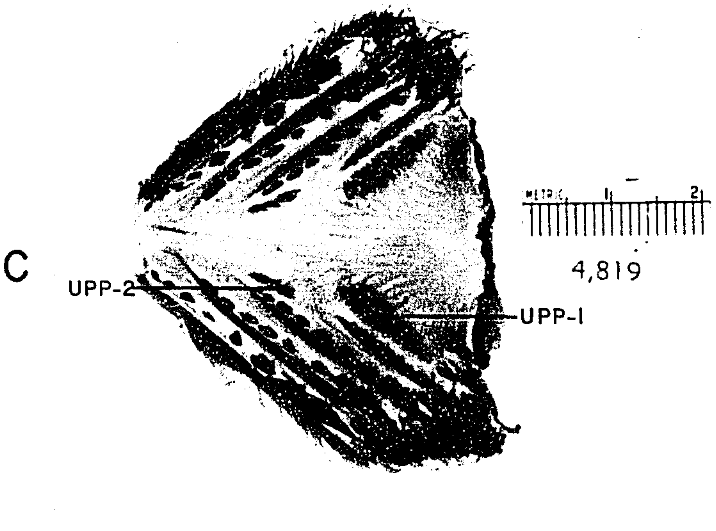
Branchial skeleton, teeth on lingual plate, teeth on basibranchial plate, and teeth on upper and lower pharyngeal plates of Salmonidae

A. *Cristivomer namaycush*
B. *Cristivomer namaycush*
C. *Cristivomer namaycush*
D. *Salvelinus alpinus alpinus*. Lower pharyngeal plates were detached
E. *Salvelinus alpinus alpinus*
F. *Salvelinus alpinus oquassa* - Quebec
G. *Salvelinus alpinus oquassa* - Pushineer Lake, Maine
H. *Salvelinus alpinus oquassa* - Floods Pond, Maine
I. *Salvelinus malma*
J. *Salvelinus fontinalis fontinalis*
K. *Salvelinus fontinalis fontinalis*. Teeth on the basibranchial plate and lingual plate much enlarged
L. *Salvelinus fontinalis timagamiensis*
M. *Salmo gairdnerii*

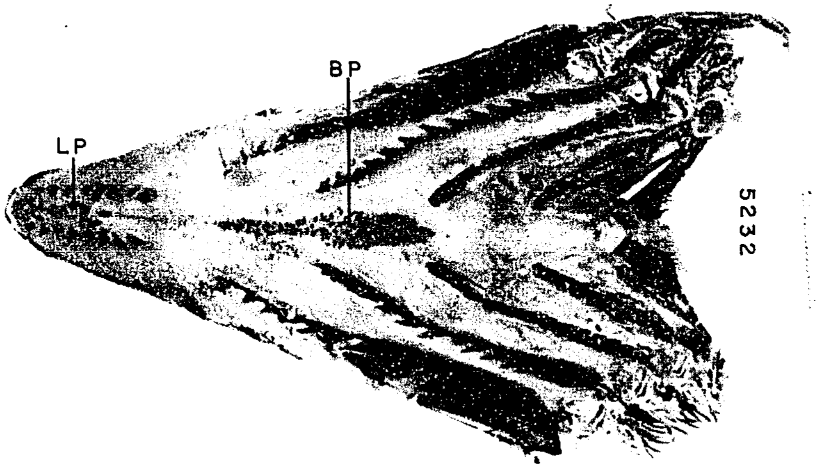
Abbreviations: BB, basibranchial; BP, basibranchial plate; CB, ceratobranchial; EB, epibranchial; HB, hypobranchial; HH, hypohyal; LP, lingual plate; PB, pharyngobranchial; LPP, lower pharyngeal plate; UPP 1-2, upper pharyngeal plates.


A
LP
BB
HH
HB
BP
CB
LPP
PB
EB
UPP-2
UPP-1
4,830
1
2

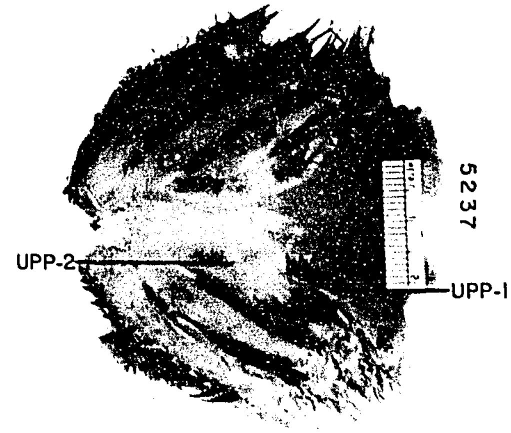

B
LP
BP
4,819
METRIC 1 2
LPP

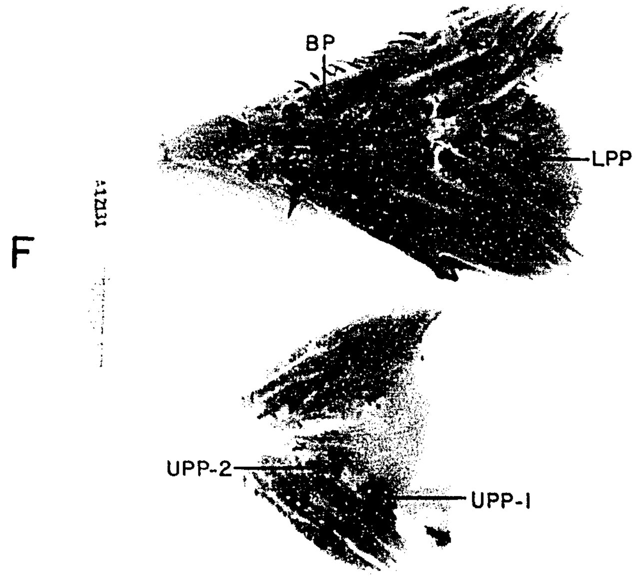

C
UPP-2
UPP-1
METRIC 1 2
4,819

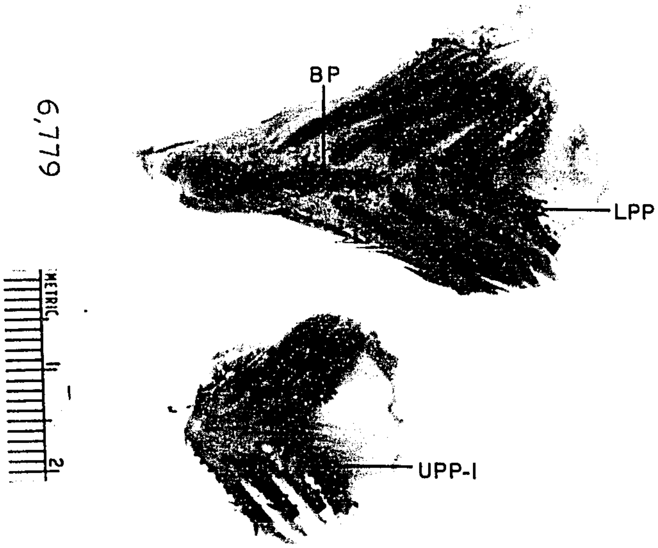
D



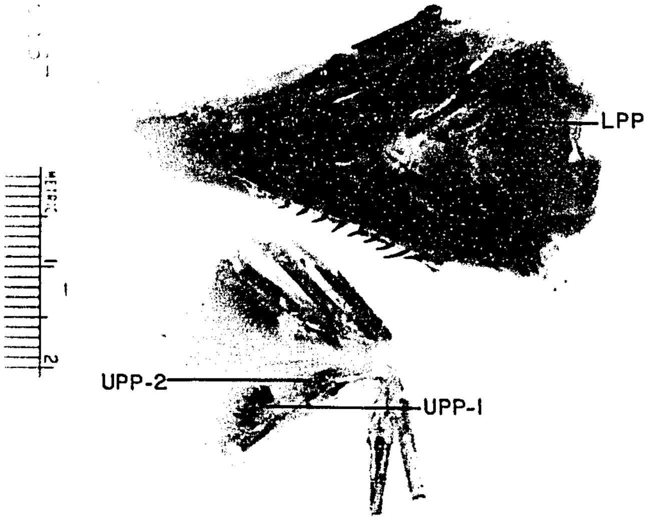
E



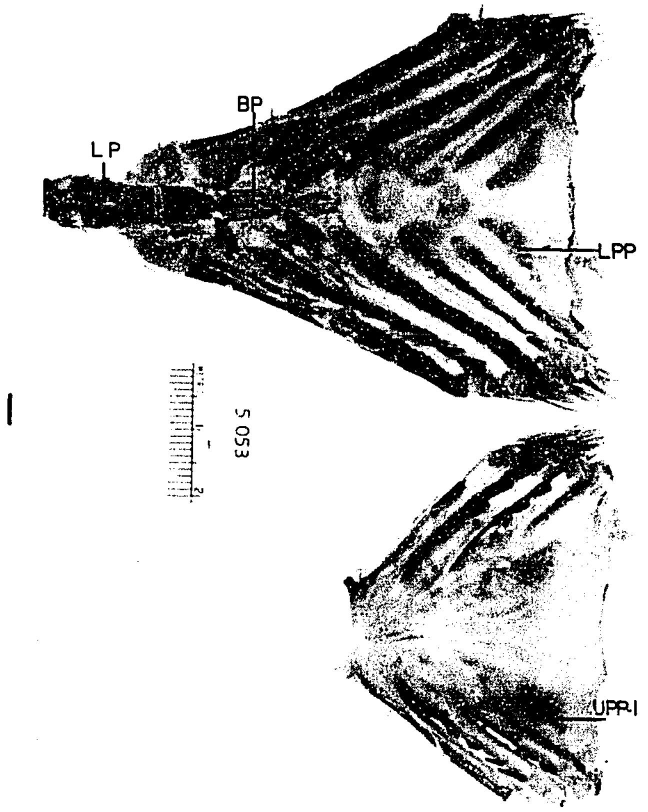

BP
LPP
F
1 mm
UPP-2
UPP-1



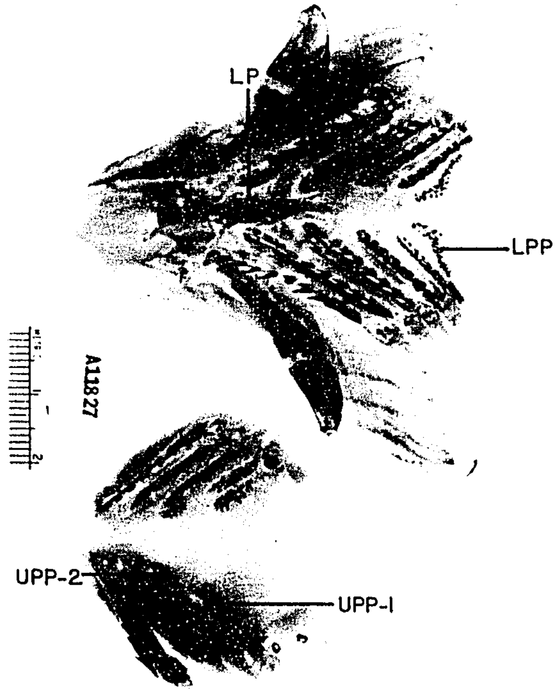
G



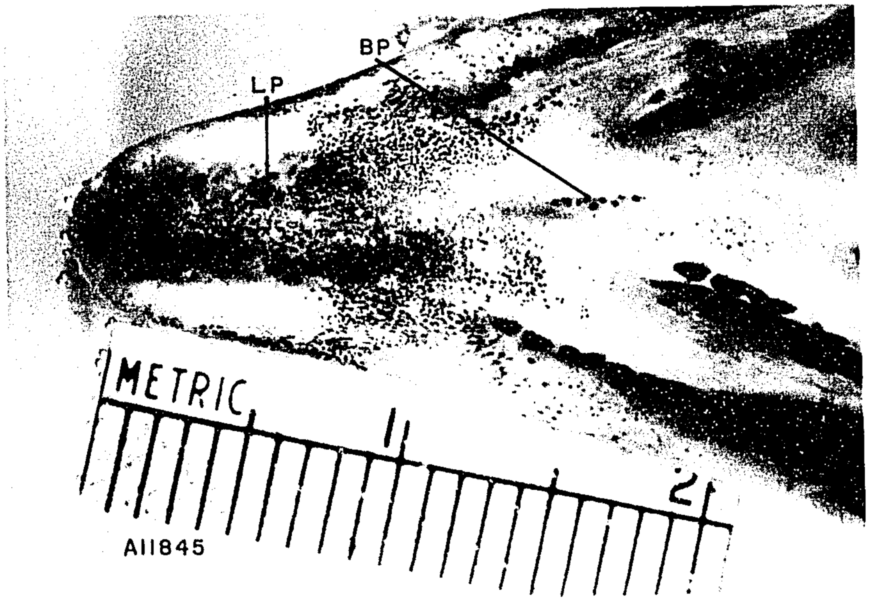
H

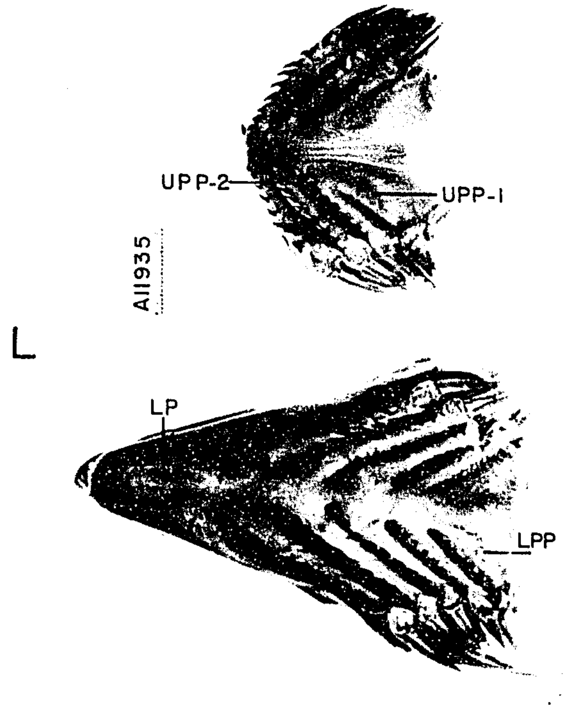

LP
BP
LPP
UPP-I
5 053
1
2

J



K




L
A11935
UPP-2
UPP-1
LP
LPP

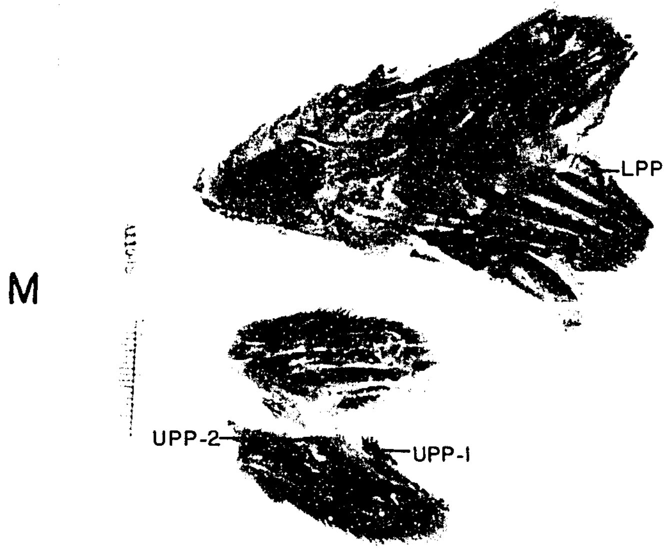
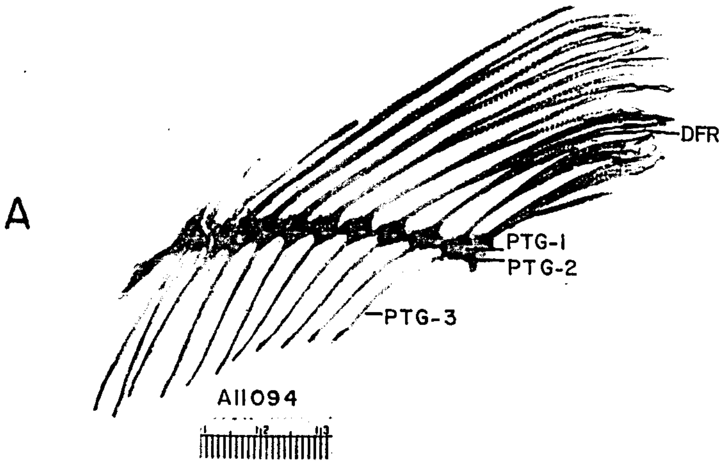

LPP
M
UPP-2
UPP-1

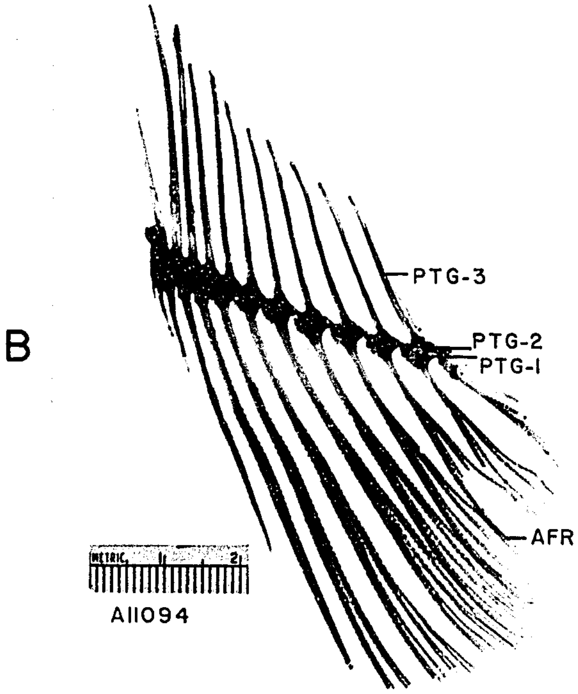
PLATE 9(A - E)

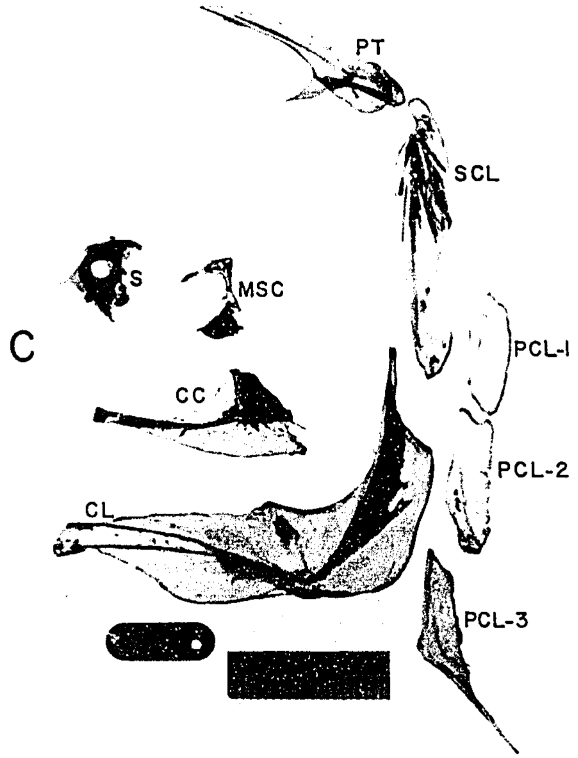
Median fins and appendicular skeletons of <u>Cristivomer</u> <u>namaycush</u>

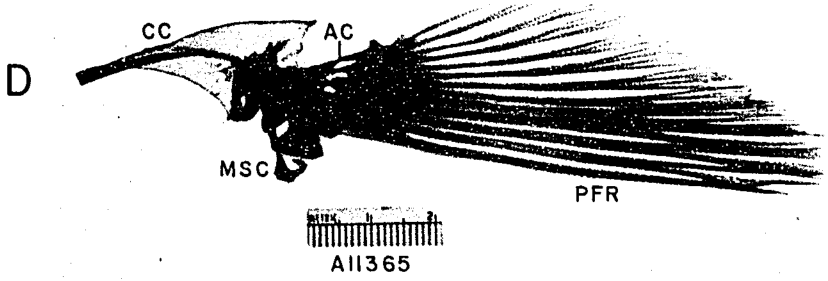
A. Dorsal fin
B. Anal fin
C. Pectoral girdle
D. Pectoral fin and part of the pectoral girdle, ventral view
E. Ventral fin

Abbreviations: AC, actinost; AFR, anal fin ray; BPTG, basipterygium; CC, coracoid; CL, cleithrum; MSC, mesocoracoid; PCL 1-3, postcleithra; PFR, pectoral fin ray; PT, posttemporal; PTG 1-3, pterygiophores; S, scapula; SCL, supracleithrum; VFR, ventral fin ray.


A
DFR
PTG-1
PTG-2
PTG-3
A11094
1
2
3


B
PTG-3
PTG-2
PTG-1
AFR
METRIC
1
2
A11094


PT
SCL
S
MSC
C
PCL-1
CC
PCL-2
CL
PCL-3


CC
AC
D
MSC
PFR
A11365

E

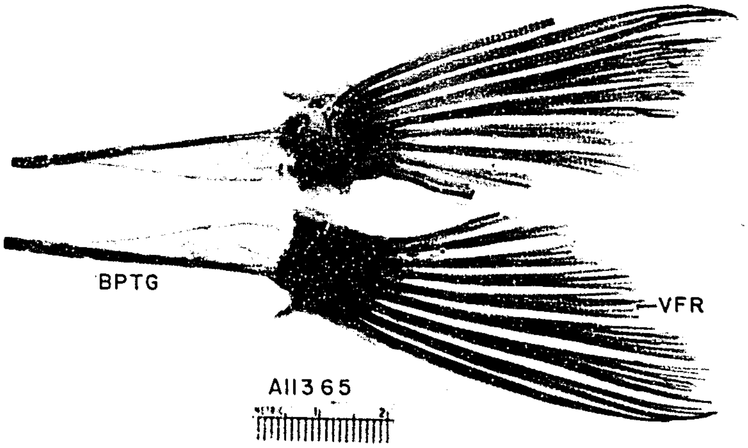


PLATE 10(A - C)

Vertebral column of *Cristivomer namaycush* .

A. Trunk vertebrae. Taken from the region just anterior to dorsal fin
B. Precaudal vertebrae
C. Caudal vertebrae. Just posterior to anal fin

Abbreviations: C, centrum; HA, haemal arch; HS, haemal spine; NA, neural arch; NS, neural spine; PAP, parapophysis; PCVE, precaudal vertebrae; POZ, postzygopophysis; PRZ, prezygopophysis; R, rib.

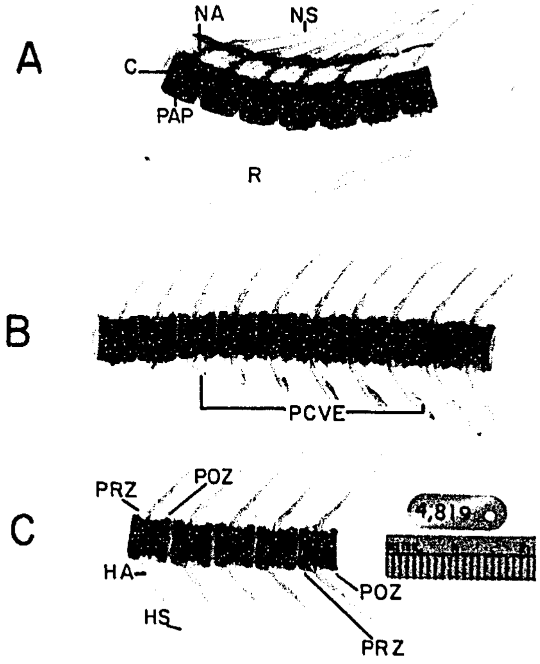
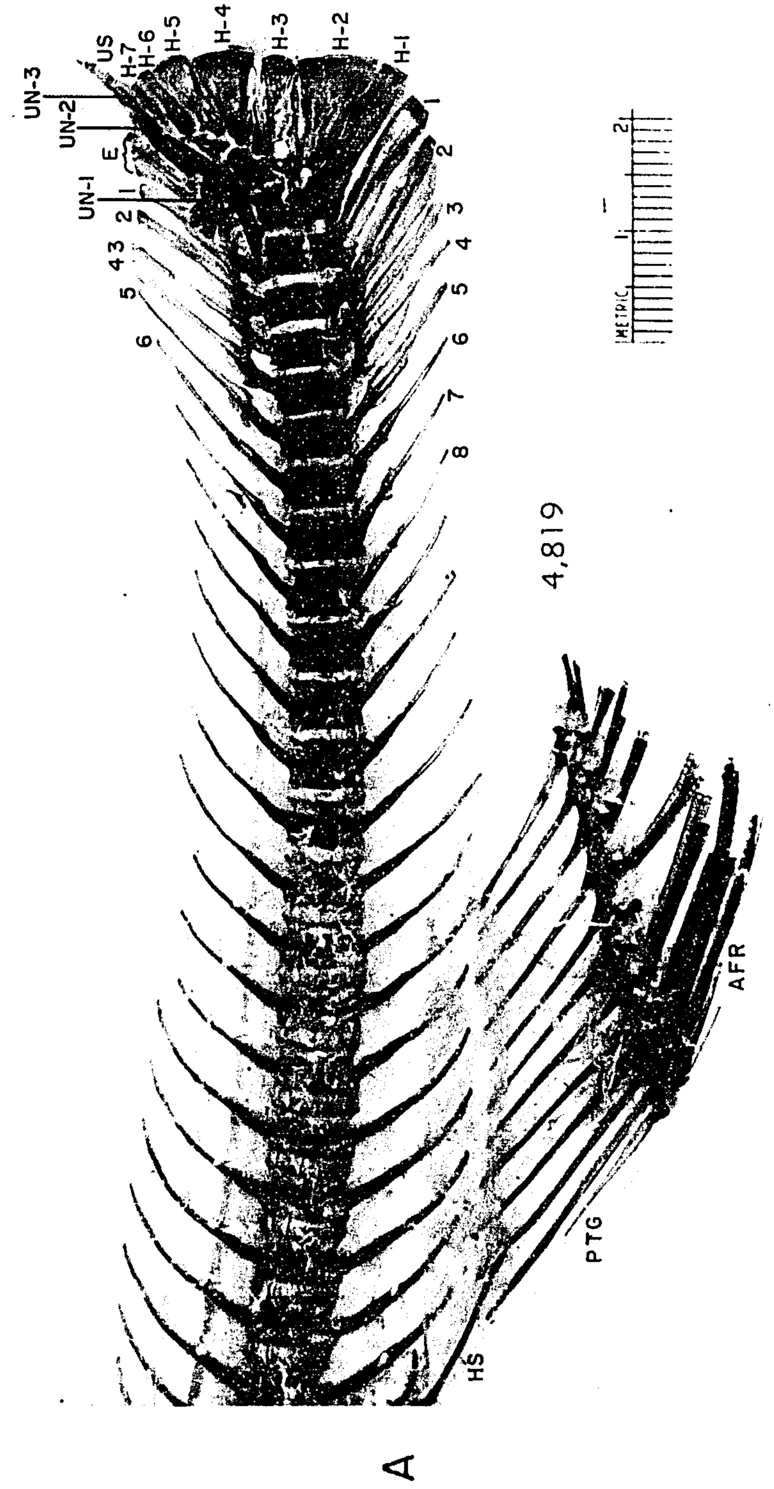

A
NA
NS
C
PAP
R
B
PCVE
C
PRZ
POZ
4,819
HA
HS
POZ
PRZ

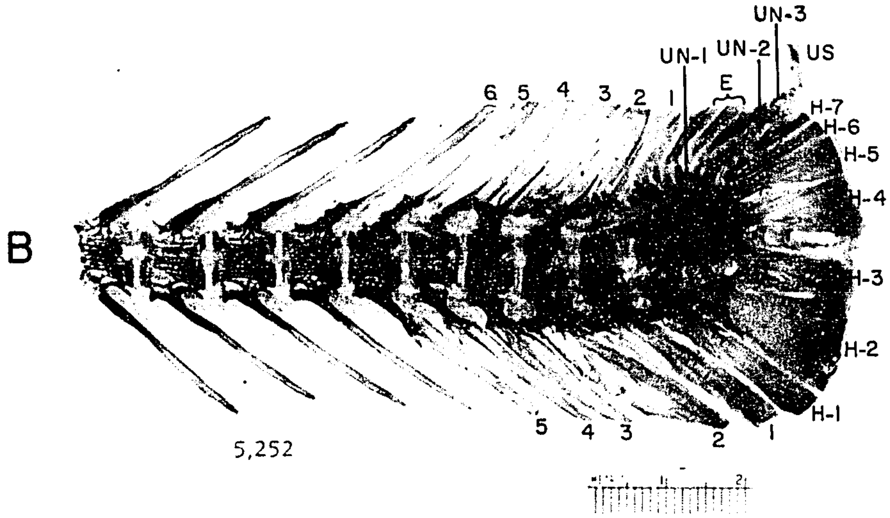
TABLE 11(A - J)

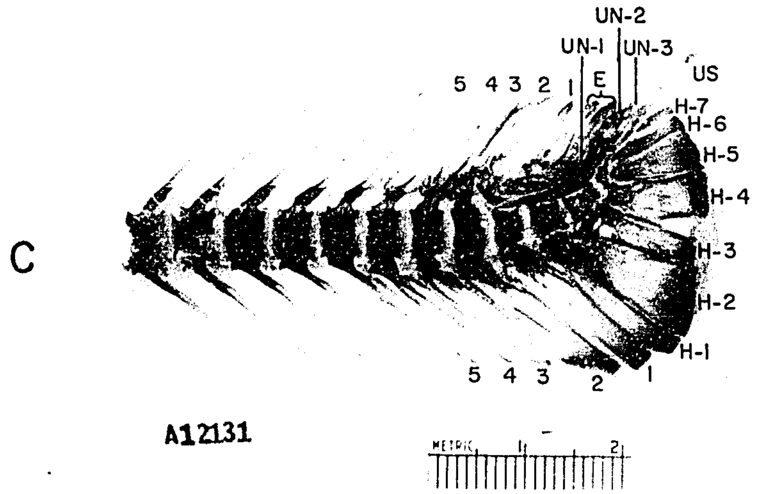
Caudal skeletons of Salmonidae

A. *Cristivomer namaycush*. Showing the attachment of anal fin to the haemal spines
B. *Salvelinus alpinus alpinus*
C. *Salvelinus alpinus oquassa* - Quebec
D(1). *Salvelinus alpinus oquassa* - Pushineer Lake, Maine
D(2). *Salvelinus alpinus oquassa* - Floods Pond, Maine
E. *Salvelinus malma*
F. *Salvelinus fontinalis fontinalis*
G. *Salvelinus fontinalis timagamiensis*
H. *Salmo gairdnerii*
I. *Salmothymus ohridanus*
J. *Hucho hucho*

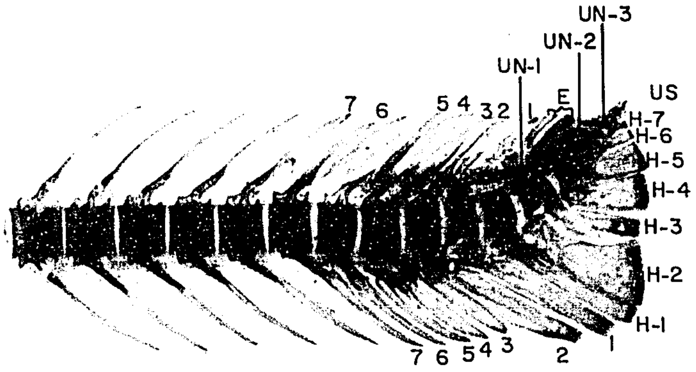
Abbreviations: E, epurals; ENS, expanded neural spines; H 1-7, hypurals; UN 1-3, uroneurals; US, urostyle. Arabic numerals (1-8) refer to expanded processes either neural or haemal.


UN-3
UN-2
E
UN-1
US
H-7
H-6
H-5
H-4
H-3
H-2
H-1
1
2
43
5
6
1
2
3
4
5
6
7
8
METRIC
1
2
4,819
AFR
PTG
HS
A

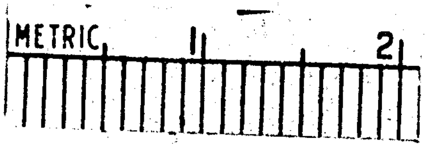

B
UN-3
UN-2
US
UN-1
E
6
5
4
3
2
1
H-7
H-6
H-5
H-4
H-3
H-2
H-1
5
4
3
2
1
5,252
METRIC
1
2


C
UN-2
UN-1
UN-3
US
5
4
3
2
1
E
H-7
H-6
H-5
H-4
H-3
H-2
H-1
5
4
3
2
1
A12131
METRIC
1
2

D-1

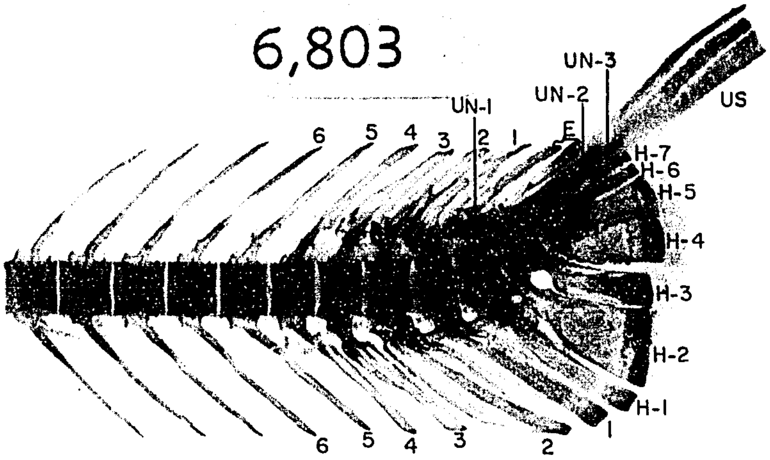


6,751

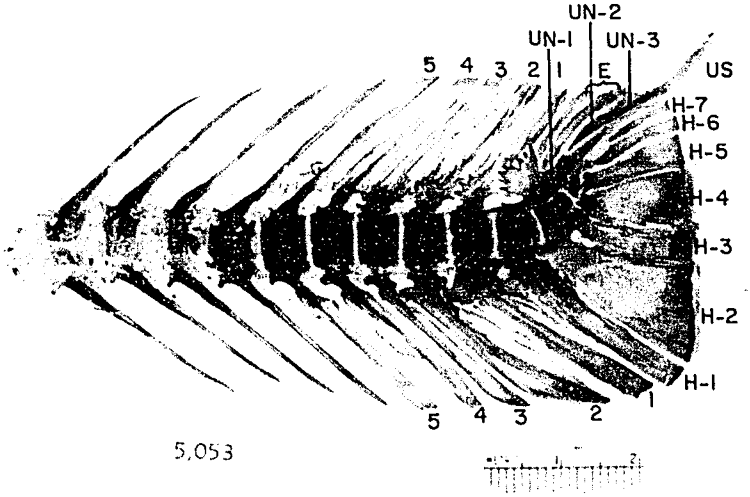


6,803

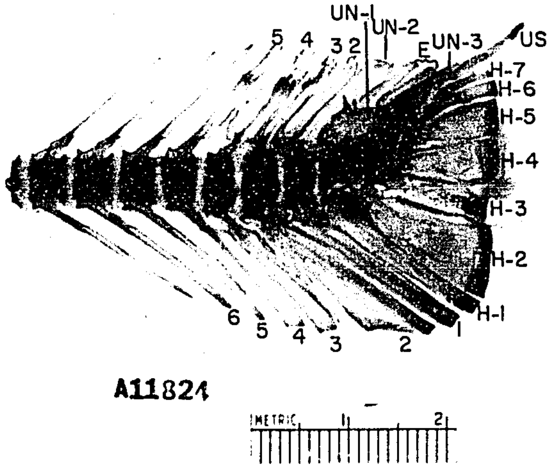
D-2



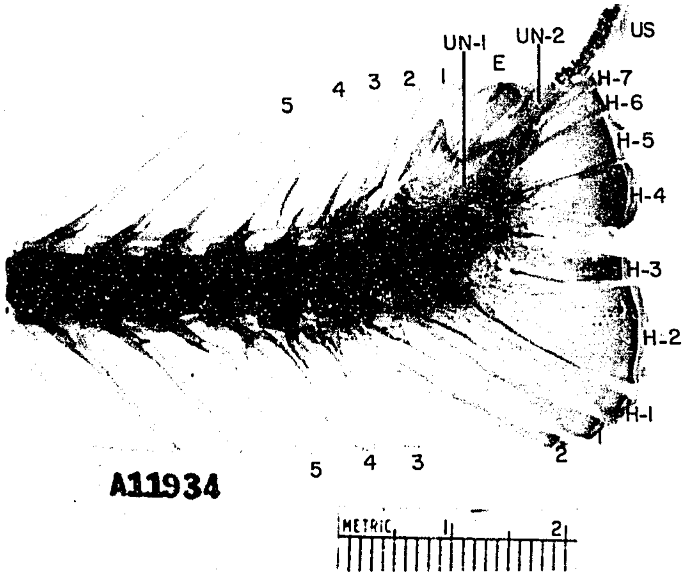
E

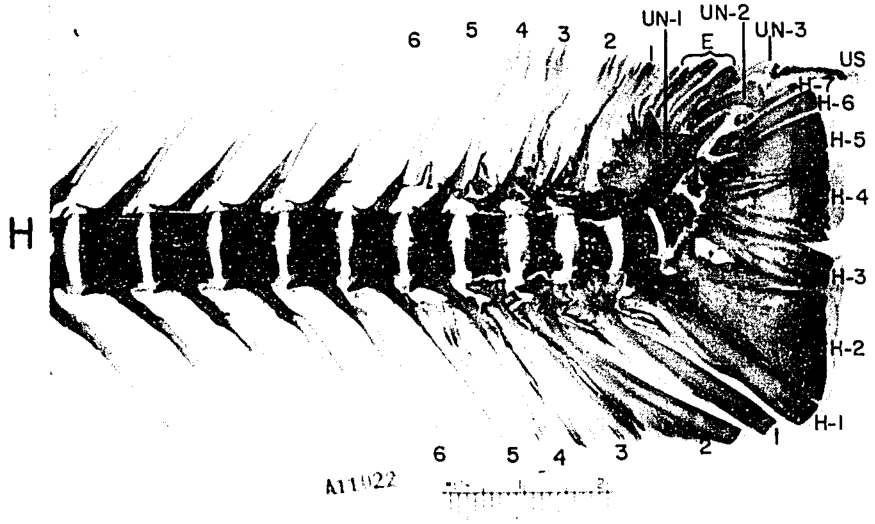


F


UN-1
UN-2
5
4
3
2
E
UN-3
US
H-7
H-6
H-5
H-4
H-3
H-2
H-1
6
5
4
3
2
1
A11824
METRIC
1
2

G


UN-1
UN-2
US
5
4
3
2
1
E
H-7
H-6
H-5
H-4
H-3
H-2
H-1
5
4
3
2
A11934
METRIC
1
2


6
5
4
3
2
1
UN-1
E
UN-2
UN-3
US
H-7
H-6
H-5
H-4
H
H-3
H-2
H-1
1
2
3
4
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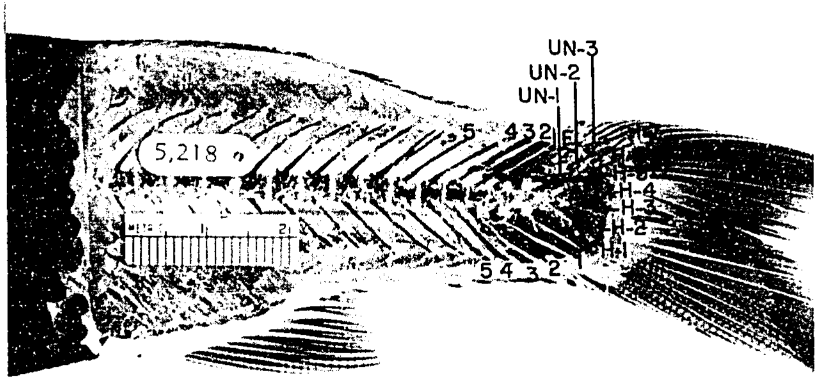
6
A11922
1
2

I


UN-3
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UN-I
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2
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H-4
H-3
H-2
H-I
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METRIC
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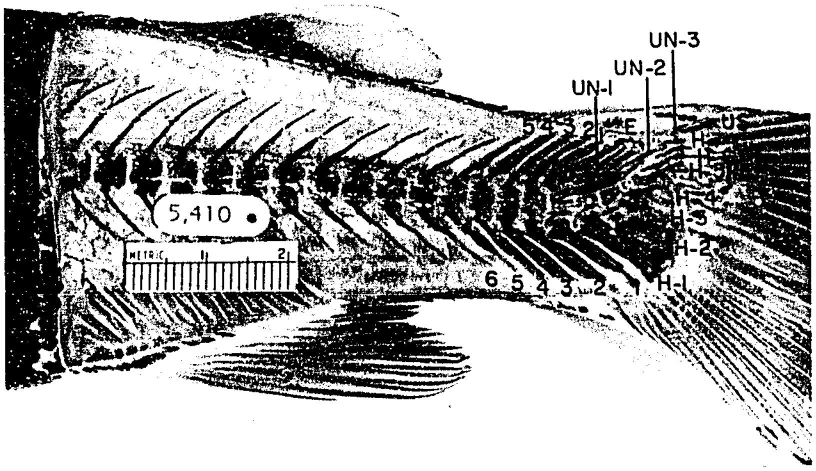
2
5
4
3
2

J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UN-2
UN-I
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4
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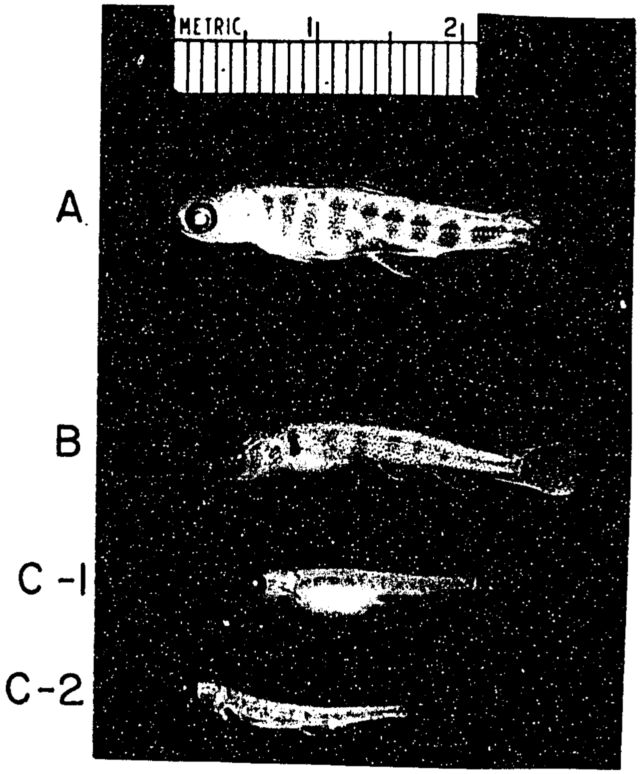
2
E
US
H
H-4
H-3
H-2
H-I
5,410
METRIC
1
2
6
5
4
3
2
1

PLATE 12(A - C-2)

Fry showing the parr marks and pigmentation on flank of the body

Total length in mm and age in days in parentheses are given

A. *Salvelinus fontinalis fontinalis*, 28 mm (88 days)
B. *Cristivomer namaycush*, 27 mm (84 days)
C-1. *Salvelinus alpinus alpinus*, 18 mm (52 days)
C-2. *Salvelinus alpinus alpinus*, 20 mm (81 days)


METRIC
1
2
A
B
C-1
C-2