THE WHITEFISHES *COREGONUS CLUPEAFORMIS* (MITCHILL) AND *PROSOPIUM WILLIAMSONI* (GIRARD) OF THE LAKES OF THE OKANAGAN VALLEY, BRITISH COLUMBIA

By J. Laurence McHugh

INTRODUCTION

In conjunction with the investigation of the productivity of Okanagan lake in respect to Kamloops trout, a special study was made of the whitefishes. Two species of the latter occur in the lake, namely, the Rocky Mountain whitefish, *Prosopium williamsoni* (Girard), and the eastern or common whitefish, *Coregonus clupeaformis* (Mitchill). The former is native to the Rocky mountains region and westward and is indigenous to the lakes of the Okanagan region. The latter is distributed across the continent, occurs naturally in northern British Columbia but not in the southern portion of the province; it was introduced into Okanagan and certain nearby lakes from lake Winnipeg. The present paper deals with these two species.

The study divides itself into three main parts ; first, an analysis of the food organisms as revealed by the stomach contents; secondly, age and rate of growth, determined by an examination of the scales; and lastly, a study of the variability and reliability of some of the characters which may be used for purposes of identification. The data collected also give information with regard to depths at which the species are commonly found. Finally the results are compared to show similarities and differences between the two species.

ACKNOWLEDGMENTS

The material on which this paper is based was supplied by Dr. W. A. Clemens, to whom the writer wishes to express thanks for his kindness in suggesting the topic and providing the necessary material, and also for his interest and assistance during the course of the investigation. The examination of the material was carried out at the University of British Columbia under the supervision of Dr. C. McLean Fraser, whose helpful suggestions and guidance have been very much appreciated.

Information concerning whitefish plantings and fishing experiments in lakes of the Okanagan valley has been kindly supplied by Mr. G. N. Gartrell, Fisheries Inspector at Summerland, B.C., and Major J. A. Motherwell, Chief Supervisor of Fisheries, Vancouver.

The assistance of Professor G. J. Spencer and Dr. G. C. Carl has been most valuable in the identification of many of the insects and insect remains present in the stomachs.

GEAR AND METHODS

A gang of 7 gill nets was used. Each net was 50 yards in length and the sizes were as follows: $1\frac{1}{4}$, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, 3, 4 and 5-inch stretched mesh. The nets were set on the bottom and thus it was possible to determine the relative abundance of fish at various horizontal depths in the bottom four-foot stratum, while the variety of mesh sizes allowed for the capture of a graded series of lengths.

Beach seines of the usual type were used, one having a small mesh to allow for the capture of small fish.

In most cases the stomach contents were removed soon after capture and preserved in four per cent formalin. A few scales were removed from the left side of the fish in the area between the dorsal fin and the lateral line.

Two length measurements were taken, the standard length being considered as the distance from tip of snout to the posterior end of the vertebral column, measured in centimetres, and the total length as the distance from tip of snout to fork of caudal fin, measured in inches.

Stomach contents were examined under the low power of the binocular microscope and the percentage volume of the various organisms present was estimated.

The scales were mounted in glycerine jelly and the age determinations were made with the use of a Promar projector. Each winter band or annulus was considered as representing the completion of one year of life (*Van Oosten, "A study of the scales of whitefishes of known ages", Zoologica, New York Zoological Society, Vol. II, no. 17, 1923*). The positions of the winter bands were marked off on cards for the determination of the growth rate.

The lengths at the end of each winter of life were calculated by the method developed by Van Oosten (*1923, loc. cit.*). Assuming the increase in diameter of the scale from winter to winter to be in the same proportion as the increase in length for the same period, the length increments were calculated from the length of the fish at the time of capture.

Counts were made of scales, fin rays, and other variable characters to permit comparison of the two species of whitefish with each other, and also with races of their own species in other lakes. Except for medial structures the counts were made on the left side of the fish. Counts were made of the bony fin *rays*, all in the pectoral and pelvic fins, but in the dorsal and anal fins the short rays anterior to the longest ray were not counted unless they equalled at least half its length, and the divided ray at the posterior end was counted as one only. *Scales* on and above the lateral line were counted only to the end of the vertebral column, ignoring the small scales in the fleshy portion of the caudal fin. *Rows of scales* above and below lateral line were counted diagonally from the insertion of the dorsal or anal fin to, but not including, the lateral line scale. All *gill rakers* were counted, whether fully developed or not. When one raker occurred exactly in the centre of the fork of the gill arch, it was included with the count for the short arm. All *vertebrae* were counted (including those in the upturned portion at the posterior end) after removing the flesh from one side of the fish.

EASTERN WHITEFISH, *COREGONUS CLUPEAFORMIS* (MITCHILL)

As far as can be ascertained, this species was first introduced to the Okanagan valley in the year 1894, eggs being brought from lake Winnipeg, hatched in the New Westminster hatchery, and the fry planted in Okanagan and Kalamalka lakes, to the number of 1,200,000. That the venture was successful to some extent is shown by the fact that, no later plantings being known until 1928, adult whitefish of this species were captured by Professor J. R. Dymond in July, 1928, in Okanagan lake near Kelowna.

In order to determine the possibility of establishing a commercial fishery in Okanagan lake, a permit was issued to a resident of Kelowna, Mr. Straumfjord, in November, 1928. He had gained his fishing experience in Manitoba, and conducted operations regularly until October, 1929, except for a short period in the early part of the year when ice conditions prevented the placing of nets in the water. The results proved financially unsatisfactory, and the results of an investigation of other lakes in the same drainage system proved equally unsatisfactory. Although the Eastern whitefish is known to have been planted in Kalamalka and Okanagan lakes only, the species has been found to exist in other lakes of the system, all downstream from Okanagan lake, which suggests that the fish have migrated down stream during some stage of their existence. That neither during Straumfjord's experiments, nor during the survey of 1935 were any whitefish of the genus *Coregonus* taken in Woods or in Kalamalka lake, seems to indicate that these fish are more scarce in the upper reaches of the river system.

Table IX shows the monthly catch in each of the lakes for the whole period of the experiment. In cases where the number of days' fishing for the month was available, the number of fish caught per day (index of abundance) was obtained

TABLE IX Catch of the Eastern and Rocky Mountain whitefish in the various lakes, for each month in which fishing took place.

			Eastern whitefish			Rocky Mt. whitefish	
Lake	Year	Month	No. of fish	No. of days	Fish per day	No. of fish	Fish per day
Woods	1929	November	0	2		23	11.5
Kalamalka	1929	November	0	1		5	5.0
Okanagan	1928	Nov.-Dec.	330			0	
	1929	Jan.-Mar.	295			0	
		April	139			1	
		May	86			0	
		June	120			44	
		July	91			2	
		August	219			0	
		September	349	28	12.5±1.9	1	
		October	220	20	11.0±1.9	0	
		November	45	3	15.0±8.3	1	0.3
Dog	1929	November	339	12	28.2±6.5	9	0.7
Vaseaux	1929	November	102	2	51.0±39.0	0	
Osoyoos	1929	November	14	1		0	

by dividing the total number of fish by the number of days required to catch them. As the reliability of this figure depends on the number of days, the probable error of each value was calculated.

It is apparent that the balance is in favour of the two lakes (Dog and Vaseaux) immediately to the south of Okanagan lake. In the table, the lakes are listed in order of sequence in the downstream direction, and it can be seen that the values increase from Kalamalka lake at the upper end of the system to Dog and Vaseaux lakes, and decline from there to Osoyoos lake at the south.

Further consideration of the data in table IX suggests the possibility of an inverse relation between the abundance of the introduced and the native species in succeeding lakes of the system. Apparently the native whitefish is the dominant species in the upper lakes of the river, while the introduced form increases in abundance and becomes dominant in a downstream direction.

In 1928 and 1929 eggs from the Waterhen river, lake Winnipegosis, were hatched in the Dominion government hatchery at Summerland on Okanagan lake. From these, 4,780,000 fry were placed in Okanagan lake and its tributaries in 1928, and 4,680,000 in 1929. Conclusive evidence of the success of these plantings is not available, but the rather meagre catches of 1935 would lead one to believe that Okanagan lake in its present state is unsuitable for the profitable rearing of the Eastern whitefish.

Forty-five specimens were taken in 1935 in the gill nets, and one was found dead in the water near the lake shore.

Food

The contents of 55 stomachs of fish taken in Okanagan lake were examined and the following organisms were identified: bryozoan statoblasts; four genera of water fleas, - *Daphnia*, *Eurycercus*, *Leptodora* and *Bosmina*; two genera of copepods,- *Cyclops* and *Epischura*; unidentified ostracods; two families of flies (Diptera),- the Chironomidae and Tipulidae;- larval and pupal caddis flies; nymphs of mayflies; remains of Hymenoptera and other insects; the water mites or Hydrachnidae; molluscs, represented by both clams and snails; and fish, represented by sculpins (*Cottus asper*). Plant material recognized consisted of algae (*Nostoc*, *Chara*, and a number of filamentous species); pond weeds (*Potamogeton*): unidentified seeds; and other remains of the higher plants. Other substances found were bottom ooze, sand particles, clinkers, and bits of wood, sometimes forming a large portion of the stomach contents.

The food of 37 specimens taken in 1935 is given in table X. In addition to these, the contents of the stomachs of 18 individuals taken by Straumfjord in 1929 were examined. No record of the ages of these fish was available. The results are presented in table XI.

Three individuals in the first year of life had eaten chiefly midge and cranefly larvae (70 to 80%). Additional items included bryozoan statoblasts, ostracods, and filamentous algae.

TABLE X. Food organisms of 37 Eastern whitefish, July-August, 1935. Column A—Number of stomachs containing organisms. Column B—Average percentage in all stomachs. Column C—Greatest percentage in any one stomach.

		A	B	C
Water fleas :	*Daphnia*	8	8	100
	Eurycercus	4	X	X
	Leptodora	4	4	100
	Bosmina	1	X	X
Copepods :	*Cyclops*	7	X	X
	Epischura	1	X	X
Ostracods :	Ostracoda	18	X	X
Water mites :	Hydracarina	25	X	5
Midge larvae :	Chironomidae	18	6	100
Midge pupae :		14	5	70
Cranefly pupae .	Tipulidae	10	4	15
Caddis larvae :	Trichoptera	4	X	X
Caddis pupae :		4	X	X
Mayfly nymphs :	Ephemeroptera	12	7	90
Ants, etc.:	Hymenoptera	2	X	X
Clams :	Pelecypoda	1	X	X
Snails :	Gastropoda	18	6	75
Sculpins :	*Cottus* sp.	12	18	95
Bryozoa :	Statoblasts	6	X	X
Algae :	Filamentous	16	16	95
	Chara	14	10	5
	Nostoc	5	3	70
Pond weeds :	*Potamogeton*	2	X	X

TABLE XI. Food organisms of 18 Eastern whitefish, September-October, 1929. Column A—Number of stomachs containing organisms. Column B—Average percentage in all stomachs. Column C—Greatest percentage in any one stomach.

		A	B	C
Water fleas :	*Eurycercus*	13	21	90
	Leptodora	4	X	5
Ostracods :	Ostracoda	5	X	X
Water mites :	Hydracarina	13	2	20
Midge larvae :	Chironomidae	13	41	95
Midge pupae		3	X	X
Mayfly nymphs :	Ephemeroptera	2	4	75
Other insect remains .		2	X	X
Clams :	Sphaeriidae	14	5	50
Bryozoa :	Statoblasts	2	X	X
Algae	Filamentous	2	X	10
	Nostoc	2	X	X
Higher plants .	Seeds	4	X	X
	Other spermatophyte	8	X	X
Unidentified	remains	12	2	25

Three specimens in the second year had taken chiefly filamentous algae (60%) and snails (up to 75%). Other items were water fleas, copepods, ostracods, water mites, midge larvae, and algae, including *Chara*.

Twenty-six individuals in the third year contained a great variety of organisms. The most important materials were water fleas, copepods, aquatic insect larvae, small fish, filamentous algae and *Chara*.

The food of five fish in the fourth year consisted of aquatic insect larvae, small fish and algae for the most part.

Age, Growth, Spawning

The scale method of computing the age and the length at the end of each winter of life has been used, practically as described by Van Oosten (*Life history of the lake herring [Leucichthys artedi Le Sueur] of lake Huron as revealed by its scales, with a critique of the scale method. Bull. U.S. Bur. Fish., vol. XLIV, Doc. no. 1053, 1929*).

The winter check in growth shows itself as a succession of less distinct and much broken, closely applied circuli. The length of an individual at the end of each successive year is calculated according to the following formula:

$$\frac{\text{Length of scale at end of year } X}{\text{Total length of scale}} = \frac{\text{Length of fish at end of year } X}{\text{Length of fish at time of capture}}$$

The length of the scale at any selected time was measured from the centre of the focus anteriorly. The results produced by this method are open to criticism for the reason that they exhibit the effect described by Van Oosten (*1929, loc. cit.*) as "Lee's phenomenon". This shows itself in table XII as a decrease in the average calculated length in the early years of life as the fish increase in age, and an increase in calculated length in the later years with increasing age.

The age of a fish in its first year, the scales of which do not show a winter check, is represented by the numeral I, that of one in the second year by II, and so on.

Table XII shows the average standard length at the end of each year of life for each year class. The last value in each horizontal row represents the actual

Table XII. Standard length attained by the various year classes of Eastern whitefish at the end of each year of life.

Year class	Age group	Average calculated standard length in mm. attained at end of each year I	II	III	IV	V	VI	VII	Individuals
1929	VII	119	205	268	312	347	373	(383)	1
1930	VI	105	172	238	293	325	(342)		1
1931	V	113	232	279	308	(321)			1
1932	IV	114	192	254	(283)				2
1933	III	132	228	(262)					28
1934	II	141	(200)						7
1935	I	(130)							4
Weighted average		131	224	259	304	336	373		

The figures in brackets represent the length in the year of capture—i.e. only a partial year's growth.

standard length at the time of capture. The year class was determined by reckoning back from the year of capture, according to the number of winter checks. Each vertical column contains the average standard lengths of fish of equal age, while the horizontal rows show the yearly increase in length for each age group. In determining the averages for the whole sample, the individual averages were weighted to the number of individuals represented, so that the last horizontal row contains the true average standard lengths at the end of each year of life.

The data are presented graphically in figure 12. The portion at the end of each curve indicated by a broken line represents the growth from the previous spring to the time of capture, and hence cannot be considered as a full year's growth. Up to the end of the third year of life this curve of average values can be considered as fairly accurate, since up to this point the size of the samples

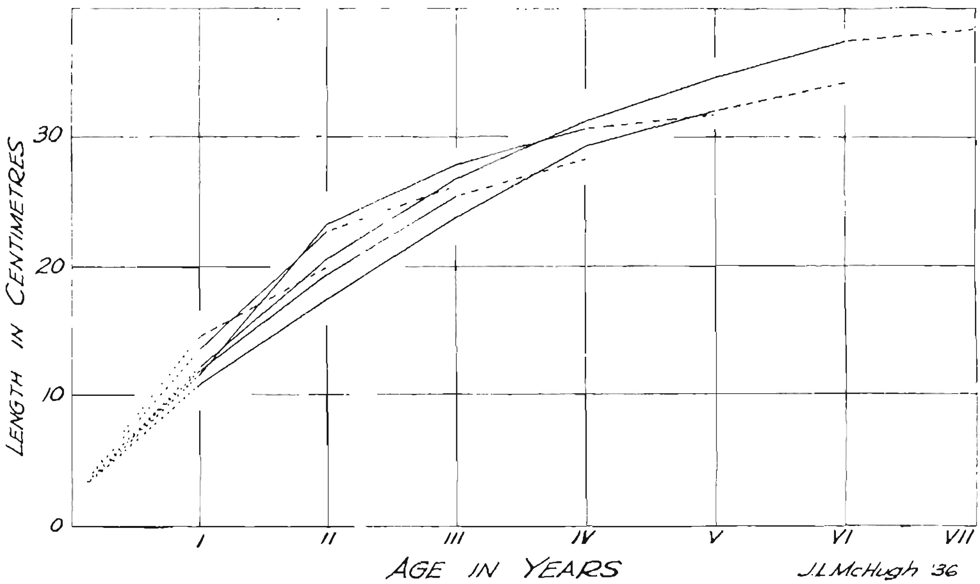

FIGURE 12. Rates of growth of the age classes of the Eastern whitefish in Okanagan lake.

remains relatively large. From here on, however, the significance of each point decreases, due to the small number of fish which were in their fourth year or older. It is evident that the average yearly increment in length of the Eastern whitefish in Okanagan lake decreases as the fish increases in age.

The only record available as to the spawning habits of the Eastern whitefish in Okanagan lake is found in reports of Mr. Gartrell, fisheries inspector. On December 13, 1928, he reported that specimens captured would not have been ready for spawning for approximately two weeks, while on December 31 he stated that most of the fish in recent catches had spawned.

VARIABILITY OF INDIVIDUAL CHARACTERS

The methods of examination have been described. As this work was done on formalin preserved specimens, it was thought advisable to compare only characters which could not be altered by shrinkage or loss of normal shape.

The results of the counts made from the Okanagan specimens are summarized in table XIII. When these are compared with counts made on fish from lakes of Manitoba, Ontario, and the eastern states, it is found that in all cases the results are closely comparable. It must be concluded that the Okanagan population is not significantly modified with respect to any character examined.

TABLE XIII. Variability in individual characters of the Eastern whitefish in Okanagan lake.

Fin rays	Minimum	Maximum	Most frequent value	No. of individuals
Dorsal	10	12	11	43
Anal	9	13	11	41
Pectoral	15	17	16	40
Pelvic	10	12	11	41
Scale counts				
In lateral line	70	85	77	40
In row above lateral line	62	84	77	38
Rows above lateral line	10	11	10	41
Rows below lateral line				
—from pelvic	8	9	9	42
—from anal	8	9	8	40
Gill rakers				
Short arm	10	12	11	43
Long arm	15	20	18	43
Total	26	31	29	43
Branchiostegals	8	10	9	37
Vertebrae	56	60	58	42

ROCKY MOUNTAIN WHITEFISH *PROSOPIUM WILLIAMSONI* (GIRARD)

During his experiments, Straumfjord found the 3½-inch stretched mesh to be the most suitable size for the capture of adult Eastern whitefish. Having obtained this information, he used this type of net exclusively until operations ceased. For the entire period, the catch of Rocky Mountain whitefish amounted to only nine fish in Okanagan lake. This might be interpreted in various ways: (1) that these fish inhabit waters of a different depth from those frequented by the Eastern whitefish; (2) that they do not normally feed on the bottom, thus inhabiting waters above the level of the nets; (3) that the numbers of the species present in the lake were relatively small; or (4) that the species seldom reached a size sufficiently large to allow it to become caught in the nets. The last explanation would seem to be the proper one since the results of the 1935 survey seem to show that the habitats of the two species overlap to some degree, that they both feed to a great extent on bottom organisms, and that the numbers of each, taking the total catch as a criterion, are fairly close to being equal, whereas the data show that the Rocky Mountain whitefish does not reach as great a length as the Eastern whitefish. Table IX shows the catches of Rocky Mountain whitefish in each lake as compared with the figures for the eastern species.

The fish taken in 1935 consisted of 35 obtained in the gill nets and 6 in a small-meshed seine.

Food

The organisms identified in the contents of 40 stomachs of fish taken in Okanagan and Woods lakes are given in table XIV.

The food of three individuals of the first year taken in the mouth of Trout creek consisted chiefly of aquatic insect larvae, water fleas and copepods, while the food of another individual, also in the first year and captured off the mouth of Mission creek, consisted of the water flea, *Daphnia*, only.

The food of the fourteeen individuals of the second year was comprised chiefly of water fleas, copepods, and aquatic insect larvae, but two individuals had fed largely upon terrestrial beetles.

TABLE XIV. Food organisms of 36 Rocky Mountain whitefish. Column A—Number of stomachs containing organisms. Column B—Average percentage in all stomachs. Column C—Greatest percentage in any one stomach.

		A	B	C
Water fleas :	*Daphnia*	31	63	100
	Scapholeberis	4	X	X
	Alona	2	X	X
	Leptodora	1	X	X
	Diaphanosoma	4	X	20
Water mites :	Hydracarina	2	X	X
Shrimps :	Amphipoda	1	X	X
Midge larvae :	Chironomidae	6	X	5
Midge pupae :		28	5	60
Caddis larvae :	Trichoptera	6	4	90
Caddis pupae :		8	3	25
Cranefly pupae :	Tipulidae	7	3	25
Blackfly larvae :	Simuliidae	5	X	5
Flies :	Empididae	2	X	X
Mayfly nymphs :	Ephemeroptera	12	8	70
Stonefly nymphs :	Plecoptera	3	X	80
Beetles :	Dytiscidae	2	X	45
	Carabidae	2	X	50

Sixteen specimens of the third year had also eaten largely of water fleas and copepods with considerable amounts of aquatic insect larvae in addition.

Two individuals of the fourth year had taken *Daphnia* and aquatic insect larvae.

The older specimens appear to depend upon water fleas and copepods for their main food supply and *Daphnia* is undoubtedly the most important organism, forming approximately two-thirds in volume of all the food taken. The remainder is made up almost exclusively of aquatic insect material obtained from the lake bottom.

AGE, GROWTH AND SPAWNING

The age of each fish was determined by the scale method, and the length at the end of each winter of life by the method described previously. The results are presented in table XV, which corresponds in form to table XII. The data for the two individuals from Woods lake are not included.

The curve in figure 13 represents the weighted averages, and consequently shows the average standard length at the end of each year of life for the whole sample. With it, for purposes of comparison, is given a similar curve for the Eastern whitefish.

The decreasing slope of the curve for the Rocky Mountain whitefish shows

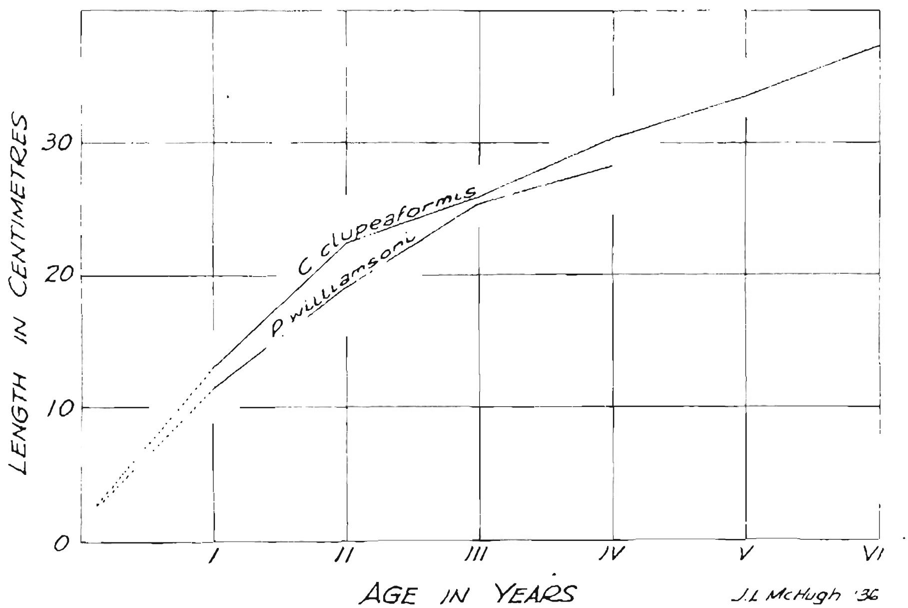

FIGURE 13. Rates of growth of the Eastern and Rocky Mountain whitefishes in Okanagan lake.

TABLE XV. Standard length attained by the various year classes of Rocky Mountain whitefish at the end of each year of life. The figures in brackets represent the length in the year of capture—i.e. only a partial year's growth.

Year class	Age group	Average calculated standard length in mm. attained at the end of year I	II	III	IV	V	No. of individuals
1931	V	113	193	255	282	(294)	1
1932	IV						0
1933	III	114	191	(218)			16
1934	II	119	(166)				16
1935	I	(60)					4
Weighted average		116	191	255	282		

that the average yearly increment in length decreases as the age of the fish increases. The curves for the two species are similar in slope but it can be seen that the eastern species grows more rapidly in its first year and maintains its superiority in length throughout life. It also appears that the Rocky Mountain whitefish has a shorter span of life, although this has not been definitely proved.

Spawning is said to take place in November but no exact information is available.

VARIABILITY OF INDIVIDUAL CHARACTERS

Published morphological records of the Rocky Mountain whitefish indicate a considerable degree of variation in the various meristic characters. Table XVI is a summary of counts made in this investigation. Two of the individuals were taken in Woods lake, and the remainder in Okanagan lake. These results appear to lie within the range covered by the same species in other localities, and thus the Okanagan lake population exhibits no significant differences with respect to the characters examined.

TABLE XVI. Variability of individual characters of the Rocky Mountain whitefish in Okanagan lake.

	Minimum	Maximum	Most frequent value	No. of individuals
Fin rays				
Dorsal	11	14	12	19
Anal	10	12	11	19
Pectoral	16	19	18	19
Pelvic	10	12	11	18
Scale counts				
In lateral line	75	89	82	19
In row above lateral line	73	89	81	19
Rows above lateral line	9	10	9	19
Rows below lateral line				
—from pelvic	8	9	8	18
—from anal	7	8	8	17
Gill rakers				
Short arm	6	11	9	19
Long arm	11	15	13	19
Total	17	25	22	19
Branchiostegals	7	9	8	19
Vertebrae	56	60	58	19

DEPTH RANGE

All Straumfjord's catches were made in the $3\frac{1}{2}$-inch mesh, and therefore the depths given refer in the main to fish of a certain size range. He gives the average weight of the Eastern whitefish caught in this mesh as one pound. In Okanagan lake during September, October, and November, 1929, all catches were made at depths from 10 to 150 feet (3 to 46 m.). In Dog, Vaseaux, and Osoyoos lakes in November, 1929, the Eastern whitefish were taken from 4 to 40 feet (1 to 12 m.).

Eastern whitefish in Okanagan lake during July and August, 1935, were captured at depths ranging from 20 to 138 feet (6 to 42 m.). A complete series of settings at all depths was made across the lake from Okanagan Mission, the deepest set being greater than 138 feet (42 m.), but at this depth no whitefish were taken.

The depths at which Rocky Mountain whitefish were taken ranged from the shallow waters of Trout and Mission creeks to a depth of 50 feet (15 m.). This last was the greatest depth at which this species was found.

SUMMARY AND CONCLUSION

Two species of whitefish are known to exist in lakes of the Okanagan valley. The Rocky Mountain whitefish, *Prosopium williamsoni*, is the native species, and the Eastern whitefish, *Coregonus clupeaformis*, an introduced species.

Commercial fishing of either of the species is unprofitable.

The food of the Eastern whitefish in Okanagan lake seems to exhibit a considerable seasonal variation. During the period July to August plant material formed the greatest bulk of the stomach contents. Next in order of quantity were small fish, Cladocera and insect material. In September and October insect food predominated, followed by Cladocera and Pelecypoda. The most important food of the Rocky Mountain whitefish for the July-August period was the cladoceran, *Daphnia*, and the remainder consisted of insect material.

The annual increment in the length of each species decreases with increasing age. The Eastern whitefish grow faster than the native whitefish and attain a greater size.

The two species can be distinguished readily from each other by the difference in the number of gill rakers. The Eastern whitefish has consistently a larger number of gill rakers than the Rocky Mountain whitefish. The rays in the pectoral fin and the branchiostegals also differ on the average, but since there is an overlapping of the values in both cases, these characters cannot be used alone to differentiate between the two species.

Both species are found on or near the bottom after the first few months of life. The native whitefish apparently inhabits shallower waters than the Eastern whitefish, although the ranges of the two overlap to some extent.

As far as can be ascertained, the Eastern whitefish spawns in the latter part of December and the Rocky Mountain whitefish in late autumn.