Some Aspects of Food and Growth of Fish Species in Babine Lake, British Columbia

Terry D. Beacham and J. G. McDonald

Department of Fisheries and Oceans
Resource Services Branch
Pacific Biological Station
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ABSTRACT

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Food preferences and growth rates of various fish species in Babine Lake were analyzed. Kokanee fed primarily on plankton and insects, with no fish recorded in the diet. Insects were generally the most significant component of the diet of rainbow trout, although fish could account for over 40% of the volume of stomach contents of rainbows over 25 cm fork length. For these large rainbows, the proportion of insects consumed declined from July through October. Fish formed the major component of the diet of lake trout. Plankton and insects were the main foods of redside shiners. Analysis of instantaneous growth rates indicated that they were greater than 0.20 for rainbow trout until age 9 and for lake trout until age 7. There was no evidence to indicate that increased production of sockeye salmon fry by means of artificial spawning channels increased the relative contribution of sockeye fry to the diet of piscivorous fishes.

Key words: Babine Lake, growth, kokanee, lake trout, rainbow trout, redside shiner, stomach contents.

RÉSUMÉ

Beacham, T. D., and J. G. McDonald. 1982. Some aspects of food and growth of fish species in Babine Lake, British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 1057: iv + 23 p.

Les préférences alimentaires et les taux de croissance de plusieurs espèces de poissons du lac Babine sont analysés. Le saumon rouge se nourrit principalement de plancton et d'insectes, mais d'aucun autre poisson. Les insectes composent l'essentiel du régime alimentaire de la truite arc-en-ciel; toutefois, le poisson peut constituer 40% du contenu stomatal des truites de plus de 25 cm de longueur à la fourche. Chez celles-ci, la proportion d'insectes diminue de juillet à octobre. Le poisson est le principal aliment de la truite fardée. Le plancton et les insectes sont les principaux aliments du méné rose. Le taux de croissance instantanée est supérieur à 0,20 chez la truite arc-en-ciel jusqu'à 9 ans, et chez la truite fardée jusqu'à 7 ans. Aucune indication ne donne à penser qu'une production accrue d'alevins de saumon rouge dans les frayères artificielles a augmenté la quantité relative d'alevins dans le régime alimentaire des poissons piscivores.

Mots-clés: lac Babine, croissance, saumon rouge, truite fardée, truite arc-en-ciel, méné rose, contenu stomacal.

INTRODUCTION

Babine Lake is the largest lake in the Skeena River drainage and produces one of the largest sockeye salmon (*Oncorhynchus nerka*) stocks in British Columbia. Godfrey (1955) has described the physical characteristics of Babine Lake. Attempts were begun in 1965 to improve sockeye production through artificial spawning channels and water flow control on two major tributary streams--Fulton River and Pinkut Creek, thereby increasing fry output and increasing the utilization of the lake as a nursery area (McDonald 1969). Fry outputs more than tripled in abundance, increasing from an annual average of 41 million in 1961-67 to 153 million in 1970-76 (Ginetz 1977). A program to assess the project and potential lake rearing capactity was initiated, and from 1966 onwards, the fish species present were sampled mainly by purse seine. The distribution and feeding of juvenile sockeye in Babine Lake has been previously summarized by Narver (1970) and McDonald (1973). Griffiths (1968) described food preferences and growth of rainbow trout and lake trout sampled in Babine Lake in 1967.

In the present study, information on the food of kokanee (*Oncorhynchus nerka kennerlyi*), lake trout (*Salvelinus namaycush*), rainbow trout (*Salmo gairdneri*) and redside shiner (*Richardsonius balteatus*) is described in some detail, along with growth of lake trout and rainbows. Further information on the food of species sampled infrequently is also included. Samples were collected during 1965-68 concurrent with the construction and expansion of the artificial spawning channels, and again in 1971 and 1973 in order to assist in evaluating the effects of the spawning channels. The present report outlines the growth patterns and the food preferences of some fish species in Babine Lake, and examines whether or not increased sockeye fry production was accompanied by changes in dietary components of predaceous fish.

METHODS

Samples were collected mainly by seining from a 35-ft (10.7 m) drum seiner. The general methodology was outlined by Scarsbrook and McDonald (1970). Briefly summarized, the seine was half purse, 275 m in length and 16 m in depth, with mesh size varying from 0.5 cm stretched measure in the bunt to 3.8 cm in the lead. Each set took about 20 to 30 minutes to complete. Sampling was done during three or four periods in a year, being late June or early July, mid-August, possibly late September and regularly late October. Babine Lake was initially divided into five sampling areas (Fig. 1).

For the collection of the stomach samples, fish were preserved in a 10% formalin solution for periods from 2 to 12 months. During processing of specimens, fork length was recorded to the nearest mm. The whole gut was then removed and cut into three sections corresponding to the cardiac portion of the stomach, the pyloric portion, and the intestine. Food items were grouped as to kind and percentage volume of each kind was estimated by inspection for each gut section and for the whole gut.

For the collection of the growth data, fork length was recorded to the nearest mm and whole weight to the nearest g on freshly caught trout. Trout were aged by means of scales. Scales from the larger trout often had several spawning checks which could be confused with an annulus. These checks are a result of scale resorption during spawning and often obliterate a genuine annulus. For this reason, a spawning check was counted as a annulus. Von Bertalanffy growth curves were fitted to observed mean length-at-age by use of the computer program outlined in Rivard (1980).

RESULTS

KOKANEE

Kokanee fed primarily on plankton and insects, with no fish recorded in the diet. The samples from 1965 were derived from Honeymoon Bay and Norlakes Bay, shallow water areas of the north arm of Babine Lake near the upper Babine River, whereas samples from 1966 and 1967 were derived from the deeper main lake areas. Insects comprised 86% by volume of the stomach contents of sampled kokanee in 1965, but less than 10% in 1966 and 1967 when kokanee were sampled from the main lake area. Insects were presumably more available to kokanee in shallow water areas near the shoreline than in the deeper, offshore area.

In 1966, kokanee were sampled in lake areas 1-5 (Fig. 1). Variability in dietary constituents of kokanee owing to fish size and seasonal variation was investigated. Kokanee were defined as "small" (≤160 mm fork length) and "large" (>160 mm). These lengths corresponded to small kokanee being mainly age 2 and large kokanee mainly age 3 with some age 4.

There were no differences in dietary constituents of large and small kokanee within periods or areas examined (Fig. 2). Large and small kokanee fed mainly on plankton from July through October, with insects comprising a larger portion of the diet in July than in subsequent periods. There were differences in proportions of plankton in the diet among kokanee in the different regions of Babine Lake within a sampling period, but if the majority of the unidentified matter were plankton, then diets of kokanee in different areas were similar, being over 90% plankton by volume.

In 1967, kokanee were sampled exclusively in area 3 near Pierre Creek. Identifiable plankton comprised at least 60% of the stomach contents of kokanee (Table 1). In 1967, emphasis was placed on identifying the genera present in the planktonic portion of the diet. In July, Heterocope comprised over 40% of the total volume of stomachs examined (Fig. 3), but in August and September Daphnia comprised over 40% of siomach contents. By October, the copepod Calanoida accounted for over 25% of the stomach contents. Although several genera of zooplankton were present in the lake, kokanee mainly fed on only the three previously mentioned genera.

The data from the 1960s indicated that kokanee did not consume fish to any significant degree. Having established this finding, no samples of kokanee stomachs were collected in the 1970s in order to evaluate diet constituents under conditions of increased production of sockeye fry.

RAINBOW TROUT

Stomach content analysis for rainbow trout has been among the most extensive for all species examined in Babine Lake. As part of an investigation into variability in diet compositions between size classes, rainbow trout were defined as "small" ($\leq$25 cm fork length) and "large" (>25 cm). These lengths corresponded to ages of about 3 years or less for small rainbows and age 4 or older for large rainbows.

The analysis indicated that insects were generally the most significant diet component of rainbow trout, although in larger rainbows, fish could account for up to 76% of the volume of the stomach contents (Table 2). In large rainbow trout, the percentage volume of stomach contents attributable to insects generally declined from July through October, possibly owing to decreasing availability of insects during this period. A detailed analysis of rainbow stomach contents in 1967 and 1968 indicated that the order Hymenoptera was the most abundant of the insect orders, at times constituting 25% of the volume of insects consumed. Coleoptera and Diptera were also frequently consumed by rainbows. Of the fish species eaten by rainbows, juvenile *Oncorhynchus nerka* was the most common one, at times constituting 30% of the volume of fish remains in rainbow stomachs.

Fish formed a small part of the diet of small rainbow trout but a considerable part (up to 76%) of the diet of large rainbows. Because data are sparse and seasonal variation in the amount of fish content is considerable, a close comparison between periods of low and high fry outputs is not possible. When data are pooled and mean values of the proportions of fish in the stomachs are compared for the two periods, small rainbows appear to have increased the proportion of fish in their diet from 3% in 1965-68 to 10% in 1971 and 1973 ($t = 2.0$, $df = 11$, $P < 0.05$). However, the amount of fish in the stomachs of large rainbows remained constant between 33% and 34% ($t = 0.07$, $df = 10$, $P > 0.10$).

The length-weight relationship for fish is generally described by the equation

$$W = aL^b \text{ or } \log W = \log a + b \log L$$

where W is the body weight (g) and L is the total length (mm). A linear regression, fitted to the length and weight data for rainbow trout obtained during sampling in 1968, produced the following relationship (sexes combined):

$$W = 0.00005038\ L^{2.743}\ (n = 151,\ r^2 = 0.98).$$

Growth rates of rainbow trout were investigated by examining mean lengths and mean weights at age (Table 3). The small number of fish sampled at ages above 5 years introduced considerable uncertainty into average mean lengths and weights. A von Bertalanffy growth curve was fit to the mean length at age data in Table 3 in order to obtain an average growth curve. The equation fit

$$L_t = L_\infty (1 - e^{k(t-to)})$$

produced the following results:

$$L_\infty = 77.1 \text{ cm}$$
$$K = 0.082 \qquad (r^2 = 0.97)$$
$$to = 0.057 \text{ y.}$$

Fitting the previous length-weight relationship to the estimated mean length at age allowed average weights at age and instantaneous growth rates to be calculated (Table 4). Instantaneous growth rates of rainbow trout decreased progressively from 0.79 at age 2 to 0.14 at age 10.

LAKE TROUT

Lake trout were not frequently caught owing to their preference for waters deeper than the purse seine routinely sampled. Variability in diet composition owing to the size of trout could not be examined, owing to small sample sizes. The analysis indicated that fish formed the major component of the diet of lake trout within all intervals examined (Table 5). Juvenile Oncorhynchus nerka was the most common identifiable species taken, at times accounting for up to 50% of all fish contents in the gut.

During the late 1960s when the artificial spawning channels commenced operating, fish accounted for over 95% of the diet of lake trout. Only one year of stomach samples was available from the 1970s, those of 1973, and the limited number of samples indicated that insects accounted for between 20 to 30% of the diet in that year. Although the data were limited, there was no evidence to suggest that increased production of sockeye fry in the 1970s was accompanied by an increase in the proportion of sockeye in the diet of lake trout.

A length-weight relationship derived by linear regression for lake trout sampled in 1968 produced the following relationship (sexes combined):

$$W = 0.00002509\ L^{2.816} \qquad (n = 20,\ r^2 = 0.86)$$

where weight is measured in g and length in mm.

Growth curves derived from observed mean lengths and weights at age were irregular (Table 6), owing to small sample sizes. The fitting of a von Bertalanffy growth equation to the mean lengths at age in Table 6 produced the following results:

$L_\infty = 62.2$ cm
$K = 0.22$ ($r^2 = 0.83$)
$t_0 = 1.8$ y.

Estimated mean lengths and fitting of the previous length-weight relationship to these lengths to provide mean weights at age indicated that instantaneous growth rates of lake trout were above 0.20 for ages 7 and younger (Table 7).

REDSIDE SHINER

Redside shiners were sampled for stomach contents in only 1965. The analysis indicated that plankton comprised 70% of the diet by volume, with insects accounting for most of the remainder (Table 8). No further data were available on more detailed constituents of the gut contents.

OTHER SPECIES

During the course of the investigations on Babine Lake, several species were caught and sampled for stomach contents only infrequently. Among these was the peamouth chub (*Mylocheilus caurinus*), and samples from 1966 (n=20) indicated that plankton (cladocerans) and snails were the major components of the diet. Lake whitefish (*Coregonus clupeaformis*) were also sampled in 1965 and 1966 (n=47), and the data indicated that they fed mainly on plankton and occasionally benthic invertebrates such as snails. Fish were also recorded occasionally in the stomach. Five coho (*Oncorhynchus kisutch*) smolts sampled in 1966 fed entirely on insects.

A length-weight relationship for whitefish in 1967 and 1968 was

$$W = 0.000848\, L^{3.70} \quad (n = 97,\ r^2 = 0.88)$$

where weight is in g and length is in mm.

DISCUSSION

Food preferences of fish in Babine Lake were similar to those of the same species in different areas. Echo (1954) found that kokanee in Montana lakes fed exclusively on plankton, similar to the kokanee sampled in Babine Lake in 1966 and 1967. Rainbow trout have been reported to feed extensively on insects, with benthic invertebrates such as snails also contributing to the diet (Parsons 1955; Trojnar and Behnke 1974). Larger rainbows consumed a higher quantity of fish than did smaller rainbows, similar to the results of the present study and those of Griffiths (1968). Ginetz and Larkin (1976) indicated that the amount of rainbow trout predation on sockeye fry may be influenced by stream velocity, light intensities, and previous exposure to predators. Lake trout have been reported to be largely piscivorous (Hacker 1956; Rawson 1961), although lake trout in smaller lakes may have considerable proportions of plankton in the diet (Martin 1966). Godfrey (1955) reported that over 90% of the volume of stomach contents of lake trout from Babine Lake in 1946 was fish, with kokanee at times comprising over 40% of the stomach contents. The results of the present study confirm these trends, as did those of Griffiths (1968). Godfrey (1955) also reported that peamouth chub fed extensively on snails and benthic invertebrates. The results from the present study indicate similar patterns, although extensive feeding on plankton by peamouth chub was not recorded by Godfrey. Lake whitefish have been reported to feed on benthic invertebrates, plankton, insects, and occasionally small fish (Godfrey 1955; Watson 1963), similar to the results recorded in the present study.

Available data do not suggest any substantial change in the proportion of fish in the diet of rainbow and lake trout from the late 1960s to the early 1970s when sockeye fry abundance was greatly increased. Although some increase in the amount of fish in the diet of small rainbows was apparent, the amount remained small (10%). No increase in the proportion of fish in the diets of large rainbows or lake trout was observed. Although there was no evidence to indicate a change in the functional response (Holling 1965; Peterman and Gatto 1978) of predators to increased abundance of sockeye fry, changes in abundance of potential predators (numerical response) need to be investigated in this regard.

The data presented in the present report were derived from sampling fish during the summer and autumn. The seasonal trends in diet compositions of rainbow trout suggest that as insects become scarce during the winter, fish may be the major diet component during the winter. A winter sampling program is necessary to evaluate this hypothesis.

Natural mortality rates of rainbow trout and lake trout in Babine Lake are unknown. Healey (1978) suggested that the instantaneous natural mortality of lake trout is about 0.20 per year. If this mortality rate is relatively constant over ages, then a cohort of lake trout in Babine Lake attain maximum biomass at about 7 years of age. However, Power (1978) indicated that ages of lake trout derived from scales may seriously underestimate the age of older trout when compared with ages derived from otoliths. If this is the case with lake trout from Babine Lake, then calculated growth rates and mortality rates will be higher than those that actually occur. Further work on validating ageing techniques for lake trout from Babine Lake is necessary to investigate this potential bias. If the annual instantaneous natural mortality rate of rainbow trout is also about 0.20, then a cohort of rainbows attains maximum biomass at age 9. Exploitation of fish below these ages would reduce the yield from the stock. If management of these stocks is intended, future work should concentrate on refining estimates of growth and mortality.

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Table 1. Percentage volume of stomach contents of kokanee caught in Babine Lake, 1965-67.

Item	Period		
	June-July	Aug.-Sept.	Oct.
		1965	
Insects	86		
Plankton	14		
Number examined	53		
Empty stomachs	1		
Mean length (cm)	18.9		
		1966	
Insects	9	3	2
Plankton	43	70	40
Unidentified	48	27	58
Number examined	97	97	92
Number empty	0	0	0
Mean length (cm)	15.9	16.1	15.6
		1967	
Insects	4	9	
Plankton	81	79	59
Unidentified	15	12	41
Number examined	50	40	10
Number empty	4	12	1
Mean length (cm)	19.5	17.7	16.8

Table 2. Percentage volume of stomach contents of small (≤25 cm) and large (>25 cm) rainbow trout caught in Babine Lake, 1965-73.

Item	Size					
	≤25 cm			>25 cm		
	July	Aug.-Sept.	Oct.	July	Aug.-Sept.	Oct.
				1965[a]		
Insects		42				
Plankton		51				
Unidentified		7				
Number examined		13				
Empty stomachs		0				
Mean length (cm)		14.0				
				1966		
Fish		5		28	16	30
Insects	20	13	23	58	23	47
Plankton	3	3	1		1	7
Unidentified	77	79	76	14	60	16
Number examined	18	39	15	11	25	9
Empty stomachs	0	1	1	2	3	3
Mean length (cm)	15.3	20.1	21.7	35.7	36.1	38.7
				1967[b]		
Fish		8	13	7	59	76
Insects	100	90	75	93	41	12
Plankton		2	12			12
Number examined	7	32	26	22	13	14
Empty stomachs	0	0	0	0	0	0
Length range (cm)		10.5-25.0			25.0-59.9	

Table 2 (cont'd)

Item	Size					
	≤25 cm			>25 cm		
	July	Aug.-Sept.	Oct.	July	Aug.-Sept.	Oct.
			1968			
Fish		2		8	43	
Insects	72	27		75	27	
Plankton		4				
Unidentified	28	67		17	30	
Number examined	3	30		6	13	
Empty stomachs	0	0		0	0	
Mean length (cm)	18.5	19.3		28.8	32.1	
			1971			
Fish		17			39	
Insects		77			55	
Plankton		5			4	
Unidentified		1			2	
Number examined		15			17	
Empty stomachs		0			0	
Mean length (cm)		18.2			30.9	
			1973			
Fish	3	4	15	21	40	37
Insects	89	92	80	76	50	45
Plankton	8	3	3	3	7	13
Unidentified		1	2		3	6
Number examined	6	31	15	11	21	18
Empty stomachs	0	0	0	0	1	0
Mean length (cm)	21.2	19.8	19.6	36.3	34.8	33.9

[a]All summer months combined.

[b]Derived from Griffiths (1968).

Table 3. Observed mean length (cm) and mean weight (g) at age for rainbow trout caught in Babine Lake in 1968. Standard deviations are in parenthesis.

Age	Mean	length	Mean	Weight	Number
2	16.0	(1.1)	59	(9.0)	3
3	19.0	(3.0)	97	(23.9)	38
4	22.5	(4.2)	152	(64.3)	51
5	27.2	(3.6)	255	(51.1)	33
6	32.8	(5.2)	438	(216.2)	11
7	34.3	(3.6)	499	(167.9)	6
8	43.3	(10.3)	1146	(695.6)	4
9	39.6	(3.7)	706	(250.0)	2
10	46.0	(3.2)	1183	(147.6)	3
12	48.5		1507		1

Table 4. Estimated mean length (cm) and mean weight (g) of rainbow trout and instantaneous growth rates derived from fitting a von Bertalanffy curve to length-at-age data in Table 3 and a length-weight relationship to estimated length at age.

Age	Mean length	Mean weight	Instantaneous growth rate
2	14.6	44	0.79
3	19.5	97	0.57
4	24.1	172	0.44
5	28.2	266	0.35
6	32.1	377	0.29
7	35.6	503	0.24
8	38.9	640	0.20
9	41.9	785	0.18
10	44.7	936	0.14
12	49.6	1245	

Table 5. Percentage volume of stomach contents of lake trout caught in Babine Lake, 1966-73.

Item	Period		
	July	Aug.-Sept.	Oct.
		1966	
Fish	99	100	100
Insects	1		
Number examined	8	3	4
Empty stomachs	3	0	2
Mean length (cm)	48.4	39.7	53.8
		1967[a]	
Fish	98		99
Insects	2		
Plankton			1
Number examined	21		4
Number empty	3		1
Mean length examined (31 to 64 cm)			
		1968	
Fish	100	99	
Insects		1	
Number examined	4	6	
Number empty	2	0	
Mean length (cm)	36.7	45.5	
		1973	
Fish	66	71	78
Insects	34	29	22
Number examined	6	3	4
Empty stomachs	3	0	0
Mean length (cm)	39.6	38.3	44.0

[a]Derived from Griffiths (1968).

Table 6. Observed mean length (cm) and mean weight (g) at age for lake trout caught in Babine Lake in 1968. Standard deviations are in parenthesis.

Age	Mean	length	Mean	Weight	Number
4	20.8		91		1
5	36.7	(6.3)	648	(433)	2
6	43.2	(8.9)	1114	(813)	2
7	37.5	(5.5)	629	(292)	3
8	40.2	(2.9)	811	(229)	3
9	50.7	(4.3)	1573	(618)	3
10	50.7	(8.1)	1897	(941)	3
11	61.4		2135		1
13	54.4		1936		1

Table 7. Estimated mean length (cm) and mean weight (g) of lake trout and instantaneous growth rates derived from fitting a von Bertalanffy curve to length-at-age data in Table 6 and a length-weight relationship to estimated length at age.

Age	Mean length	Mean weight	Instantaneous growth rate
4	24.2	130	0.76
5	31.8	278	0.49
6	37.8	454	0.34
7	42.6	637	0.25
8	46.5	814	0.18
9	49.6	977	0.14
10	52.1	1122	0.11
11	54.1	1247	0.15
13	57.0	1444	

Table 8. Percentage volume of stomach contents of redside shiner caught between July and October of 1965 in Babine Lake.

Item	Percentage
Plankton	70
Insects	22
Unidentified	8
Number examined	26
Empty stomach	7
Mean length (cm)	6.8

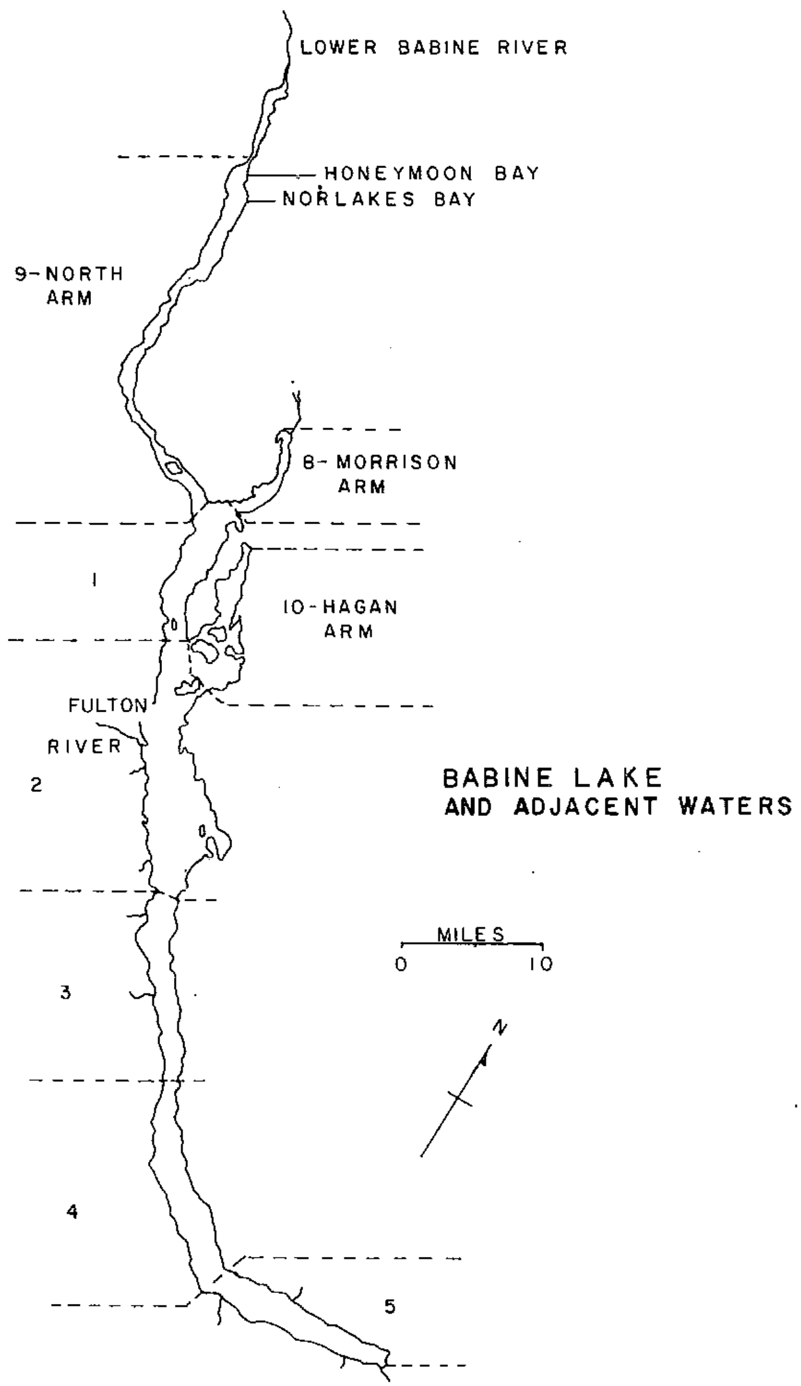

Fig. 1. Babine Lake indicating lake areas defined during the study.

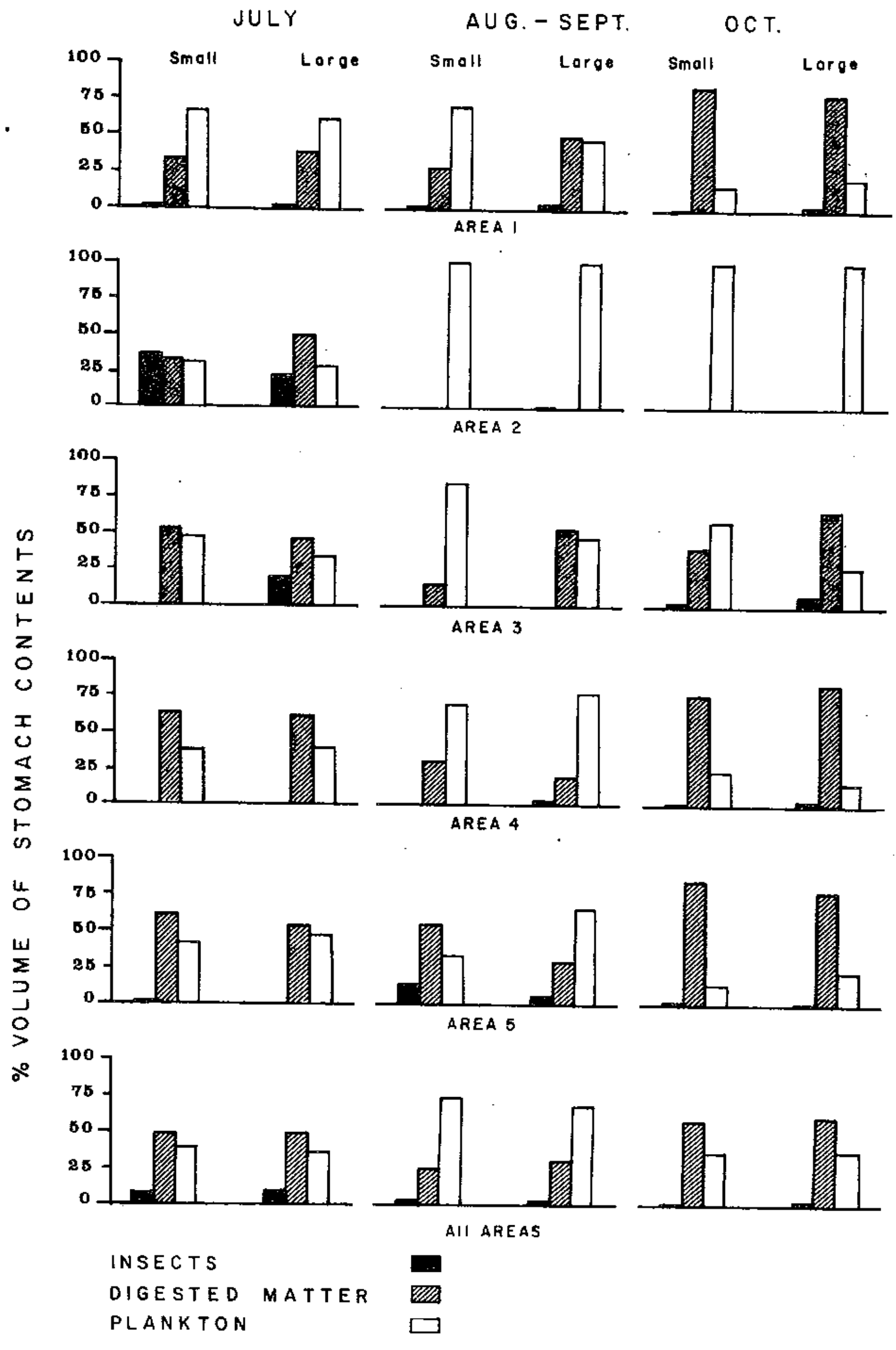

Fig. 2. Percent volume of stomach contents of small kokanee (≤160 mm fork length) and large kokanee (>160 mm) sampled in Babine Lake in 1966.

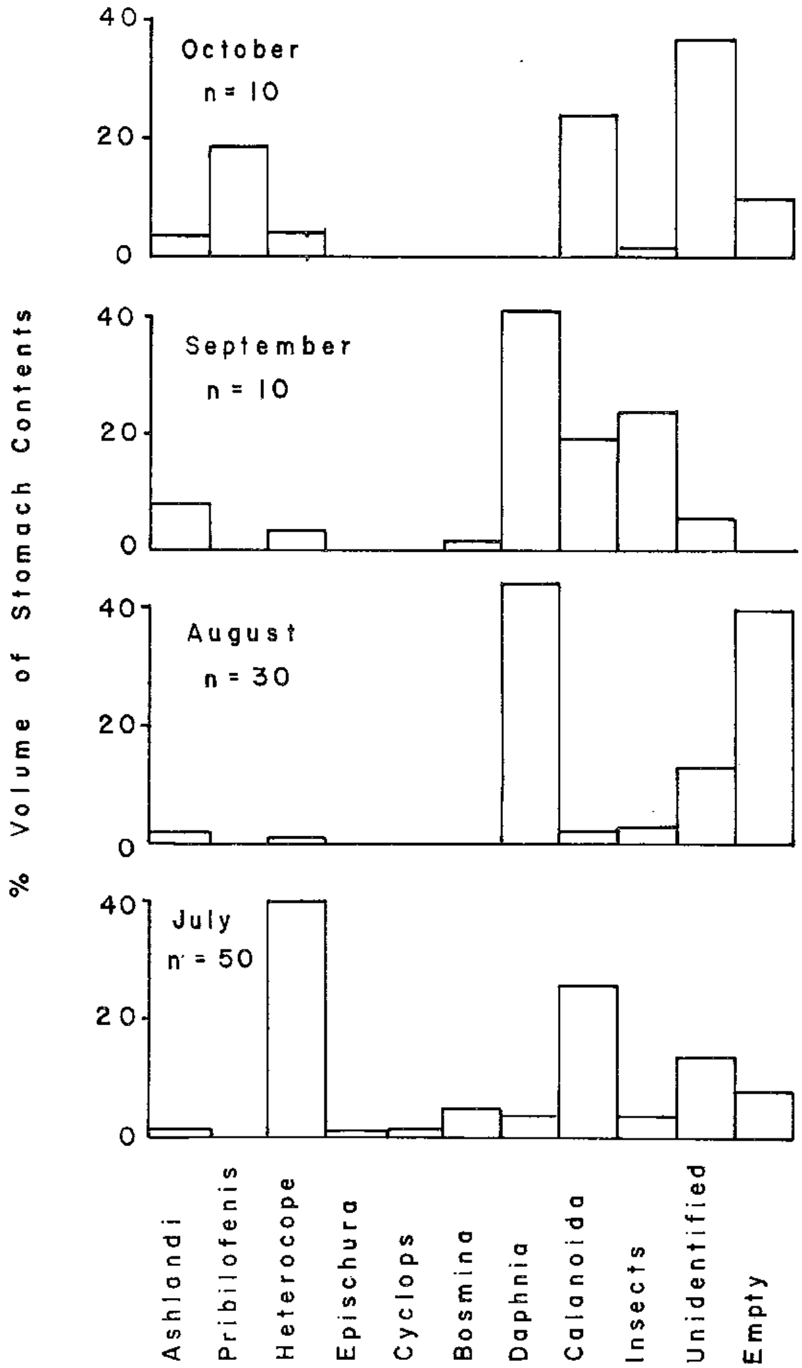

Fig. 3. Percent volume of stomach contents of kokanee sampled in Babine Lake in 1967.