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FOOD OF LAKE TROUT IN LAKE TAHOE[1]

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Stomachs of 1,389 lake trout *(Salvelinus namaycush)* from Lake Tahoe were examined. Of these, 1,097 contained food and were used in food habit determinations. Lake trout were separated into five size groups (inches FL): under 5.0, 5.0 to 9.9, 10.0 to 14.9, 15.0 to 19.9, and over 19.9. The food habits of these groups were evaluated on an annual and seasonal basis. Lake trout less than 5.0 inches preyed heavily on cladocerans and copepods, which occurred in over 90% of the stomachs. No fish remains were found in this size group. Fish (all Piute sculpins, *Cottus beldingii*), occurred in 28.9% of the stomachs of the 5.0- to 9.9-inch lake trout and provided the highest fraction (56.0%) of the weight. However, cladocerans appeared most frequently (52.6%) in the stomachs. In the 10.0- to 14.9-inch group, 66% of the stomachs contained cladocerans and 43% contained fish, with fish contributing the greater weight. Cladocerans were again important by frequency in the diet of the 15.0- to 19.9-inch lake trout, but were of little consequence by weight. Fish, primarily sculpins, occurred in 65.1% of the stomachs and comprised 84.7% of the weight. Only in stomachs of lake trout over 19.9 inches did fish exceed a frequency of 90%. Tahoe suckers *(Catostomus tahoensis)* were the major food item. The greatest seasonal variation in diet involved the occurrence of fish, which was highest in spring and lowest in summer. In previous Tahoe studies, sculpins were the most important food item for lake trout over 14.9 inches. The data indicated that trout less than 15.0 inches lack suitable forage organisms.

INTRODUCTION

The first confirmed introduction of lake trout (known locally as "mackinaw") into Lake Tahoe was made in 1889 by the former Nevada Fish Commission (Miller and Alcorn, 1945). Earlier plants may have been made beginning in 1886, and subsequent plants were also made. As early as 1903, occasional lake trout to 10 lb were caught (Juday, 1907). By 1923 they were considered plentiful (Kemmerer, Bovard, and Boorman, 1923). Today, the Tahoe sport fishery is dominated by the lake trout (Cordone and Frantz, 1966).

In 1960, California and Nevada initiated a cooperative Lake Tahoe Fisheries Study to evaluate the status of the game fish populations and find ways to improve fishing. An assessment of the food habits of lake trout was one phase of the life history investigation of this species. The purpose was to determine if a need existed for new forage organisms to supplement the lake trout's diet.

Results of earlier life history investigations of Lake Tahoe lake trout, including some food habits data, were described by Miller (1951) and Corlett and Wood (1958). The physical and chemical characteristics

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of Lake Tahoe are described by McGauhey et al. (1963) and Weidlein, Cordone, and Frantz (1965).

METHODS AND MATERIALS

Lake trout stomachs were collected from from January 1962 through September 1964. The greatest number (52%) came from angler-caught fish sampled during both a lakewide creel census by boat and a creel census at the Cave Rock Public Boat Landing (Cordone and Frantz, 1966.). Bottom gill nets set at depths from 25 to 900 ft at widely scattered locations around the lake captured many lake trout. This source comprised 44% of the stomachs analyzed. The remaining 4% were from lake trout captured during bottom trawling operations.

All lake trout were measured to the nearest 0.1 inch FL. Stomachs were removed, labeled, and preserved in 10% formalin. The stomachs of 1,389 fish were examined and of these 292 were empty. Food items were identified and counted, and then damp-dried before weighing on a triple-beam balance to the nearest 0.01 g. Length measurements were taken from all ingested fish and crayfish in suitable condition. Crayfish were measured in inches from the tip of the acumen to the end of the telson, and fish were measured in inches FL, except sculpins, which were measured in inches m.

The number of unidentified fish in stomachs was reduced by identification of vertebrae. Surplus tissue was removed from vertebrae of the unidentified fish with potassium hydroxide and then the vertebrae were stained with Alizarin Red. These were compared with stained vertebrae of known origin for final identification.

The lake trout ranged from 1.5 to 33.2 inches FL. They were separated into five size classes to permit determination of changes in diet with changes in length: under 5.0 inches, 5.0 to 9.9, 10.0 to 14.9, 15.0 to 19.9, and over 19.9. Seasonal variation in food habits was analyzed as follows: winter (January, February, March), spring (April, May, June), summer (July, August, September), and autumn (October, November, December). Comparisons between years were not attempted; rather, samples from different years were combined.

RESULTS

Food of Lake Trout

The number of stomachs examined varied by size group, with the fewest in the two smallest size groups, and the greatest number in the 15.0- to 19.9-inch size group (Table 1). The percentage of empty stomachs increased directly with length, ranging from 6.7% in fish under 5.0 inches to 30.0% in fish over 19.9 inches.

Lake Trout Under 5.0 Inches

Only four groups of foods were found in these small lake trout (Table 2). Cladocerans and copepods were clearly the most important, supplying over 90% of the stomach contents by weight and frequency of occurrence. Cladocerans were found in 61% of the stomachs and copepods in 21%; 14% contained both cladocerans and copepods. Tendipedid larvae and pupae ranked second in utilization, while amphipods and oligochaetes were of lesser importance. The latter are numerous

TABLE 1

Number and Percentage of Lake Trout Stomachs With and Without Food, by Size Groups and Seasons

Size group (inches FL)	Under 5.0				5.0 to 9.9				10.0 to 14.9				15.0 to 19.9				Over 19.9				All fish			
	With food		Empty		With food		Empty		With food		Empty		With food		Empty		With food		Empty		With food		Empty	
Season	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Winter	9	100.0	0	0.0	7	70.0	3	30.0	11	91.7	1	8.3	83	76.1	26	23.9	26	57.8	19	42.2	130	73.5	49	26.5
Spring	2	100.0	0	0.0	14	93.3	1	6.7	53	89.8	6	10.2	237	84.6	43	15.4	79	79.8	20	20.2	385	84.6	70	15.4
Summer	11	91.7	1	8.3	6	85.7	1	14.3	35	83.3	7	6.7	136	84.5	25	15.5	40	65.6	21	34.4	228	80.6	55	19.4
Autumn	6	85.7	1	14.3	11	100.0	0	0.0	51	80.9	12	19.1	203	74.4	70	25.6	77	68.7	35	31.3	348	74.7	118	25.3
All year	28	93.3	2	6.7	38	88.4	5	11.6	150	85.2	26	148	659	80.1	164	19.9	222	70.0	95	30.0	1,097	79.0	292	21.0

TABLE 2

Percentage Frequency of Occurrence and Percentage of Total Weight of Food in Stomachs of Lake Tahoe Lake Trout, by Five Size Groups

Size group (inches FL)	Under 5.0		5.0-9.9		10.0-14.9		15.0-19.9		Over 19.9	
Number of stomachs with food	28		38		150		659		222	
Item	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)	Frequency (%)	Weight %	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)
Fish (total)	--	--	28.9	56.0	43.3	63.3	65.1	84.7	90.1	91.2
Piute sculpin (*Cottus beldingii*)	--		28.9	56.0	30.0	42.5	38.4	22.1	27.9	4.8
Tahoe sucker Catostomus *tahoensis*,		--	--	--	2.7	7.4	7.1	18.2	32.4	44.5
Tui chub Gila bicolor		--	--	--	2.0	2.4	9.9	14.3	13.5	7.0
Lahonton redside Richardsonius *evegulus*)	--		--	--	2.0	1.2	2.1	2.0	1.3	0.2
Lahontan speckled dace Rhinichthys osculus *robustus*)			--		--	--	0.3	0.0	--	--
Lake trout (*Salvelinus* namaycush		--		--	3.3	6.8	1.8	1.9	4.0	1.3
Other trout	--			--	--	--	2.3	9.0	6.3	16.6
Kokanee salmon (*Oncorhynchus* nerka	--	--	--	--	--	--	1.8	3.1	7.7	4.9
Mountain whitefish (*Coregonus williamsoni*)			--	--	0.7	2.4	6.4	12.7	10.8	11.3
Unidentified fish	--	--	--	--	6.0	0.6	10.2	1.3	14.9	0.6
Fish eggs[2]	--	--	2.6	0.4	2.0	5.6	1.1	1.5	1.3	0.0
Crustacea										
Cladocera[3]	96.4	90.8	52.6	32.8	66.0	26.3	38.2	1.9	0.9	0.0
Ostracoda Candona *tahoensis*)	--	--	2.6	0.0	--	--	0.1	0.0	--	--
Amphipoda (*Stygobromus* sp.)	7.1	2.2	13.2	4.0	0.7	0.1	0.3	0.0	--	--
Crayfish (*Pacifastacus leniusculus*)	--	--	--	--	3.3	2.0	12.6	11.7	17.1	8.8
Tendipedidae	14.3	3.8	21.0	1.3	12.7	0.1	10.6	0.1	0.9	0.0
Larvae	7.1	2.6	18.4	1.3	9.3	0.1	5.8	0.0	0.9	0.0
Pupae	7.1	1.2	5.3	0.0	5.3	0.0	7.1	0.1	--	--
Plecoptera (*Capnia* sp.)	--	--	7.9	5.4	--	--	0.8	0.0	0.4	0.0
Terrestrial insects[4]	--	--	--	--	0.7	1.4	0.8	0.0	--	--
Oligochaeta	3.6	3.2			0.7	1.1	--	--	--	--

[1] Composed primarily of planted Lahontan cutthroat (*Salmo* clarkii *henshawi*) and Yellowstone cutthroat trout (*Salmo* clarkii *lewisi*), and planted and wild rainbow trout Salmo gairdnerii , and possibly wild brown trout Salmo *trutta*).

[2] Because of their size and the time of year they were eaten, these are most likely lake trout eggs.

[3] Primarily Daphnia palm. Copepods mostly *Epischura nevadensis*) were rare except in fish under 5.0 inches long.

[4] All were apterous stoneflies, either C. *heroica* or C. *lahontana*

[5] Hymenoptera, Hemiptera, Diptera, and Coleoptera.

in Tahoe (Frantz and Cordone, 1966), but were rarely encountered in lake trout stomachs. No fish were found in stomachs of this group.

Lake Trout 5.0 to 9.9 Inches

Cladocerans and fish were the most important items in the diet of lake trout in this size group (Table 2). The only species of fish ingested was the sculpin. The highest number in any one stomach was four, with a total weight of 1.46 *g.* Other foods contributed much less to the diet, comprising approximately 11% of the total weight. Tendipedid larvae and pupae were present in 21% of the stomachs, but contributed only 1.3% by weight. A maximum of 66 tendipedids occurred in one trout, whereas a record 426 plecopterans occurred in another stomach. Amphipods were much more important to lake trout in this size range than to those in other size categories. The number of amphipods per stomach ranged from 2 to 195. Ostracods and fish eggs were insignificant.

Lake Trout 10.0 to 14.9 Inches

Fish and cladocerans remained the major food types within this group (Table 2). One 13.8-inch lake trout had ingested over 3,500 cladocerans with a weight of 2.8 *g.* A greater variety of food types was found in these lake trout, particularly the different species of fishes.

Sculpins far exceeded other species of fishes in the diet of lake trout in this group. Single stomachs contained as many as nine sculpins. Lake trout and suckers were utilized to a moderate degree, while chubs, redsides, and whitefish were of lesser importance. Tendipedid larvae and pupae were found in 12.7% of the stomachs, but contributed little to the overall weight. Crayfish appeared for the first time in the stomachs of these fish and occurred as frequently as lake trout. Fish eggs, amphipods, oligochaetes, and terrestrial insects were taken only occasionally.

Lake Trout 15.0 to 19.9 Inches

The consumption of fish overshadowed all other food items of lake trout in this size range (Table 2). Cladocerans, which were very important in the smaller size groups, occurred frequently in stomachs of trout in this group, but contributed little to the weight of stomach contents. Sculpins were the most important food in this group. Large numbers were occasionally present, with one stomach containing 40 sculpins. The average number in stomachs containing them, however, was 2.9.

Other fish species were also important, with suckers and chubs comprising a large proportion of the stomach contents. The number of suckers or chubs found in any one stomach did not exceed four. Whitefish were fourth in importance and trout, other than lake trout, were next. Most of the trout were planted rainbow and cutthroat trout. Lake trout, kokanee, redsides, and dace were only a minor component of the diet.

Crayfish were the third most important food. Forage items of minor consequence were fish eggs and invertebrates other than cladocerans and crayfish.

Lake Trout Over 19.9 *Inches*

Lake trout in this size group relied almost entirely on fish for their sustenance (Table 2). Suckers comprised the greatest proportion of the food items. The greatest number of suckers found in any one stomach was six.

Sculpins were second in frequency of occurrence but represented a minor proportion of stomach contents by weight. In several instances, however, large numbers were eaten by individual trout : one 23.7-inch trout had consumed 31 sculpins. The average number of sculpins per stomach was 2.9.

All fish species. except dace and redsides, were important in the diet of these large lake trout. Whitefish, chubs, and kokanee salmon contributed significantly to the diet of trout in this size group. Lake trout were eaten occasionally, with nine stomachs each containing one fish.

Trout, other than lake trout, were important also. These consisted of planted and wild rainbow, Lahontan cutthroat, Yellowstone cutthroat, and unidentified *Salmo* which may have included brown trout. Virtually all trout stocked in the lake were marked and when digestion was only moderate such fish could be identified (Cordone and Frantz, 1968). Lake trout appeared to feed heavily on these planted trout. Gill nets were not generally set close to the area where trout were stocked, except for one set in June 1962 off Tahoe City in 40 ft of water two days after a release of Lahontan cutthroat. Stomachs of 8 lake trout that were caught contained 74 cutthroat. In another area, close to where Yellowstone cutthroat were released, three stomachs of angler-caught lake trout each contained from four to nine cutthroat. Crayfish were the only invertebrate of consequence to appear in the diet of the largest lake trout. They were the third most important food, occurring in 17.1% of the stomachs. Fish eggs occurred infrequently.

Seasonal Variation

The percentage of lake trout stomachs with food was highest in spring and summer and lowest in winter and autumn (Table 1). Similarly, the mean weight of food per stomach for all size groups was generally highest in spring and summer and lowest in winter and autumn.

Because of few samples, the two smallest lake trout size groups were combined for the seasonal food habits analysis (Table 3). Lake trout under 10.0 inches utilized sculpins most avidly in the spring. Cladocerans were important during all seasons but particularly in winter, and to a lesser degree in summer. Amphipods and stoneflies were significant only in summer. Tendipedid larvae were consumed primarily in spring and to some extent in winter. Their pupae were most common in summer.

Sculpins also were most important for 10.0- to 14.9-inch lake trout in the spring months (Table 4). The greatest variety of fish was eaten in autumn, with spring second. Cladocerans were an important component of the diet during all four seasons, but especially in winter and summer Crayfish were found in less than 6% of the stomachs from spring through autumn. Tendipedid larvae were consumed throughout the four seasons but most frequently in winter and summer. Their pupae were most common in summer and somewhat less common in

TABLE 3

Percentage Frequency of Occurrence and Percentage of Total Weight of Food in Stomachs of Lake Trout Under 10.0 Inches, by Seasons

Season	Winter		Spring		Summer		Autumn	
Number of stomachs with food	16		16		17		17	
Items	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)
Piute sculpin	6.2	58.7	31.2	61.1	5.9	37.7	11.8	50.5
Fish eggs	--	--	--	--	--	--	5.9	2.4
Crustacea								
Cladocera	93.7	34.8	56.2	38.0	70.6	21.4	64.7	46.5
Ostracoda		--	6.2	0.0		--	--	--
Amphipoda	6.2	0.8		--	23.5	17.2	11.8	0.5
Tendipedidae	12.5	5.4	37.5	0.9	17.6	0.3	5.9	0.1
Larvae	12.5	5.4	37.5	0.8	5.9	0.1	--	--
Pupae		--	6.2	0.0	11.8	0.2	5.9	0.1
Plecoptera	--	--	--	--	17.6	23.4	--	--
Oligochaeta	6.2	0.8		--	--	--	--	
Mean weight (g) per stomach	0.2		0.6		0.3		0.2	

Includes copepods.

TABLE 4

Percentage Frequency of Occurrence and Percentage of Total Weight of Food in Stomachs of Lake Trout 10.0 to 14.9 Inches, by Seasons

Season	Winter		Spring		Summer		Autumn	
Number of stomachs with food	11		53		35		51	
Items	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)
Fish (total)	27.3	52.3	54.7	70.0	37.1	34.2	39.2	65.7
Piute sculpin	18.2	48.8	43.4	53.6	25.7	21.1	21.6	35.5
Tahoe sucker			--	--	--	--	7.8	19.0
Tui chub			1.9	2.4	2.9	9.9	2.0	0.3
Lahontan redside	9.1	3.1	3.8	2.4	--	--	--	--
Lake trout			5.7	11.6	--	--	3.9	4.1
Mountain whitefish				--	--	--	2.0	6.2
Unidentified fish	9.1	0.3	3.8	0.0	8.6	3.1	5.9	0.6
Fish eggs		--	--	--	--	--	5.9	14.4
Crustacea								
Cladocera	81.8	46.7	56.6	24.1	74.3	54.4	66.7	17.8
Amphipoda		--	--		2.9	0.8	--	--
Crayfish		--	5.7	2.6	2.9	0.4	2.0	2.1
Tendipedidae	27.3	0.9	13.2	0.1	22.9	0.5	2.0	0.0
Larvae	27.3	0.9	7.5	0.0	17.1	0.4	2.0	0.0
Pupae		--	7.5	0.0	11.4	0.2	--	--
Terrestrial insects		--	1.9	3.1	--	--	--	
Oligochaeta			--	--	2.9	9.6	--	
Mean weight (g) per stomach	0.8		1.6		0.6		1.4	

spring. Other invertebrates were taken seasonally : amphipods and oligochaetes in summer and terrestrial insects in spring.

Most species of fishes encountered in the stomachs of 15.0- to 19.9-inch lake trout were present each season (Table 5). Spring continued to be the period when sculpins contributed the most, occurring in 53.6%

TABLE 5

Percentage Frequency of Occurrence and Percentage of Total Weight of Food in Stomachs of Lake Tahoe Lake Trout 15.0 to 19.9 Inches, by Seasons

Season	Winter		Spring		Summer		Autumn	
Number of stomachs with food	83		237		136		203	
Items	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)
Fish (total)	63.9	90.2	73.8	91.3	58.8	76.4	59.6	81.3
Piute sculpin	32.5	14.3	53.6	35.4	41.2	17.9	21.2	10.3
Tahoe sucker	3.6	24.9	5.1	14.0	6.6	23.0	11.3	17.6
Tui chub	8.4	16.6	10.5	9.4	6.6	12.0	11.8	22.1
Lahontan redside	2.4	0.1	2.5	3.7	1.5	0.6	2.0	1.5
Lahontan speckled dace		--	0.8	0.0	--	--	--	--
Lake trout	2.4	1.1	2.1	2.0	2.2	2.3	1.0	1.0
Other trout	1.2	0.0	2.9	15.9	3.7	11.4	1.0	0.4
Kokanee salmon	3.6	7.2	2.5	3.6	0.7	0.3	1.0	3.8
Mountain whitefish	10.8	24.2	3.4	6.0	2.2	8.2	10.8	22.2
Unidentified fish	12.0	1.6	9.3	1.3	7.3	0.7	12.3	1.7
Fish eggs	--	--	--	--		--	3.4	5.2
Crustacea								
Cladocera	47.0	2.0	34.2	2.2	40.4	1.6	37.9	1.7
Ostracoda		--	--	--	0.7	0.0	--	--
Amphipoda		--	--	--	0.7	0.0	0.5	0.0
Crayfish	7.2	7.5	9.7	6.1	21.3	21.8	12.3	11.7
Tendipedidae	12.0	0.3	13.5	0.2	16.2	0.1	3.0	0.0
Larvae	12.0	0.3	3.4	0.0	10.3	0.1	3.0	0.0
Pupae	1.2	0.0	11.4	0.2	13.2	0.1	0.5	0.0
Plecoptera	4.8	0.0	--	--	0.7	0.0	--	--
Terrestrial insects		--	1.3	0.1	0.7	0.0	0.5	0.0
Mean weight (g) per stomach	3.7		5.9		6.6		5.1	

of the stomachs. Whitefish were equally important in winter and autumn, occurring in about 10.8%. The number of stomachs containing suckers increased from winter to autumn, whereas by weight the percentage was greatest in winter and summer. Chubs occurred in the diet most frequently in spring and autumn.

Cladocerans occurred in 34 to 47% of the stomachs during all seasons, but constituted only about 2% of the stomach contents by weight. Occurrence of crayfish increased from a low of 7.2% in winter and 9.7% in spring to a substantial 21.3% in summer, followed by a decrease to 12.3% during autumn. Tendipedids contributed little weight to the lake trout diet ; however, larvae were taken frequently in winter and summer, and pupae in spring and summer. Other organisms were of minor importance, with ostracods occasionally taken in summer, amphipods in

summer and autumn, stoneflies in winter and summer, and terrestrial insects from spring through autumn.

Seasonal food habits of lake trout over 19.9 inches consisted primarily of fish, with crayfish of secondary importance (Table 6). Suckers

TABLE 6

Percentage Frequency of Occurrence and Percentage of Total Weight of Food in Stomachs of Lake Tahoe Lake Trout Over 19.9 Inches, by Seasons

Season	Winter		Spring		Summer		Autumn	
Number of stomachs with food	26		79		40		77	
Items	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)
Fish (total)	96.1	96.7	93.7	96.9	85.0	80.3	87 0	87.6
Piute sculpin	34.6	5.9	44.3	8.4	22.5	1.0	11.7	0.6
Tahoe sucker	38.5	59.8	32.9	38.0	42.5	65.9	24.7	38.4
Tui chub	11.5	2.4	8.9	7.7	12.5	6.5	19.5	6.9
Lahontan redside	--	--	3.8	0.5	--	--	--	--
Lake trout	3.8	0.6	7.6	2.1	2.5	0.8	1.3	0.2
Other trout	7.7	0.6	13.9	33.7	--	--	1.3	0.4
Kokanee salmon	11.5	15.7	7.6	3.7	7.5	5.2	6.5	4.8
Mountain whitefish	23.1	10.8	5.1	2.4	--	--	18.2	35.5
Unidentified fish	23.1	0.7	5.1	0.4	17.5	0.8	20.8	0.8
Fish eggs		--	--	--	--	--	3.9	0.0
Crustacea								
Cladocera		--	1.3	0.0	--	--	2.6	0.0
Crayfish	11.5	3.3	15.2	3.1	30.0	19.8	14.3	12.3
Tendipedidae larvae		--		--	5.0	0.0	--	--
Plecoptera	3.8	0.0	--		--	--		--
Mean weight (g) per stomach		14.9		48.5		37.1		27.4

were the most common food item in all seasons except spring, when more sculpins appeared. The weight of suckers, however, clearly exceeded that of any other species in all seasons. Occurrence of suckers was highest in summer and lowest in autumn. Sculpins occurred most frequently in spring and winter, and less frequently in summer and autumn. Whitefish were important in winter and autumn, but were unimportant in spring and absent in summer. The percentage of stomachs with chubs was highest in autumn. Kokanee salmon were found in 11.5% of the stomachs in winter, and gradually decreased from spring through autumn. Lake trout and "other" trout were more prevalent in lake trout stomachs during spring. The occurrence of ''other" trout during this period is largely due to predation on planted Lahontan and Yellowstone cutthroat in May and June of 1962. Spring was the only period when a few stomachs contained redsides. As in the diet of smaller lake trout, fish eggs occurred only in a few stomachs and only in autumn. Because of their size and their appearance in autumn only, it seems likely that these were lake trout eggs. Whitefish eggs are much smaller, and beach spawning of kokanee salmon was extremely limited when the study was made.

Consumption of crayfish during the summer was second to that of suckers. Other invertebrates were unimportant.

Size of Fish Eaten

As anticipated, the larger lake trout consumed larger prey (Table 7). Suckers and whitefish 9 to 11 inches long were not uncommon in the stomachs of 20- to 25-inch lake trout. Although not part of this study, a 34-inch (19.2 lb) lake trout caught in 1961 contained a 16.5-

TABLE 7

Mean and Maximum Lengths of Fish and Crayfish Ingested by Lake Tahoe Lake Trout, by Size Groups

Size group (inches FL)	5.0-9.9			10.0-14.9			15.0-19.9			Over 19.9		
Item	No.	Mean length	Max. length	No.	Mean length	Max. length	No.	Mean length	Max. length	No.	Mean length	Max. length
Piute sculpin	9	1.9	2.3	57	1.9	3.1	454	2.0	4.2	116	2.4	4.1
Tahoe sucker				4	3.1	3.8	27	4.4	7.8	38	6.4	11.5
Tui chub				2	1.9	2.9	38	3.5	5.8	15	4.3	9.5
Lahontan redside			--	--	--	--	8	3.1	3.8	2	3.4	3.4
Lake trout				5	2.8	3.0	7	4.3	6.4	4	5.0	7.5
Other trout				--	--	--	33	5.0	6.0	15	4.8	7.1
Kokanee salmon		--		--	--	--	3	3.9	4.5	6	5.6	7.3
Mountain whitefish				1	3.7	3.7	23	4.7	7.1	9	8.6	11.9
Crayfish				2	1.6	1.8	44	2.3	4.2	46	2.9	4.3

inch lake trout. Corlett and Wood (1958) describe a 36-inch lake trout which had eaten three fish, one of which was at least 19 inches long. The smallest lake trout with fish was a 5.2-inch specimen which had eaten a 1.3-inch sculpin.

DISCUSSION

Comparisons with Previous Tahoe Studies

The two previous studies on food of lake trout in Tahoe by Miller (1951) and Corlett and Wood (1958) were compared with the present study. Miller obtained 191 stomachs from May through September in 1948 and 1949. They were taken from fish 9 to 32 inches FL, but most were from fish over 15 inches. During their study from 1954 through 1958, Corlett and Wood collected 386 stomachs from lake trout ranging from 14 to 36 inches FL. Of these, 255 contained food and the contents were evaluated only by percentage frequency of occurrence. For comparative purposes, results of these two studies were compared with food habits of lake trout over 14.9 inches from the present study.

In all studies, fish were by far the most significant food, with the sculpin the most common of the fishes (Table 8). Miller lists the chub as the second most common food and the sucker as the third in frequency of occurrence. The occurrence of bottom food was fourth. Miller stated, "Among the bottom foods the only form of note is the crayfish. . . . ". Those of lesser importance and in decreasing order were redsides, plankton, surface food, whitefish, and lake trout. Miller found that the suckers contributed the greatest percentage by volume, followed closely by chubs and sculpins.

TABLE 8

Comparisons of Lake Tahoe Food Habit Studies for Lake Trout

	Present study 1962-64		Corlett and Wood (1958) 1954-58	Miller (1951) 1948-49	
Size (inches FL)	15 to 33		14 to 36	9 to 32	
	Frequency (%)	Weight (%)	Frequency (%)	Frequency (%)	Volume[1] (%)
Fish (total)	71.4	89.1	89.9	80.8	95.7
Piute sculpin	35.7	10.3	45.5	50.2	23.9
Tahoe sucker	13.5	36.1	4.7	14.0	33.6
Tui chub	10.8	9.3	3.9	23.2	23.8
Lahontan redside	1.9	0.8	14.9	4.9	2.6
Lahontan speckled dace	0.2	0.0	--	--	--
Lake trout	2.4	1.4	--	0.7	0.7
Rainbow trout	--	--	1.2	--	--
Other trout	3.3	14.2		--	--
Trout, unidentified	--		2.7	--	--
Kokanee salmon	3.3	4.3	1.6	--	--
Mountain whitefish	7.5	11.8	3.1	1.4	1.7
Unidentified fish	11.3	0.8	46.3	19.6	2.7
Fish eggs	1.1	0.5	0.8	--	--
Cladocera	28.8	0.6	--		--
Ostracoda	0.1	0.0	--	--	--
Amphipoda	0.2	0.0	--	--	--
Plankton		--	5.9	2.8	0.1
Crayfish	13.7	9.7	5.5	--	--
Bottom food	--	--	--	18.9	3.07
Tendipedidae					
Larvae	4.5	0.0	1.2		--
Pupae	5.3	0.0	--		--
Plecoptera	0.7	0.0	--	--	--
Aquatic insects	--	--	0.8	--	--
Terrestrial insects	0.6	0.0	--	--	--
Surface food	--	--	--	2.1	0.0

[1] Volume was measured in cc and was generally comparable with weight.
Miller lists two subspecies: *G.b. ahnaii* (included here) and *G.b. pedinife,* which had 9.8% by frequency of occurrence and 8.5% by volume.

Corlett and Wood found that redsides were the second most important food item in frequency of occurrence, followed by plankton, crayfish, suckers, chubs, whitefish, trout, kokanee salmon, and midge larvae, in that order. Fish eggs, assumed to be lake trout eggs, and aquatic insects were of minor importance.

The present study indicates that cladocera are the second major food in frequency of occurrence but unimportant by percentage weight. Crayfish, suckers, and chubs ranked third, fourth, and fifth in occurrence and the whitefish ranked sixth. Other food items of decreasing importance in occurrence were immature tendipedids, trout, kokanee salmon, redsides, and fish eggs. In percentage weight, suckers were first by a large margin, followed by trout, whitefish, sculpins, crayfish, chubs, and kokanee salmon.

Several obvious differences exist among the three studies, but it was not possible to determine the reasons for them. Sampling may be involved, since the two earlier studies were restricted in sample size, seasonal representation, and the area and depth from which lake trout were collected. Certain differences in methods of stomach analysis may

also be involved. It is also possible, however, that annual variations in prey abundance and availability were responsible.

Need for Additional Forage Supply

The literature suggests that lake trout are opportunistic feeders, with a strong predilection for relatively large prey organisms. In Lake Superior, young-of-the-year (1.1 to 3.7 inches TL) and age I and II (3.6 to 8.9 inches TL) lake trout subsisted almost entirely on *Mysis relicta* (Eschmeyer, 1956). For both groups, fish occurred in 9% of the stomachs and contributed about 12% by weight. A 1.5-inch lake trout contained fish larvae. Numerous other studies describe the heavy utilization by juvenile lake trout of relatively large invertebrates, such as *Mysis* and *Pontoporeia*, and of small fish as well (e.g., Larkin, 1948; Cuerrier and Schultz, 1957; Webster, Bentley, and Galligan, 1959; Rawson, 1961; Hacker, 1962; Dryer, Erkkila, and Tetzloff, 1965). Several authors have commented on the significance of such a diet. In one Wisconsin lake, in a year when *M. relicta* was especially abundant, survival of young stocked lake trout increased threefold (Threinen, 1962). Investigations at Waterton Lakes in Canada led Cuerrier and Schultz (1957) to state, "The availability of small fish for young lake trout seems to be a very important factor in the successful development of the population". Results at another Canadian water, Lake Minnewanka, indicated that a scarcity of forage fish for lake trout under 15 inches was responsible for poor growth and survival of the population (Cuerrier, 1954).

McCaig and Mullan (1960) noted a marked increase in lake trout growth rates subsequent to establishment of an abundant population of the American smelt (*Osmerus mordax)* in a Massachusetts reservoir. Perhaps the best testimony of the impact of food habits on lake trout biology came from a long-term study of a series of Canadian lakes in Algonquin Park (Martin, 1966). In lakes where lake trout depended heavily on plankton for summer food, they grew more slowly, did not attain as great a size or age, and matured at a smaller size and younger age in comparison with lake trout in lakes where fish are an abundant summer forage. Annual yield in numbers was higher in planktonivorous than piscivorous populations, but yield in pounds was comparable. We interpreted the Lake Tahoe lake trout population, at least that segment under 15 inches, as more planktonivorous than piscivorous.

During the summer months, most Lake Tahoe lake trout are found in the hypolimnion close to the bottom, whereas most of the potential forage fishes are found in the littoral portion of the epilimnion (Lake Tahoe Fisheries Study, unpubl. data). A number of other workers have described similar distribution patterns (e.g., Martin, 1952; Cuerrier, 1954). However, at Lake Tahoe considerable overlap exists, since in summer a few lake trout are taken in shallow water. Also, sculpins are abundant at 200 ft and common at 400 ft.

The summer distribution data, the predominance of plankton in the diet of fish under 15 inches, and the relatively slow growth rate of Lake Tahoe lake trout (Hanson and Cordone, 1967) indicated a need to augment the summer supply of forage organisms in the deep, cold waters occupied by the lake trout. This led to the introduction of the

opossum shrimp, *Mysis relicta*, and the Bonneville cisco, *Prosopium gemmiferum* (Frantz and Cordone, 1965; Linn and Frantz, 1965). The shrimp is now established in Lake Tahoe, but its utilization by lake trout has not yet been measured. The status of the cisco is unknown.

CONCLUSIONS

The diet of lake trout in Lake Tahoe shows several obvious patterns that vary with size of fish and time of year. As trout increase in length they change from an invertebrate to a fish diet. Cladocerans dominate the intake of lake trout under 5.0 inches, and remain significant until trout attain a length of about 15 inches. Other invertebrates, such as immature tendipedids and amphipods, tend to be fairly important in the diet of small trout but also decline substantially in importance when the fish reach a length of about 15 inches. The crayfish is the one exception to this trend. It is significant in the diet of lake trout under 15 inches and is of moderate importance in the diet of larger fish.

Fish are not found in the stomachs of lake trout under 5.0 inches. They become a progressively significant component in the diet of larger trout. Fish between 5.0 and 9.9 inches consume Piute sculpins only, and these remain the most prevalent fish in lake trout stomachs until the trout attain a length of about 20 inches. After this, more Tahoe suckers than sculpins are eaten and, because they are much larger, suckers make up an even greater portion of the total weight consumed. A wider variety of fishes is taken by lake trout over 15 inches, with tui chubs and mountain whitefish assuming prominent roles also.

Lake trout feed more avidly on fish during the spring months than during any other time of year. Not only are there fewer empty stomachs in spring, but the actual weight consumed is generally higher at this time of the year. The fewest fish in lake trout stomachs occur in summer. The percentage contribution of sculpins by both frequency and weight is highest during spring for all sizes of lake trout. Because of the dominance of sculpins in the diet of lake trout, the values for all fish combined generally show the same spring peak. However, other species of fishes do not follow the same pattern as the sculpin. Mountain whitefish are much more prevalent in lake trout stomachs in autumn and winter. Since whitefish spawn in November and December, this may be a function of greater availability, related to their pre- and post-spawning behavior. Suckers and chubs occur most frequently in summer and autumn, kokanee salmon in winter, and lake trout and redsides in spring and winter. Definite trends are observed for the major invertebrates in the lake trout diet. Cladocerans are most common in stomachs of 10- to 20-inch fish in winter, followed by summer, autumn, and finally spring. Crayfish contribute most in the summer to lake trout over 15 inches.

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