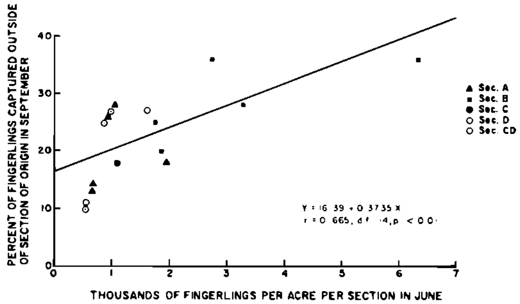

FIGURE 1.—Regression of emigration on density of brook trout during their first summer of life in Lawrence Creek.

trout in September is not a valid reflection of the distribution of the spawning effort.

Dispersal of fingerlings downstream from sections A and B consistently exceeded dispersal upstream from C and D. In September, 1959, for example, sections AB contained 1,615 immigrants from sections CD whereas CD contained 4,490 immigrants from AB. Immigrant fingerlings accounted for 25 per cent of the September stock of fingerlings in AB and 55 per cent in CD. Thus, even though many fingerlings dispersed from the main spawning areas in sections A and B, the September stocks of fingerlings in these sections still consisted largely of resident fingerlings (Table 2).

Dispersal of fingerlings upstream from B to A exceeded the downstream movement of fingerlings from A to B by approximately 26 per cent. Dispersal downstream from B to CD exceeded the upstream movement of fingerlings from CD to B by 170 per cent. Dispersal downstream from B to CD exceeded dispersal upstream from B to A by 300 per cent. Each percentage is a mean of five observations.

During five successive summers, as density of fingerlings increased the percentage of fingerlings that were subsequently recaptured outside the section in which they were marked also increased. This relationship is illustrated in Figure 1 for which the correlation coefficient, $r = 0.665$, is highly significient (14 d.f., $r = 0.623$ at 1 per cent level). Over the range of observed values 10 per cent of the fingerlings emigrated from their section of origin when their density in June was 548 per acre, and 36 per cent emigrated when their density was 6,323 per acre.

The observations reported here indicate more movement of fingerling brook trout over short distances of stream in both directions than have been previously assumed. McFadden (1961), for purposes of calculating mortality and recruitment in this population, assumed no movement of fingerlings between sections. Such calculations remain valid only to the extent that the dispersal of the fingerling trout between sections was compensatory, yet in the present study, compensatory movement was not sufficient to eliminate a definite bias toward downstream movement. In addition, the stability of the stocks tended to decrease as the stock density increased, adding another variable to be considered in interpreting dispersal of the population.

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Food Habits of the Brook Trout in West Lost Lake[1]

INTRODUCTION

Studies of the seasonal variations in the food habits of fishes must continue long enough to distinguish between actual food habits of the fish and cycles of abundance of the organisms used as food. West Lost Lake contained no other fish. My investigation covered variation in food habits as influenced by shifts in the increasing size and age of the fish and changes in the abundance of some of the food items in the lake.

METHODS

Fieldwork was conducted from August 1962, to November 1963. Tanner (1960) described the limnological characteristics of West Lost Lake.

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TABLE 1.—*Summary of the stomach contents of 239 brook trout, 5 to 12.5 inches long from West Lost Lake, Michigan. (N, number of full stomachs; A, per cent frequency of occurrence; B, per cent weight; C, per cent volume*

Year, month	*N*	Crayfish			Daphnia			Insects			Trout eggs		
		A	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*
1962													
August	16	12	35	23	69	27	40	56	37	38	—	—	—
September	27	22	23	31	59	22	31	67	45	36	—	—	—
October	14	—	—	—	43	29	48	93	55	36	14	16	16
November–December	14	14	28	22	36	14	15	86	58	63	—	—	—
1963													
January–February	12	25	72	56	50	7	16	58	21	28	—	—	—
March	14	27	51	45	27	10	14	73	39	41	—	—	—
April	20	10	5	4	—	—	—	88	95	96	—	—	—
May–June	15	—	—	—	6	3	3	88	97	97	—	—	—
July	18	5	2	3	57	14	18	36	84	80	—	—	—
August	56	8	24	17	68	32	38	60	44	43	—	—	—
September	25	19	46	41	61	30	31	77	24	28	—	—	—
October–November	8	—	—	—	37	44	43	75	55	51	12	1	5

Brook trout do not reproduce in the lake, and it is stocked each year at the rate of 100 trout (mean length, about 5 inches) per surface acre.

During August and September 1962, and from April to September 1963, stomachs were removed from all angler-caught fish. In autumn, winter, and spring when the lake was closed to fishing, stomachs were obtained at least every 2 months by collecting fish with an A.C. shocker or by hook and line. Of 273 stomachs examined, 239 contained identifiable food items. Since the total population at any time during sampling period did not exceed 600 fish, this sample represents a considerable portion of the fish in the lake.

For monthly periods, when possible, I determined for each food item in the series of trout stomachs the identity, weight in grams, volume in cubic centimeters by displacement of water, and frequency of occurrence. The fish were grouped according to the following total lengths in inches: 4.6 to 8.5 and 8.6 and over because feeding habits were similar within these length intervals.

RESULTS AND DISCUSSION

The predominant organisms found in the trout stomachs were insects, chiefly dragonfly (Aeschnidae) nymphs, midge (Tendipedidae and Culicidae) larvae and pupae, mayfly (Baetidae and Heptageniidae) nymphs, water boatmen (Corixidae); Cladocera (*Daphnia galeata mendotae*); and crayfish (*Orconectes virilis*). Occurrence varied with the season by weight and by volume.

In the spring and early summer, April to July, insects were an important part of the food of the trout. The months of their peak of incidence were May and June (Table 1).

Tanner (unpublished) sampled the invertebrate bottom fauna of West Lost Lake in the summer of 1948, and reported that midges of the family Tendipedidae comprised 63.5% of the total volume. Based on his quantitative estimates this amounted to a standing crop of about 10.9 kg. The next most abundant group, the larvae and pupae of *Chaoborus* sp. formed 31.3% of the total volume for an estimated standing crop of 5.4 kg. Dragonfly nymphs formed 1.3% (standing crop of 2.2 kg) and mayfly nymphs 1.6% (standing crop of 2.7 kg) of the total volume. These same groups comprised most of the insects present in over 80% of the trout stomachs examined in 1962 to 1963. The other groups of insects were seasonally irregular in occurrence and in total numbers. The frequency of occurrence of insects in the diet of the trout followed a cyclical pattern from a high of 93% in October 1962, to a low of 60% in August 1963 (Table 1).

In late summer and fall, daphnia became an important component of the diet of the trout when it comprised between 29% (October 1962) and 44% (October 1963) of the total weight. The frequency of occurrence of daphnia was highest in August 1962 at 69%; it was 0 in April of 1963 but rose to a high again in August 1963. Cyclic occurrence of daphnia is apparent as for insects (Table 1).

No data on the seasonal abundance of daphnia are available for West Lost Lake.

Wells (1960) reported that in Lake Michigan the population trend for *D. galeata mendotae* showed an absence of adults in winter and early spring and a peak of abundance in early August. Borecky (1956) reported that in Pymatuning Reservoir on the Pennsylvania–Ohio border, *D. galeata mendotae* showed two maxima, one in June and the other during late August and early September. In a southern Michigan lake, Hall (1964) showed two maxima for *D. galeata mendotae*, late spring and early fall and a minimum density in early March. Wells (1960) reported collecting ephippia in October and November. I found the same occurrence in trout stomachs from fish taken during these months from West Lost Lake.

In winter, crayfish were an important item in the diet (Table 1). Momot (unpublished) showed that trout predation accounted for 60% of the overwinter mortality of young-of-the-year crayfish. Trout fed exclusively on this age group of crayfish, which reached its peak of availability in winter. The important factors were: (1) in the spring young-of-the-previous-year were larger than the maximum size consumed by trout, (2) the young-of-the-present-year had not hatched and were unavailable to the trout in the spring, (3) after hatching, the young-of-the-year remained in shallow water and were unavailable to the trout during the summer since the trout were confined to the deeper, cooler waters of the lake. As the surface waters cooled in autumn and the lake became homothermous the consumption of crayfish by trout increased (notice the difference between August and September 1963, in Table 1).

An unexpected decrease in consumption of crayfish occurred in October. In the months previous to and following it, the crayfish were conspicuous as a part of the diet of the larger brook trout, which eat over 90% of the crayfish. This was associated with the appearance of trout eggs in the diet, although information on how the spawning behavior might alter the food habits of the trout is unknown.

Some data exist demonstrating that feeding habits were as much influenced by availability as by the abundance of food organisms at a particular time. The total weight of trout food

TABLE 2.—*Average monthly distribution of the major food items among the various size groups of trout (expressed as % of the total)*

Food item	5- to 7-inch trout	8-inch trout	9-inch trout	10-inch and longer trout
Crayfish	0	4	38	58
Cladocera	27	38	30	5
Insects	9	25	38	28

comprised of bottom invertebrates present in the summer of 1963 was about 5.1 kg/hectare. Assuming that the 1963 estimated standing crop of bottom invertebrates was approximately the same as in 1948, young-of-the-year crayfish comprised 49.6% and the other bottom invertebrates (chiefly insects) 50.4% by weight of the trout food present in the lake. In August 1963, insects comprised 64.7% and young-of-the-year crayfish 35.3% by weight of the bottom invertebrates found in trout stomachs. This indicated selection by trout for insects. This probably reflects availability as well as abundance because, as the lake became homothermous in the fall, the consumption of crayfish by trout increased. For example in September 1963, crayfish comprised 65.4% compared to 34.6% by weight of the bottom invertebrates found in trout stomachs.

Comparison of the variation in monthly predation by various size groups of the trout further enhances understanding of dietary dynamics. Small fish, 5-to-8-inches long, fed predominantly on daphnia during the winter months, and on insects in the spring and summer months. Crayfish occurred only sporadically and in small amounts. For fish 9 inches and more in length, insects were the most important food items in the spring and summer and crayfish predominated in the fall and winter.

On the foregoing data, the trout population can be divided into two ecological categories each having a different pattern with respect to its predation upon and utilization of the food available in the lake. The approximate point of division of these two categories is at a mean length of 8 inches.

When considering categories of the major food items of the trout in West Lost Lake, most of the crayfish were eaten by large trout, most of the insects by medium-sized trout, and most of the daphnia by small trout (Table 2). This preferential sequence further demonstrates the different trophic pattern prevalent among various size groups within the same population of fish.

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Limnetic Cottid Larvae and Their Utilization as Food by Juvenile Sockeye Salmon

INTRODUCTION

Freshwater cottids, lacking a swim bladder, are usually benthic fishes. This paper presents data on the planktonic occurrence of larvae of *Cottus aleuticus* in limnetic areas (open water) of Brooks Lake and on the ultilization of cottid larvae as food by juvenile sockeye salmon (*Oncorhynchus nerka*). Brooks Lake is one of four lakes that serve as important rearing areas for juvenile salmon in the Naknek system.

The term larvae as used in this paper refers to small fish that have absorbed the yolk but have not assumed the general appearance of adults.

Most records of cottid–salmon relations deal with the predatory activity of cottids upon salmon eggs, alevins, or fry. Ricker (1941) found the prickly sculpin (*C. asper*) to be a predator of juvenile sockeye salmon in Cultus Lake. Hunter (1959) reported on predation of pink salmon (*O. gorbuscha*) and chum salmon (*O. keta*) by *C. asper* and *C. aleuticus*. Patten (1962) found the torrent sculpin (*C. rhotheus*) and the reticulate sculpin (*C. perplexus*) to be predators on coho salmon fry (*O. kisutch*). Pritchard (1936), Robertson (1949), and others have also discussed cottid predation on young salmon.

Records of salmon predation on cottids are scarce. Foerster (1925) found a partly decomposed 15-millimeter cottid in the stomach of an 85-millimeter migrating yearling sockeye salmon. Ricker (1937) reported 51 larval cottids from the stomach of a 138-millimeter sockeye salmon. Merrell (1964) reported that juvenile sockeye salmon from Brooks Lake in 1957 contained cottid larvae.

No previous North American literature that specifically discusses the planktonic occurrence of freshwater cottids could be found, although such might be inferred from the above accounts of sockeye salmon predation on cottid larvae. In recent laboratory experiments Krejsa (unpublished) has demonstrated that larvae of *C. aleuticus* and *C. asper* are planktonic upon hatching and, in the case of *C. asper* at least, remain so for approximately 5 weeks. He reports that two larval *Cottus* spp. in the University of British Columbia fish collection were taken by an unknown collector in a plankton tow over 1,000 feet (328 m) of water in Owikeno Lake, British Columbia. Northcote and Hartman (1959) reported unusual behavior in *C. asper* in Nicola Lake, British Columbia. The cottids were moving in a stream or band alongshore where most of them were swimming at or near the surface; those farther offshore were near the bottom. While this is not true limnetic occurrence, it illustrates that cottids are not confined to the bottom.

METHODS

The equipment used to sample cottids and other species included 1-meter- and 3.1-meter-diameter nets towed behind two outboard