This is to certify that the

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Feeding Habits of Salmonids in Michigan Waters of Eastern Lake Michigan and Southern Lake Superior

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Stuart Nelson Kogge

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Niles R. Kevern

Major professor

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FEEDING HABITS OF SALMONIDS IN MICHIGAN WATERS OF EASTERN LAKE MICHIGAN AND SOUTHERN LAKE SUPERIOR

BY

STUART NELSON KOGGE

A THESIS

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ABSTRACT

FEEDING HABITS OF SALMONIDS IN MICHIGAN WATERS OF
EASTERN LAKE MICHIGAN AND
SOUTHERN LAKE SUPERIOR

BY STUART N. KOGGE

Stomach contents from 4,390 salmonids from eastern Lake Michigan and 158 from southern Lake Superior were analyzed to determine feeding habits. In 1983, 974 (64.38%) salmonids from eastern Lake Michigan contained prey items while 1,256 (46.51%) contained prey in 1984. The percent of salmonids feeding in 1984 was significantly lower ($p<.001$) than in 1983. The decline in feeding fish is presumed to be indicative of a decline in forage availability.

Alewife (*Alosa pseudoharengus* (Wilson)) once dominated the diets of Michigan's sport fish (chinook salmon *Oncorynchus tshawytscha* (Walbaum); coho salmon, *Oncorynchus kisutch* (Walbaum); lake trout, *Salvelinus namaycush* Walbaum; rainbow trout, *Salmo gairdneri* Richardson; brown trout, *Salmo trutta* Linnaeus, and atlantic salmon, *Salmo salar* Linnaeus; (Wright,1968; Chiotti, 1973; McComish and Miller, 1976). Decline in alewife populations and opportunistic feeding behavior by salmonids led to the preponderance of smelt (*Osmerus mordax* (Mitchill)) and bloaters (*Coregonus hoyi* (Gill)), the most abundant species, in 1984.

Differences in feeding habits and intensity occurred

across regional boundaries of the lake and throughout the year with respect to various salmonid species.

In Grand Traverse Bay lake trout predominated and fed extensively on smelt. Likewise, smelt was the predominant prey item of Lake Superior salmonids. They showed a larger diversity and paucity of prey items consumed reflecting the smaller forage base of Lake Superior, in comparison to Lake Michigan.

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INTRODUCTION

The balance between predator and prey populations is important in the management of a fishery. Forage base relationships have been greatly restructured, both positively and negatively, by the introduction of a species and species extinction. Invasion of the sea lamprey (*Petromyzon marinus* Linnaeus) and alewife (*Alosa pseudoharengus* (Wilson)) led to the collapse of various fish stocks and support of an economically productive sport fishery in the Great Lakes (Smith, 1964; Christie, 1974; Stewart et al., 1981). In Lake Michigan the alewife has become well established and presently constitutes a significant portion of the forage base (Stewart et al., 1981).

Alewife were first reported in Lake Michigan in 1949 (Miller, 1957), although earlier establishment could have gone undetected due to low abundance levels (Smith, 1970). Alewife proliferated in the lake during a period of low piscivore abundance, brought about by invasion of sea lamprey and its predation on lake trout (*Salvelinus namaycush* Walbaum)(Smith, 1964; Smith, 1970; Brown, 1972). Further alewife population increases occurred after the collapse of lake trout populations by 1950 (Christie, 1974). In the 1960's sea lamprey control had been staged (Baldwin, 1968). Increasing alewife populations, along with rainbow smelt (*Osmerus mordax* (Mitchill)), a species introduced in 1912, created yet a few more imbalances in the system. Namely, 1) extreme reduction and extinction of several native species in Lake Michigan through competition for food and predation by both alewife and smelt and 2) occurrence of massive alewife dieoffs and large spawning runs (Wells and McClain, 1973; Stewart et al., 1981). Reasons for large alewife dieoffs have not been fully investigated but are believed to be due to a combination of climatic conditions, their low tolerance for cooler water temperatures, and high population densities (Smith, 1970; Hatch and Brown, 1978).

These previous events led to the introduction of pacific salmon and attempted rehabilitation of lake trout into the Great Lakes (Tody and Tanner, 1966). Both have provided noteable control over alewife populations as well as better resource utilization.

Since addition of pacific salmon into the Great Lakes, most of the bordering states and provinces have seen alewife populations reduced to more aesthetic levels, restoration of native fish stocks, and development of economically productive sport fisheries. Michigan, for example, realized an annual value of about $350 million from its Great Lakes salmonid fishery in 1983 (Jester, personal communication).

The popularity of salmon fishing has grownmultifold since the first introductions of coho salmon (Oncorynchus kisutch (Walbaum)) and chinook salmon (Oncorynchus tshawytscha (Walbaum)) in 1966 and 1967. Other species comprising Michigan's salmonid fishery include: lake trout, rainbow trout (Salmo gairdneri Richardson), brown trout (Salmo trutta Linnaeus), and atlantic salmon (Salmo salar Linnaeus). Lake run rainbow trout are frequently referred to as steelhead and will be so designated in the remainder of this thesis. Increasing popularity of these gamefish over the past decade has led to the organization of several interest groups (e.g. Michigan Steelheaders and Salmon Unlimited), economic expansion of numerous ports, increased annual stocking, and growing concern for the fisheries subsistence (Pistis, personal communication).

Salmonid fishery recruitment has been accomplished primarily by stocking. This artificial recruitment alters predator-prey density feedback mechanisms associated with natural reproduction, and may lead to a flooding of the system with predators. Ideally natural responses would keep predator populations in line with their prey (Ricker 1975; Stewart et al., 1981). With the increasing number of salmonids being planted into Lake Michigan each year, numerous questions arise regarding natural balance of predator-prey populations. For instance, is the forage base capable of sustaining continual predator salmonid influx ? Most importantly, will salmonids switch to other forage species given a decline in the alewife population? Alewife constituted the bulk of salmonid diets for the past 15 years (Smith, 1970; McComish and Miller, 1976; Stewart et al., 1981). Also, would switching to other forage species allow for self-sustainment and further stability of the fishery? Smelt, bloater (*Coregonus hoyi* (Gill)), and yellow perch (*Perca flavescens* (Mitchill)) are viewed as being potential prey items in reconstituting the forage base.

Collaboration among the Great Lakes states in setting stocking rates, with both a qualitative and quantitative understanding of salmonid diets and responses to a changing forage base will help in managing the Great Lakes' salmonid fishery (Michigan Department of Natural Resources).

Finally, it is on the premise of Stewart et al. (1981), where salmonid stomach contents revealed trends of the forage base in western Lake Michigan, that this study was undertaken for eastern Lake Michigan and southern Lake Superior salmonids.

The objectives of this study were to: 1) determine by year, region, season, size, and species the feeding habits (diet composition) of salmonids constituting Michigans' sport fishery and; 2) relate diet changes with various biotic factors (i.e. forage base and prey distributions).

STUDY AREA

The eastern portion of Lake Michigan from Michigan City, Indiana, northward, to Leland, Michigan, constituted study section I. This was subdivided geographically into three regions, south, middle, and north, corresponding to Lake Michigan's statistical districts MM-8, MM-7, and MM-6 and MM-5, respectively (Smith et al. 1961). Ports of the three regions are shown in Figure 1. Both east and west bays of Grand Traverse Bay were sampled independently of section I. Their seclusion and lack of continuity, both physically and biologically, with that of Lake Michigan led to this decision. Grand Traverse Bay was section II (MM-4). The southern shoreline of Lake Superior represented study section III (Fig. 2).

Twelve major fishing ports along the coastline from Michigan City to Leland were sampled. Within a given port, from 1 to 10 individual cleaning stations and charterboat docks were frequented to obtain salmonid data.

Figure 1.--Study sections, ports, and regions within eastern Lake Michigan.

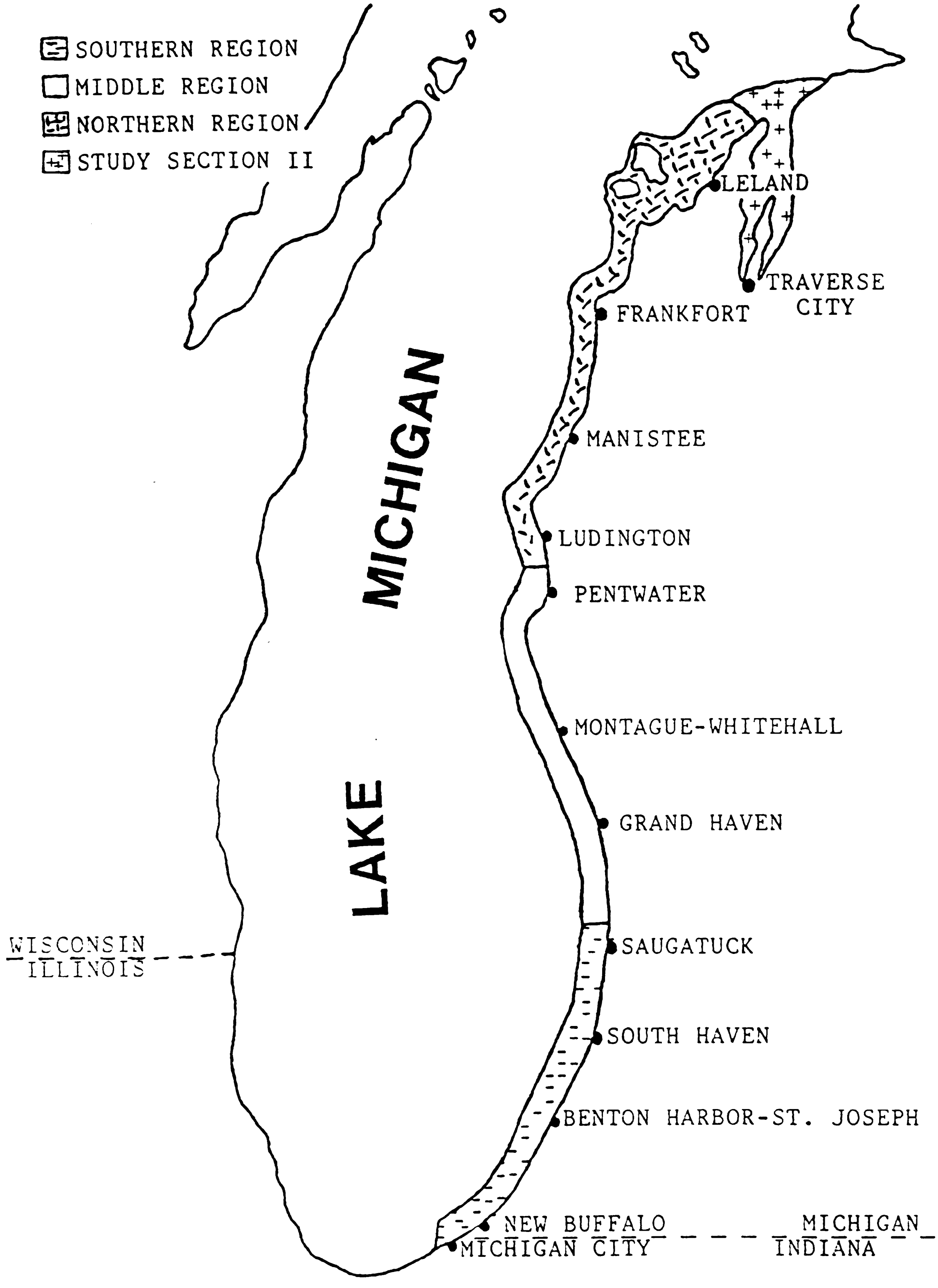
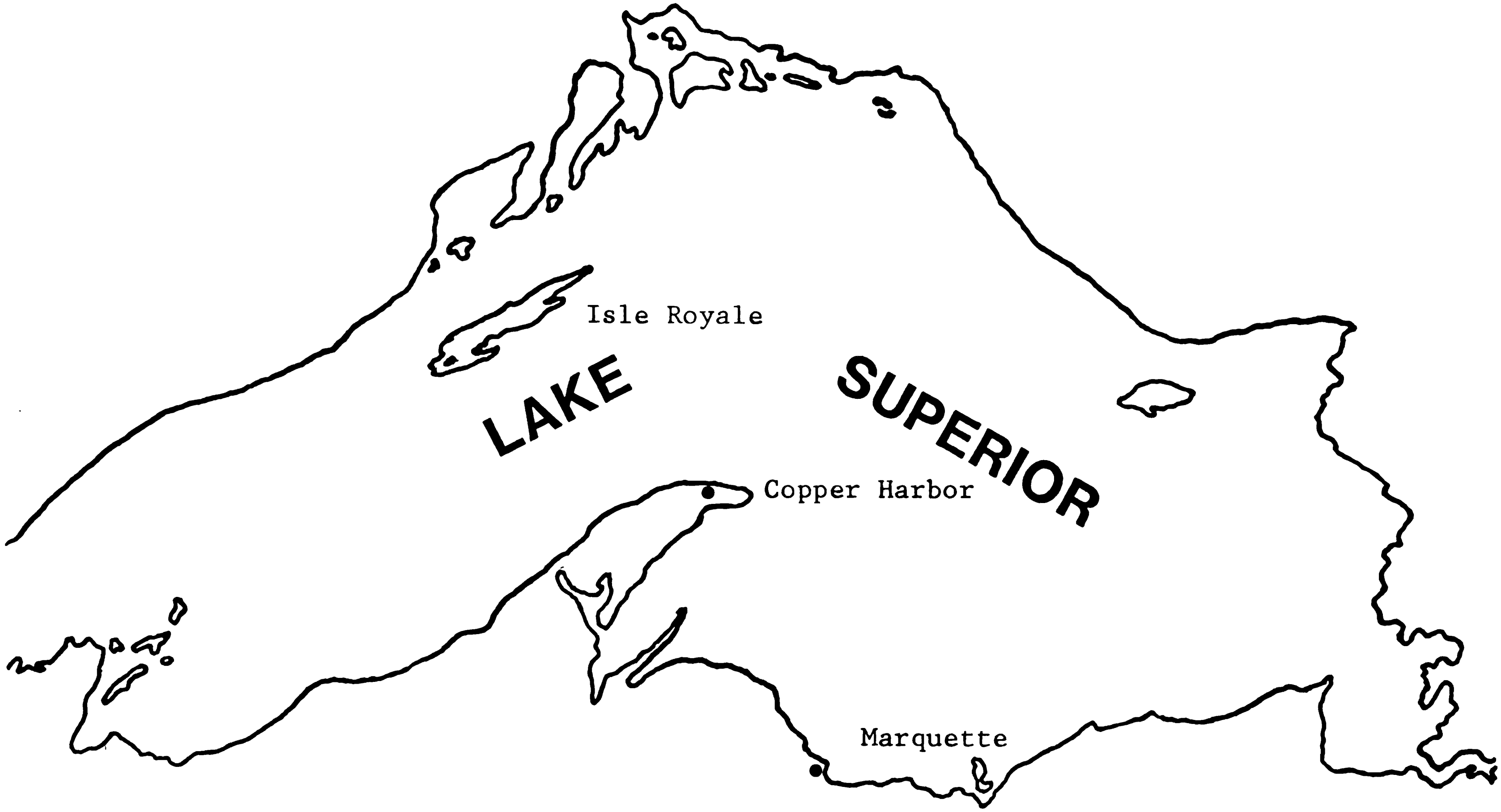

SOUTHERN REGION
MIDDLE REGION
NORTHERN REGION
STUDY SECTION II
LAKE
MICHIGAN
LELAND
TRAVERSE CITY
FRANKFORT
MANISTEE
LUDINGTON
PENTWATER
MONTAGUE-WHITEHALL
GRAND HAVEN
SAUGATUCK
SOUTH HAVEN
BENTON HARBOR-ST. JOSEPH
NEW BUFFALO
MICHIGAN CITY
MICHIGAN
INDIANA
WISCONSIN
ILLINOIS

Figure 2.--Southern shoreline of Lake Superior representing study section III.


Isle Royale
LAKE
SUPERIOR
Copper Harbor
Marquette

METHODS

Collection of salmonid data followed different routes in 1983 and 1984, although sampling efforts each year were concentrated on weekends when larger sample sizes and diversity among fish could be obtained. Reasons for differences between the two sampling schemes will be discussed in following sections.

Charterboat docks, fish cleaning stations and fishing tournaments allowed for large numbers of fish to be sampled. Anglers provided information on salmonid depth at capture and water depth; while length, weight, lamprey scars and sex were recorded whenever possible. Fish stomachs were removed and placed in numbered whirl-pac (plastic bags) matching recorded data. The "stomach" was defined as beginning at the esophagus and ending at the hind gut. The intestine was retained only where measurable material was found; this was the case for only a few insect feeding salmonids. Whirl-pacs were then filled with 15% formalin, sealed and returned to the lab for analysis.

Fish utilized in this study were caught from near the surface to a depth of 140 meters, and within 25 kilometers of shore. The majority of salmonids were brought into port between 10:30 a.m. and 1:30 p.m., 3:00 p.m. and 5:30 p.m., and 8:00 p.m. and dusk. Although no records were made at exact capture time, larger numbers of fish appeared to be caught between 6:30 a.m. and 9:00 a.m. and at dusk.

1983 SAMPLING APPROACH

Weekly sampling commenced in early spring on April 15, and ran through October. Spring sampling focused primarily on the southern region where the majority of fishing was concentrated. Spring fishing tournaments in the southern region were numerous and provided an opportunity for collecting large sample sizes. As spring progressed into summer, many anglers moved to the middle region of Lake Michigan. Fall fishing concentrated more heavily in the northern region. Thus, sampling followed major catches and movements of salmonids northward up the coastline (Sommers et al., 1981). This approach allowed for the collection of large sample sizes deemed necessary due to fluctuations occurring within salmonid diets (Peterson et al., 1982). Major diet changes were observed to occur in the course of one day among hundreds of fish (personal observation).

1984 SAMPLING SCHEME

Weekly sampling commenced on April 1 and ran through September. Early spring sampling focused on the southern region of Lake Michigan because of the: 1) higher relative number of anglers and; 2) an attempt to sample salmonids feeding extensively on zooplankton. Numerous salmonids were found feeding on microcrustacea in spring (mostly southern region) of 1983. The 1984 sampling scheme continued with collections from each of the twelve major ports throughout spring, summer and fall. This allowed for detection and comparison of feeding habit changes on the basis of region and season.

Salmonid data collected were seasonally labeled as either spring , summer, or fall samples (Table 1).

Table 1.--Seasonal delineation of salmonid diet research.

	SPRING	SUMMER	FALL
1983	April 15-May 31	June 1-July 31	August1-Sept. 30
1984	April1-June10	June 11-August 10	August11-Sept. 30

SAMPLE ANALYSIS

Analysis of stomach contents consisted of identification, enumeration, length measurement (mm), and state of decomposition of each prey item. Food items ranged from freshly ingested organisms to unidentifiable masses. Identification, where possible, was generally taken to species for macroinvertebrates, microcrustacea and fish and to family for terrestrial and aquatic insects. Regression equations utilized for determining total fish lengths from caudal peduncle lengths are given in Appendix A.

In 1983 a sedgewick rafter cell was used to estimate the large number of microcrustacea collected. While in 1984, fewer numbers appeared, allowing for total counts to be made.

STATISTICS

Descriptive statistics were utilized to rank the importance of various salmonid prey items by species, region, season, size, depth, and year. The two main descriptive statistics used were frequency of occurrence and percent of diet. The non-normal distribution of the data did not allow for parametric tests to be made. Thus, tests for independence and significant differences between parameters and descriptors were done using non-parametric statistics, primarily chi-square (Siegel, 1956). Tests for normality followed Sokal and Rohlf (1969) on the basis of skewness.

Frequency of occurrence was calculated by taking the number of individual stomachs containing a given prey item and expressing it as a percent of the total number of stomachs analyzed (Lagler, 1956). This value expressed the apparent occurrence of a prey item in a salmonid representing its utilization by the predator. This statistic, however, did not represent the actual occurrence and total mass relationship of a prey item to the diet. The proceeding weighting system was developed to provide a better descriptor (percent of diet) for presenting bulk relationship and actual occurrence of prey items in salmonid diets.

The total value of the percent of diet statistic for each salmonid stomach equaled 1.0. Prey items within a stomach were represented as a fraction of the total. The percent that a prey item contributed to salmonid diets was calculated by modifying Paloheimo's (1979) indice for the proportion of a prey item in a given predator. This was done by substituting Paloheimo's R_i and P_i values, volume searched and probability of capture for prey item i, for WV.

$$\text{percent of diet}_i = n_i(WV)_i / n_j(WV)_j$$

WV was an arbitrarily weighted value incorporating the selection of various prey items by a predator on the basis of prey size, nutritive value, and ease of capture (Werner, 1974; Werner and Hall, 1974; Rottier and Tucker, 1982). Subscript j represented all prey items.

All prey fish species were weighted equally regardless of size and species. There are several reasons for this judgement.

Smaller pelagic species were easier for salmonids to capture compared to larger prey species on the basis of swimming speed and ease of capture (Wardle, 1977). More smaller sized forage fish are needed to comprise a feeding, equal in energy expenditure, to one of fewer, larger individuals (Werner, 1974). Rottiers and Tucker (1982) reported caloric contents of forage fish (alewife, smelt and sculpins) to be similar, thus a consumption shift from one species to another would not be expected to significantly alter energy gain. Furthermore, the following were evident after data analysis: 1) there was a rare occurrence of vastly different size classes of fish being consumed within a single feeding and; 2) rare occurrence of a single feeding inclusive of both benthic and pelagic species.

The weighting procedures were applicable regardless of the state of decomposition of the various prey items. For example, four intact smelt and one decomposed alewife in a stomach would represent 80% and 20% of the diet, respectively. This continuity is based on the equal probability of catching a salmonid prior to or following a feeding on any given prey item. In 1983, fish demonstrated the ability to pack themselves full of fish and continue to behave in a feeding manner.

Reasons for the weighting values for insects and microcrustaceans are as follows.

The nutritional value of insects, on a total weight basis, was assumed to be much lower than that of fish. However, less energy was expended by the predator in consuming insects than fish. Werner (1974) noted that when prey were sessile, or much less active than the predator, the former would be conceived as a potential meal. Insects consumed were also smaller in size than fish species and thus given a 1:9 (.111) energetic value based on size, nutritional value, and energy expenditure (ease of capture) differences.

Microcrustaceans consumed were very small ranging from 2 mm for Daphnia spp. to 20 mm for Mysis oculata relicta (Loven). A value of .055 (1/18) was given on the basis of size, signifying that the presence of 18 organisms within a salmonid depicted selection of that prey item and not its consumption by chance. In the case of salmonids feeding heavily on Daphnia spp., occurrence of a fish species seemed insignificant and was presented as such.

In calculating the contribution of various fish species, insects, and microcrustaceans to salmonid diets the following weighting values (WV) were given.

fish (all species) = 1.0
insects = 1/9 (9 insects to 1 fish) =.111
microcrustaceans = 1/18 (18 micro#rustaceans to 1 fish) = .055

For example, if a stomach contained 5 alewives, 3 insects and 2 Daphnia spp. then the percent of diet values for that individual fish was:

alewife = (5*1.0)/(5*1.0)+(3*.111)+(2*.055) = .919

insects = (3*.111)/(5*1.0)+(3*.111)+(2*.055) = .061

microc. = (2*.055)/(5*1.0)+(3*.111)+(2*.055) = .020

Values were then summed for each prey item per stomach to obtain percent of diet values for the various regions, seasons, years, and species.

Great precision can not be claimed with these microcrustacean and insect estimates. Potential errors are assumed to be small because of these organism's small contribution to the overall salmonid diet.

RESULTS AND DISCUSSION

GENERAL FEEDING HABITS,1983

The stomachs of 1,513 salmonids were examined for food items in 1983. The percent of feeding fish, by species, was similar with the biased exception of steelhead, brown trout, and atlantic salmon. Their sample sizes were relatively small (Table 2). Food items were found in 974 (64.38 %) stomachs, while 540 (35.62 %) were empty.

Table 2.--Percent (number feeding/sample size) of feeding salmonid species caught in eastern Lake Michigan, 1983

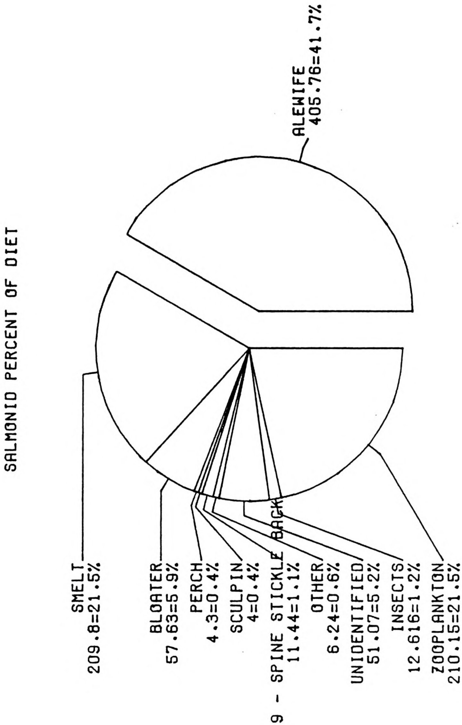
	CHINOOK S.	COHO S.	LAKE T.	STEELHEAD	BROWN T.	ATLANTIC S.
%	61.1	68.51	63.74	84.62	28.57	50
	(468)/(765)	(372)/(542)	(109)/(171)	(22)/(26)	(2)/(7)	(1)/(2)

ALL SPECIES: 64.38 (974)/(1513)

Wright (1968) reported a much larger percent of feeding fish in 1967 than that of 1983. He found that 93.4% of 1,581 lake trout stomachs examined from Lake Michigan contained food items. Differences may be explained on the basis of collection methods, fish sizes and the forage base. Wright (1968) used gill nets, while in the present study fish were caught by angling. Angling causes a larger bias towards obtaining empty stomachs since it samples fish presumably in a feeding mode. Secondly, Wright (1968) primarily sampled immature lake trout (<60 cm) while those examined in 1983 were legal size and larger (30.48 to 85 cm). Most importantly, the biomass of the forage base in the earlier 1970's was larger, predominated by alewife, compared to a smaller forage base in the early 1980's, predominated by smelt and bloaters (Wells and Hatch, 1983) (Appendix B). Decline of forage in 1983 decreased the amount of contact between predator and prey resulting in a smaller percent of feeding fish. This is a principle of fisheries management (Ricker, 1975).

The major salmonid food items in Lake Michigan were fish (77.1 %), mainly alewives and smelt (Figure 3). Zooplankton also constituted a large proportion of their diet. This was primarily caused by the large number of smaller salmonids (45 - 70 cm) feeding extensively during spring on cladocerans in southern Lake Michigan. Other microcrustacea, Pontiporeia affinis Smith and Mysis relicta oculata (Loven), were found throughout the year, and were included as zooplankton. Other investigators also found salmonids utilizing these invertebrates (VanOosten and Deason, 1938; McComish and Miller, 1967; Wright, 1968). Additional prey items were bloaters, perch, sculpins (Cottus spp.), 9-spine sticklebacks (Pungitius pungitius (Linnaeus)), insects, unidentified fish (fish remains), and other fish species. The latter included species rarely occurring in the diets (< 0.40 %), e.g. trout perch

Figure 3.--Percentage of each major prey item contributing to the diet of salmonids in eastern Lake Michigan, 1983.


SALMONID PERCENT OF DIET
ALEWIFE
405.76=41.7%
SMELT
209.8=21.5%
BLOATER
57.63=5.9%
PERCH
4.3=0.4%
SCULPIN
4=0.4%
9 - SPINE STICKLE BACK
11.44=1.1%
OTHER
6.24=0.6%
UNIDENTIFIED
51.07=5.2%
INSECTS
12.616=1.2%
ZOOPLANKTON
210.15=21.5%

(*Percopsis omiscomaycus* (Walbaum)),shiners (*Notropis* spp.), johnny darters (*Etheostoma nigrum* Rafinesque), and lake whitefish (*Coregonus clupeaformis* (Mitchill)). Terrestrial insects blown into the lake were consumed by surface feeding salmonids. The most numerous flying insects consumed were from the family Noctuidae (moths).

Presence of various prey items and their contribution to the diet of various salmonid species, are listed in Table 3. Organisms constituting insect, zooplankton, and other categories, as well as miscellaneous items consumed are given in Table 4 with respect to their frequency of occurrence.

Table 3.--Frequency of occurrence of prey items in1983 salmonid diets (percent of diet in parentheses).

	CHINOOK S.	COHO S.	LAKE T.	STEELHEAD	BROWN T.
ALEWIVES	64.24	20.70	69.72	9.09	50.00
	(57.6)	(16.95)	(64.33)	(10.00)	(50.00)
SMELT	26.98	34.68	25.69	45.45	50.00
	(19.52)	(24.57)	(18.14)	(26.37)	(50.00)
BLOATERS	7.92	12.10	0.92	0.00	0.00
	(5.69)	(8.24)	(0.31)	(0.00)	(0.00)
PERCH	0.86	0.81	0.00	0.00	0.00
	(0.64)	(0.35)	(0.00)	(0.00)	(0.00)
SCULPINS	0.21	0.00	2.75	0.00	0.00
	(0.21)	(0.00)	(2.75)	(0.00)	(0.00)
9-SPINES	1.50	2.42	0.92	0.00	0.00
	(0.99)	(1.56)	(0.92)	(0.00)	(0.00)
OTHER FISH	1.07	0.81	0.92	0.00	0.00
	(0.68)	(0.53)	(0.05)	(0.00)	(0.00)
UNIDENT-IFIED FISH	7.06	8.06	5.50	0.00	0.00
	(5.24)	(5.98)	(3.94)	(0.00)	(0.00)
INSECTS	0.64	4.84	3.67	45.45	0.00
	(9.17)	(1.74)	(2.28)	(12.55)	(0.00)
ZOO-PLANKTON	10.06	43.28	9.17	59.09	0.00
	(0.24)	(40.07)	(7.28)	(51.10)	(0.00)

Table 4.--Frequency of occurrence of organisms making up the pooled categories - insects, zooplankton, and other fish species, as well as miscellaneous items consumed in eastern Lake Michigan, 1983.

	FREQUENCY OF OCCURENCE
Invertebrates	
Crustacea	
Amphipoda	
Pontiporeia affinis	5.85
Cladocera	
Daphnia spp.	19.51
Eucopepoda	.10
Mysidacea	
Mysis relicta oculata	4.00
Insecta	
Coleoptera	
Carabidae	.21
Diptera	.21
Ephemeroptera	
Hexagenia spp.	.21
Hemiptera	
Corixidae	.21
Notonectidae	.41
Pentomatidae	.51
Hymenoptera	.31
Lepidoptera	
Noctuidae	1.44
Orthoptera	
Acrididae	.10
Trichoptera	.51
Fish	
Clupeidae	
Alosa cerepedianum	.31
Cyprinidae	
Notropis spp.	.21
Percidae	
Etheostoma nigrum	.21
Salmonidae	
Corigoninae	
Coregonus clupeaformis	.21
Oddities	
Cigarette butts	.10
Driftwood	.10
Feathers	.21
Macrophytes	.10
Mollusca	
Pisidium sp.	.10
Plastic	.41
Rocks	.21
Rope (yellow)	.10

FEEDING HABITS BY REGION AND SEASON

Studies of salmonid feeding habits have demonstrated differences between geographical location and time of year (Wright, 1968; Chiotti, 1973; Rybicki and Keller, 1978; Eck and Wells, 1983).

The 1983 northward sampling scheme demonstrated a significant correlation between the percent of feeding salmonids by season and region. Spring samples were correlated with those of the southern region. The same occurred for summer and middle region and fall and northern region (Tables 5 and 6).

The percent of feeding fish was higher in the spring (mostly southern region), resulting from littoral zones being more heavily fished and containing a larger array of available forage. In spring numerous forage species inhabited littoral zones for both feeding and spawning. Smelt aggregated in shallower regions prior to spawning. Bloaters, perch, and other smaller fish species utilized zooplankton rich littoral zones for feeding, spawning and their temperature preference (Wells and Beeton, 1963; Brandt et al., 1980; Sommers et al., 1981). Salmonids moved into the deeper cooler waters in summer, where forage was more dispersed, resulting in a lower percent of feeding fish (mostly the middle region). They moved back into the littoral zones in the fall for spawning and a presumed temperature preference allowing for overlap with forage

Table 5.--Relative percent of feeding salmonid species by region (sample sizes in parentheses), 1983.

SPECIES	SOUTH	MIDDLE	NORTH	ALL REGIONS
CHINOOK S.	67.50	53.60	60.80	61.10
	(212)	(152)	(401)	(765)
COHO S.	89.90	65.40	53.20	68.51
	(218)	(25)	(299)	(542)
LAKE T.	72.40	55.10	45.80	63.74
	(98)	(49)	(24)	(171)
STEELHEAD	85.00	100.00	80.00	84.62
	(20)	(1)	(5)	(26)
BROWN T.	66.70	00.00	00.00	28.57
	(3)	(0)	(4)	(7)
ATLANTIC S.	00.00	00.00	50.00	50.00
	(0)	(0)	(2)	(2)
ALL SPECIES	77.86	55.70	57.01	64.38
	(551)	(227)	(735)	(1513)

Table 6.--Relative percent of feeding salmonid species by season (sample sizes in parentheses), 1983.

SPECIES	SPRING	SUMMER	FALL	ALL SEASONS
CHINOOK S.	66.70	57.52	59.14	61.10
	(231)	(113)	(421)	(765)
COHO S.	89.70	69.57	52.50	68.51
	(223)	(22)	(297)	(542)
LAKE T.	76.00	46.30	52.40	63.74
	(96)	(54)	(21)	(171)
STEELHEAD	88.90	75.00	75.00	84.62
	(18)	(4)	(4)	(26)
BROWN T.	66.70	00.00	00.00	28.57
	(3)	(1)	(3)	(7)
ATLANTIC S.	00.00	00.00	50.00	50.00
	(0)	(0)	(2)	(2)
ALL SPECIES	77.93	56.70	56.15	64.38
	(571)	(194)	(748)	(1513)

abundant shallows (Sommers et al., 1981). Chinook and coho salmon have optimal temperature ranges of 12 C to 12.5 C and 11 C to 12 C, respectively, thus allowing for their observed seasonal movement (Sommers et al., 1981). Reallocation of energy in the fall for reproduction by mature salmon reflected a decline in the percent of feeding fish. This behavior was also reported by Wright (1968) and Chiotti (1973) for immature Lake Michigan lake trout and by Frantz and Cordone (1970) for mature Lake Tahoe lake trout. These fish fed most avidly during spring and less so in fall. Of those fish found feeding in the fall, at least 70 % were immature, showing a division of energy expenditure between spawning and non-spawning individuals.

Among feeding fish, alewives were the most abundant species consumed, followed by smelt and bloaters. Coho salmon, however, consumed more smelt in the southern and middle regions, as well as, in spring and fall (Tables 7 and 8). Relatively larger numbers of smelt were consumed by all species during spring and fall caused by spring spawning smelt aggregating in littoral zones. These fish dispersed in summer, and semi aggregated again in fall, following water temperature and forage availability (Sommers et al., 1981). Thus, smelt were more readily available for consumption because of their large numbers and distribution overlap with the salmonid predators. Likewise, salmonids became more pelagic during summer months (middle and northern regions), in response to water temperature, creating a distribution overlap with alewife

Table 7.--Total prey items consumed, by region, by the three major salmonids in eastern Lake Michigan, 1983.

	SOUTH			MIDDLE			NORTH			ALL REGIONS		
PREY	CHINOOK	COHO	LAKE T.	CHINOOK	COHO	LAKE T.	CHINOOK	COHO	LAKE T.	CHINOOK	COHO	LAKE T.
ALEWIFE	182	14	114	116	5	47	518	307	23	816	326	184
SMELT	76	174	59	26	78	0	137	269	19	239	521	78
BLOATER	1	3	0	73	16	1	107	116	0	181	135	1
PERCH	3	0	0	19	8	0	0	0	0	22	8	0
SCULPIN	0	0	1	1	0	1	0	0	2	1	0	4
9-SPINE	0	0	0	0	0	0	12	22	1	12	22	1
OTHER	0	0	0	5	7	0	3	2	1	8	9	1
UNIDENT.	8	65	0	3	26	7	37	56	1	48	147	8
TOTAL	270	256	174	243	140	56	814	772	47	1327	1168	277
ALL SPECIES		700			439			1633			2772	

Table 8.--Total prey items consumed, by season, by the three major salmonids in eastern Lake Michigan, 1983.

	SPRING			SUMMER			FALL			ALL SEASONS		
PREY	CHINOOK	COHO	LAKE T.	CHINOOK	COHO	LAKE T.	CHINOOK	COHO	LAKE T.	CHINOOK	COHO	LAKE T.
ALEWIFE	308	14	122	143	100	30	365	212	32	816	326	184
SMELT	70	173	52	18	0	15	151	348	11	239	521	78
BLOATER	0	3	0	12	12	1	169	120	0	181	135	1
PERCH	0	0	0	0	0	0	22	8	0	22	8	0
SCULPIN	0	0	1	0	0	1	1	0	2	1	0	4
9-SPINE	0	0	0	0	0	1	12	22	0	12	22	1
OTHER	5	7	0	0	0	0	3	2	1	8	9	1
UNIDENT.	2	65	3	3	14	4	43	68	1	48	147	8
TOTAL	385	262	178	176	126	52	766	780	47	1327	1168	277
ALL SPECIES		825			354			1593			2772	

and bloater (Wells, 1968; Brown, 1972; Brandt, 1978; Janssen and Brandt, 1980). Predator-prey distributions reflected the large percentage of these forage fishes in predator diets during this time. Perch also made an appearance, correlated with similar habitat overlap.

Table 9 presents the frequency of various prey items in salmonid diets by region. Several general observations can be observed: 1) frequency of prey items differ greatly among species, 2) occurrence of prey species shifts between regions, 3) a large percent of chinook and coho salmon feeding on microcrustaceans, 4) presence of smelt in diets correlating with its distribution overlap with salmonids, 5) presence of bloaters in the middle and northern regions of the lake associated with their larger abundance (Hatch and Wells 1983), 6) large numbers of bloaters occurring in coho salmon, 7) a slight rise in frequency of occurrence of perch in the middle region, especially coho salmon, and 8) lake trout maintaining high levels of alewife predation throughout the lake. Similar observations can also be made by viewing the frequency of occurrence of prey items by season, as well as the presence of perch and bloaters in the fall (Table 10). Alewives occurred more frequently in lake trout and chinook salmon than in coho salmon. Coho salmon diets were more evenly diversified. The cohos opportunistic habits are presumed to reflect a quicker response to a changing forage base. This was observed by the higher occurrence of the more abundant forage fish, smelt and bloaters, in coho diets (Hatch and Wells, 1983).

Table 9.--Percent frequency of occurrence, by region, of the various prey items consumed by the three major salmonids in eastern Lake Michigan, 1983.

	SOUTH			MIDDLE			NORTH			ALL REGIONS		
PREY	CHINOOK	COHO	LAKE T.	CHINOOK	COHO	LAKE T.	CHINOOK	COHO	LAKE T.	CHINOOK	COHO	LAKE T.
ALEWIFE	56.64	5.08	70.42	58.02	17.65	70.37	70.49	40.51	63.64	64.24	20.70	69.72
SMELT	28.67	31.47	33.80	20.99	29.41	3.70	27.87	39.24	27.27	26.98	34.68	25.69
BLOATER	0.70	1.02	0.00	16.05	35.29	3.70	9.43	23.42	0.00	7.92	12.10	0.92
PERCH	1.40	0.00	0.00	2.47	0.81	0.00	0.00	0.00	0.00	0.86	0.81	0.00
SCULPIN	0.00	0.00	1.41	1.23	0.00	3.70	0.00	0.00	9.09	0.21	0.00	2.75
9-SPINE	0.00	0.00	0.00	0.00	0.00	0.00	2.87	5.70	9.09	1.50	2.42	0.92
OTHER	0.00	0.00	0.00	3.70	5.88	0.00	0.82	1.27	9.09	1.07	0.81	0.92
UNIDENT.	4.90	2.54	0.00	2.47	17.65	18.52	9.84	13.92	9.09	7.06	8.06	5.50
INSECTS	1.40	3.05	2.82	0.00	11.76	3.70	0.41	6.33	9.09	0.64	4.84	3.67
MICRO-CRUST.	20,98	77.66	9.86	18.52	17.65	7.41	0.82	3.16	9.09	10.06	43.28	9.17

Table 10.--Percent frequency of occurrence, by season, of the various prey items consumed by the three major salmonids in eastern Lake Michigan, 1983.

	SPRING			SUMMER			FALL			ALL SEASONS		
PREY	CHINOOK	COHO	LAKE T.	CHINOOK	COHO	LAKE T.	CHINOOK	COHO	LAKE T.	CHINOOK	COHO	LAKE T.
ALEWIFE	60.39	5.00	69.86	72.73	68.75	64.00	64.11	35.90	81.82	64.24	20.70	69.72
SMELT	24.68	31.50	28.77	15.15	0.00	8.00	31.45	42.31	27.27	26.98	34.68	25.69
BLOATER	0.00	1.00	0.00	9.09	31.25	4.00	6.45	14.74	0.00	7.92	12.10	0.92
PERCH	0.00	0.00	0.00	0.00	0.00	0.00	1.61	1.92	0.00	0.86	0.81	0.00
SCULPIN	0.00	0.00	1.37	0.00	0.00	4.00	0.40	0.00	9.09	0.21	0.00	2.75
9-SPINE	0.00	0.00	0.00	0.00	0.00	4.00	2.82	5.77	0.00	1.50	2.42	0.92
OTHER	1.95	.50	0.00	0.00	0.00	0.00	0.81	1.28	9.09	1.07	0.81	0.92
UNIDENT.	1.30	2.50	2.74	4.55	6.25	12.00	4.03	6.41	18.18	7.06	8.06	5.50
INSECTS	1.30	3.50	4.11	1.52	6.25	0.00	0.00	0.64	0.00	0.64	4.84	3.67
MICRO-CRUST.	21.43	77.50	9.59	18.18	18.75	8.00	0.81	0.64	0.00	10.06	43.28	9.17

Frequency of occurrence for alewives in the northern region for lake trout was 63.4 %, significantly exceeding that of 49.3 % found in 1972 by Chiotti (1973). Differences between the two may indicate a prey preference as well as the inability of salmonids to switch prey items. Further evidence for this condition can be seen from the occurrence of sculpins in 37.4 % of lake trout stomachs in 1972 (Chiotti, 1973) and only 9.09 % in 1983. Even though the ratio of alewife to sculpins in 1972 greatly surpassed that of recent years (Wells and Hatch, 1983; Wells and McLain, 1972). Relative consumption of sculpins by lake trout in 1972 was greater than in 1983. This could indicate a lag--time in lake trout feeding response to forage species abundance.

During the spring, occurrence of microcrustacea in southern Lake Michigan salmonids was obvious (Table 10). Daphnia spp. made up over 70% of the spring zooplankton category (by relative weighting procedures). Possible reasons for their dietary presence can be attributed to: 1) occurrence of large pulses with an overlap in predator habitat; 2) forage of another type unavailable and; 3) increased sight recognition of these organisms because the majority were epipphial (Birge and Juday, 1922; Richman, 1958; Mellors, 1975).

Regions were used to delineate the salmonid population based on: 1) changes occurring in the forage base and diets across regional boundaries; 2) similarity to delineation by season and; 3) for standardized comparison to other pertinent studies utilizing regions according to Michigans statistical districts. To further illustrate changes occurring among species and regions the percent of diet descriptor was used.

Alewife was the major prey item in salmonid diets throughout Lake Michigan, especially the middle and northern regions (Figures 4-6). Zooplankton represented a large percentage of the coho salmon diet in the southern region, but were less evident in chinook salmon and lake trout in that region. Bloaters became a significant portion of the diet in the middle region. Insects remained insignificant throughout the year, not exceeding 5% of any diet. The exception was steelhead, in which insects constituted 19.6 %, by occurrence of the yearly diet (Figure 7). Perch remained insignificant.

FISH SIZE AND PREY SELECTION

Numerous studies on the relationship of predator length to prey length have been reported (Chiotti, 1973; McComish and Miller, 1976; Eck and Wells, 1983; Hagar, 1985). Chiotti (1973) analyzed predator-prey length relationships using mean alewife prey length where more than one fish of a given species was present in an individuals stomach. The large sample size and number of prey items found in fish stomachs during the present study permitted the use of Chiotti's method. The mean alewife length was obtained by averaging all the various sized alewives

Figure 4.--Percentage of each major prey item contributing to the diet of chinook salmon in eastern Lake Michigan, 1983.

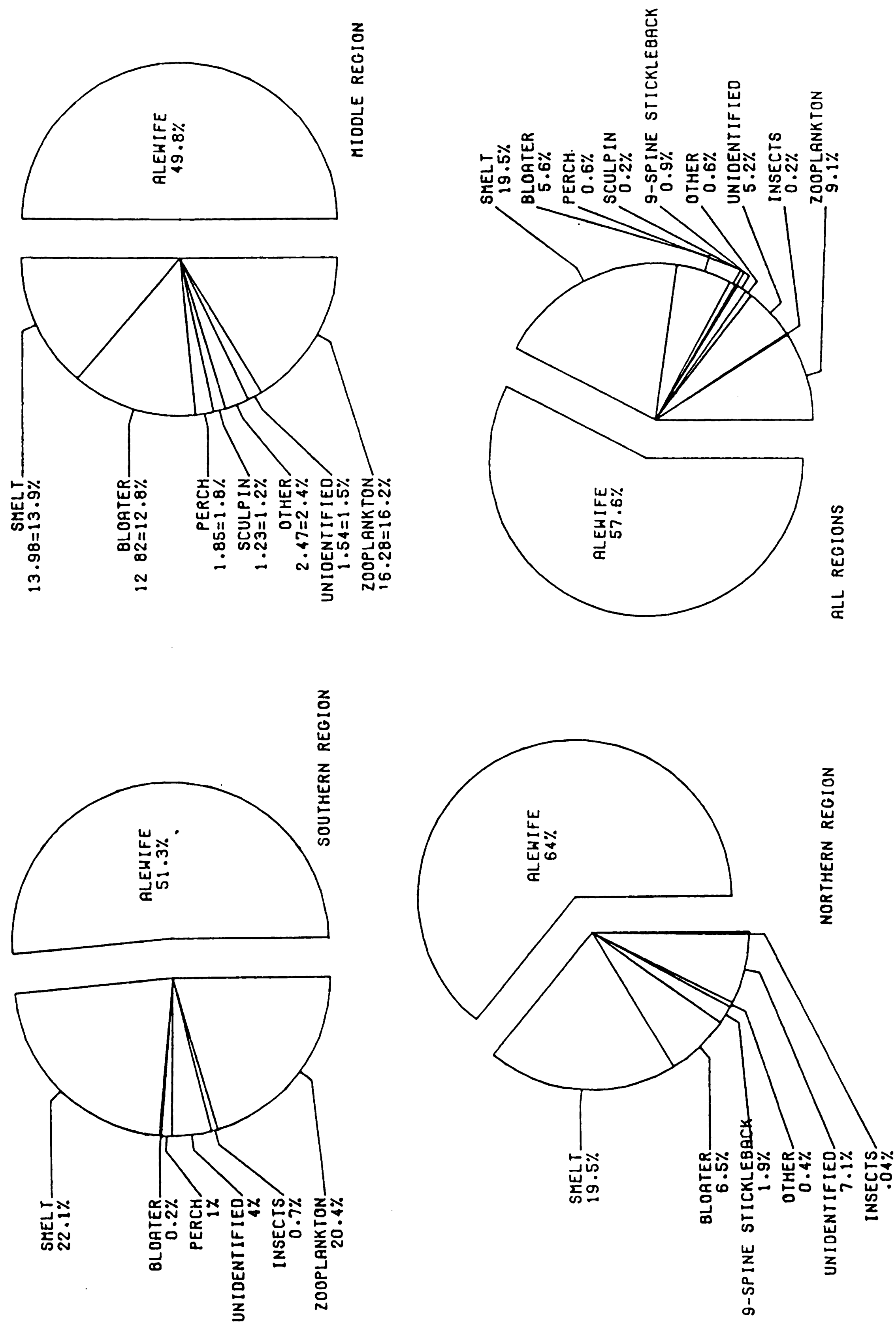
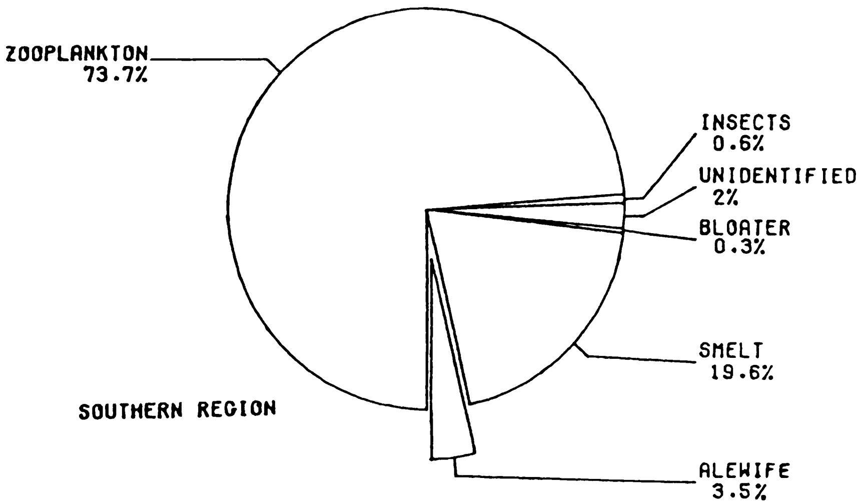
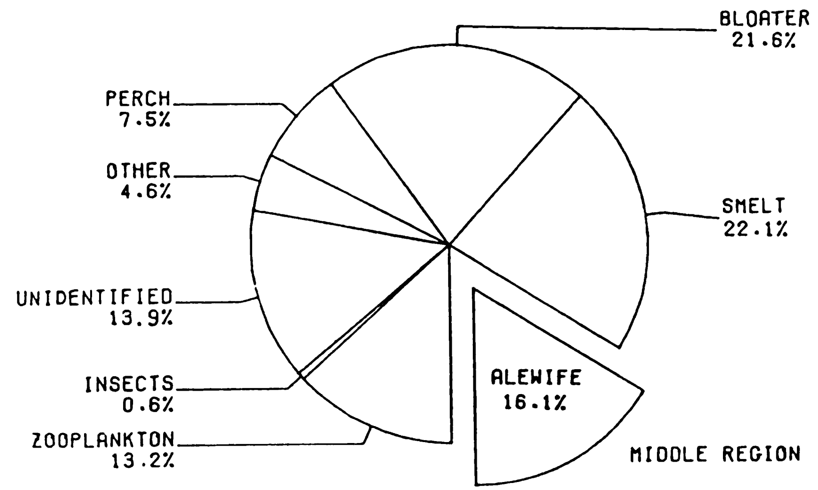
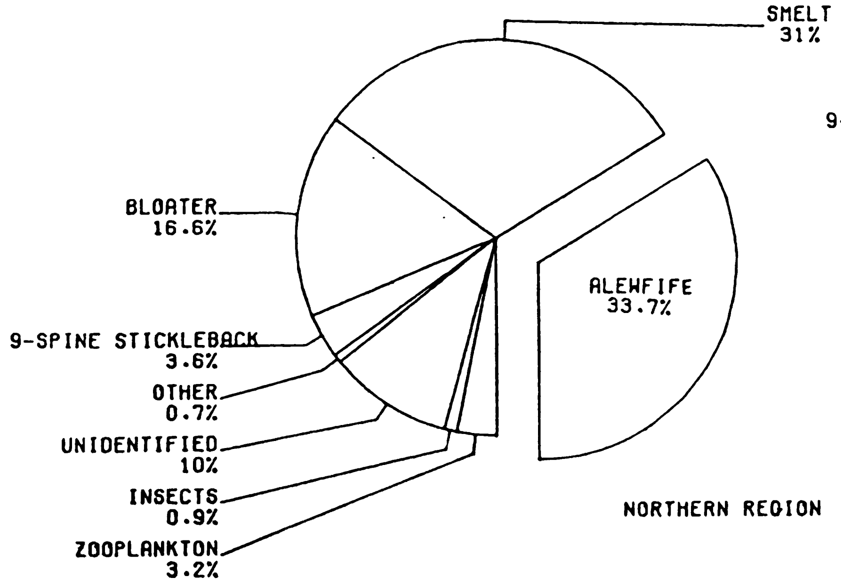

MIDDLE REGION
ALEWIFE
49.8%
SMELT
13.98=13.9%
BLOATER
12 82=12.8%
PERCH
1.85=1.8%
SCULPIN
1.23=1.2%
OTHER
2.47=2.4%
UNIDENTIFIED
1.54=1.5%
ZOOPLANKTON
16.28=16.2%
ALL REGIONS
ALEWIFE
57.6%
SMELT
19.5%
BLOATER
5.6%
PERCH
0.6%
SCULPIN
0.2%
9-SPINE STICKLEBACK
0.9%
OTHER
0.6%
UNIDENTIFIED
5.2%
INSECTS
0.2%
ZOOPLANKTON
9.1%
SOUTHERN REGION
ALEWIFE
51.3%
SMELT
22.1%
BLOATER
0.2%
PERCH
1%
UNIDENTIFIED
4%
INSECTS
0.7%
ZOOPLANKTON
20.4%
NORTHERN REGION
ALEWIFE
64%
SMELT
19.5%
BLOATER
6.5%
9-SPINE STICKLEBACK
1.9%
OTHER
0.4%
UNIDENTIFIED
7.1%
INSECTS
.04%

Figure 5.--Percentage of each major prey item contributing to the diet of coho salmon in eastern Lake Michigan, 1983.


ZOOPLANKTON
73.7%
INSECTS
0.6%
UNIDENTIFIED
2%
BLOATER
0.3%
SMELT
19.6%
ALEWIFE
3.5%
SOUTHERN REGION


BLOATER
21.6%
PERCH
7.5%
OTHER
4.6%
SMELT
22.1%
UNIDENTIFIED
13.9%
INSECTS
0.6%
ALEWIFE
16.1%
ZOOPLANKTON
13.2%
MIDDLE REGION


SMELT
31%
BLOATER
16.6%
ALEWFIFE
33.7%
9-SPINE STICKLEBACK
3.6%
OTHER
0.7%
UNIDENTIFIED
10%
INSECTS
0.9%
ZOOPLANKTON
3.2%
NORTHERN REGION

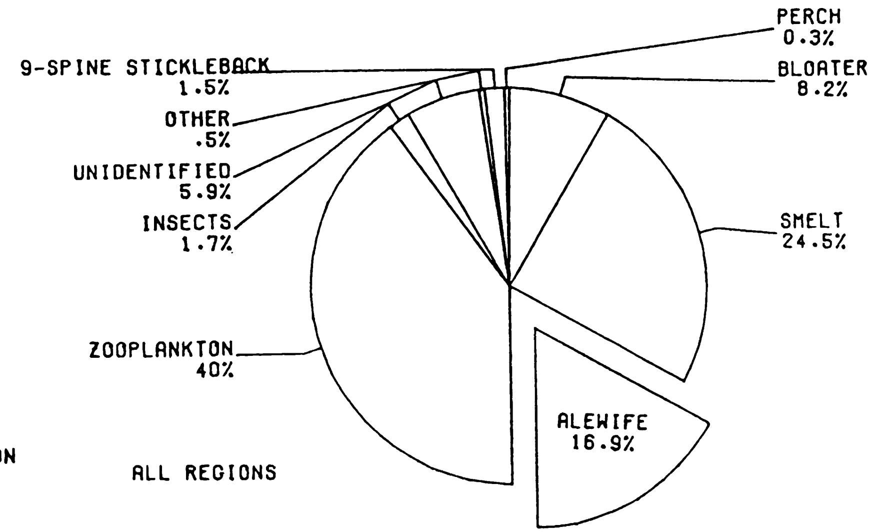

PERCH
0.3%
9-SPINE STICKLEBACK
1.5%
BLOATER
8.2%
OTHER
.5%
UNIDENTIFIED
5.9%
INSECTS
1.7%
SMELT
24.5%
ZOOPLANKTON
40%
ALEWIFE
16.9%
ALL REGIONS

Figure 6.--Percentage of each major prey item contributing to the diet of lake trout in eastern Lake Michigan, 1983.

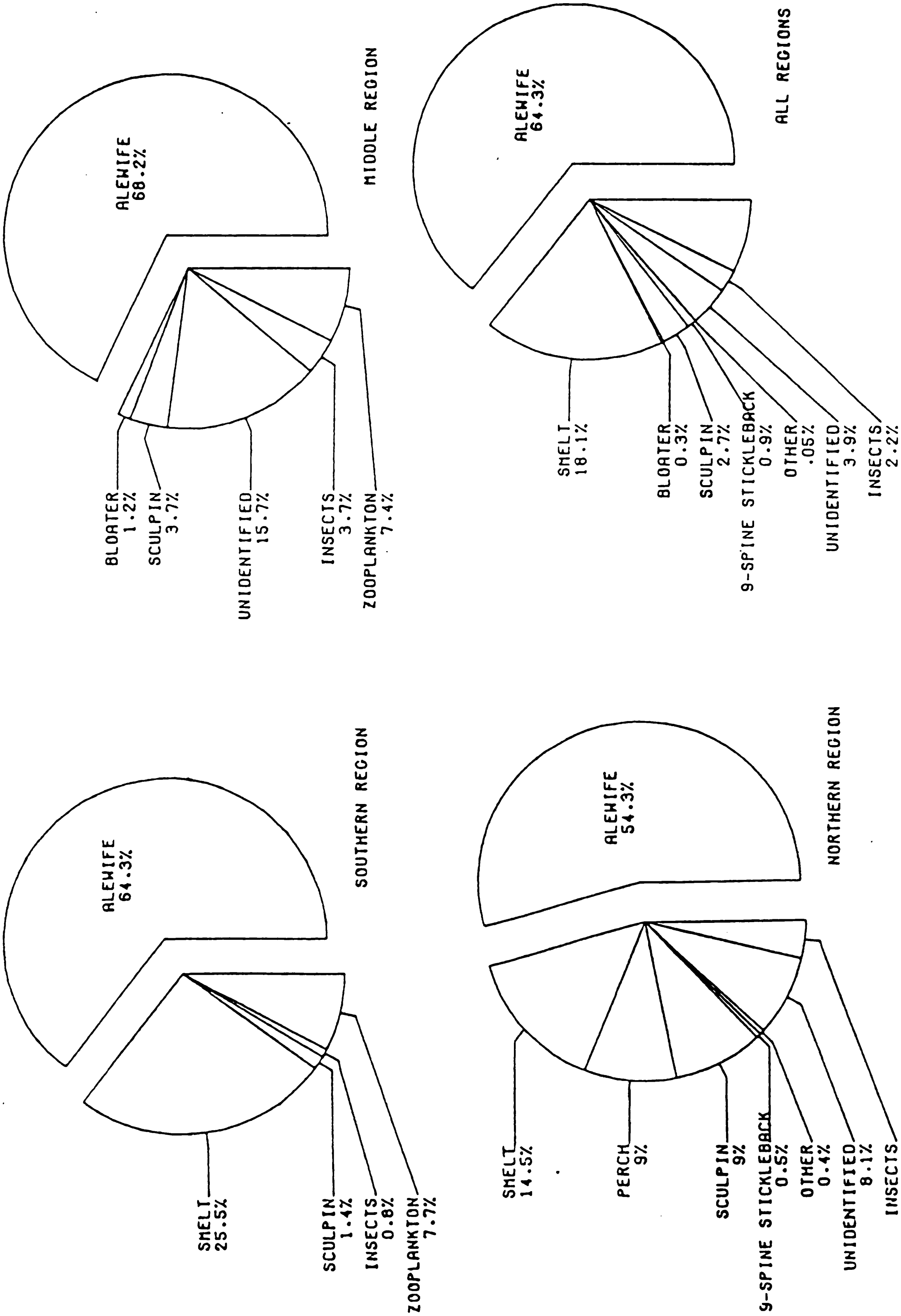
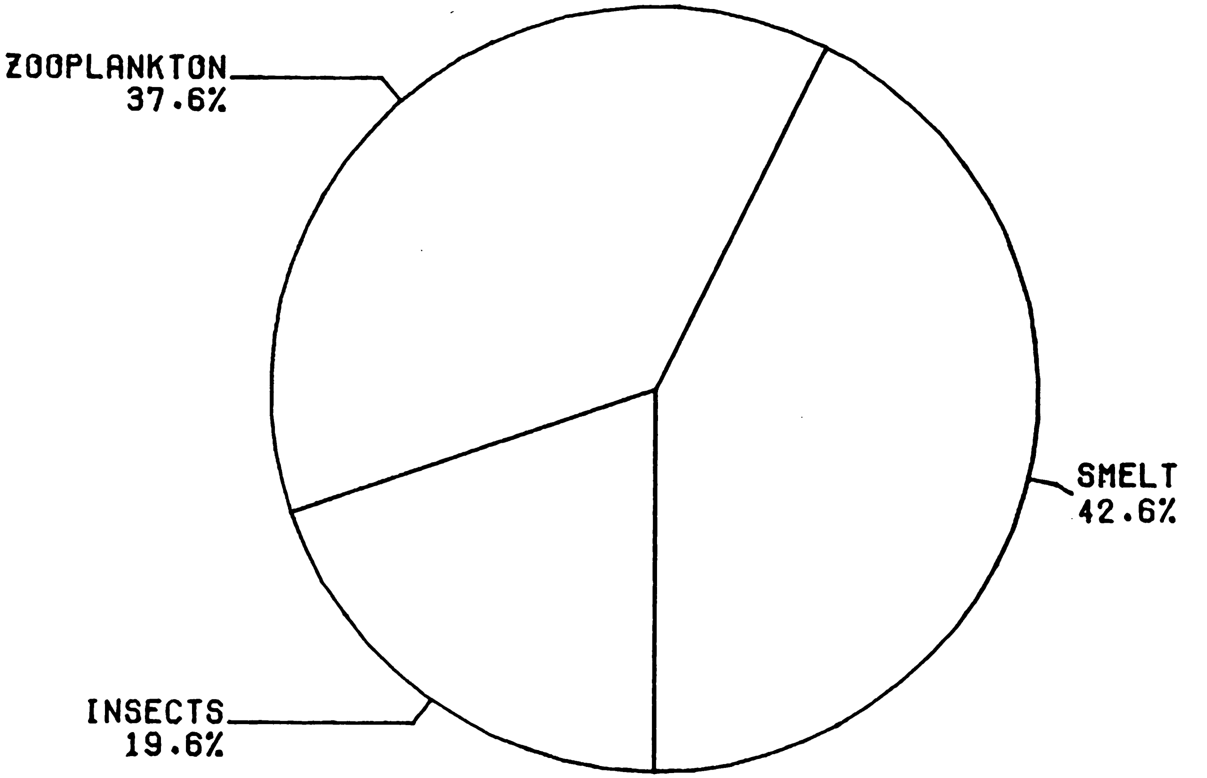

MIDDLE REGION
ALEWIFE 68.2%
BLOATER 1.2%
SCULPIN 3.7%
UNIDENTIFIED 15.7%
INSECTS 3.7%
ZOOPLANKTON 7.4%
ALL REGIONS
ALEWIFE 64.3%
SMELT 18.1%
BLOATER 0.3%
SCULPIN 2.7%
9-SPINE STICKLEBACK 0.9%
OTHER .05%
UNIDENTIFIED 3.9%
INSECTS 2.2%
SOUTHERN REGION
ALEWIFE 64.3%
SMELT 25.5%
SCULPIN 1.4%
INSECTS 0.8%
ZOOPLANKTON 7.7%
NORTHERN REGION
ALEWIFE 54.3%
SMELT 14.5%
PERCH 9%
SCULPIN 9%
9-SPINE STICKLEBACK 0.5%
OTHER 0.4%
UNIDENTIFIED 8.1%
INSECTS 3.7%

Figure 7.--Percentage of each major prey item contributing to the diet of steelhead in eastern Lake Michigan, 1983.

STEELHEAD - SPRING 1983



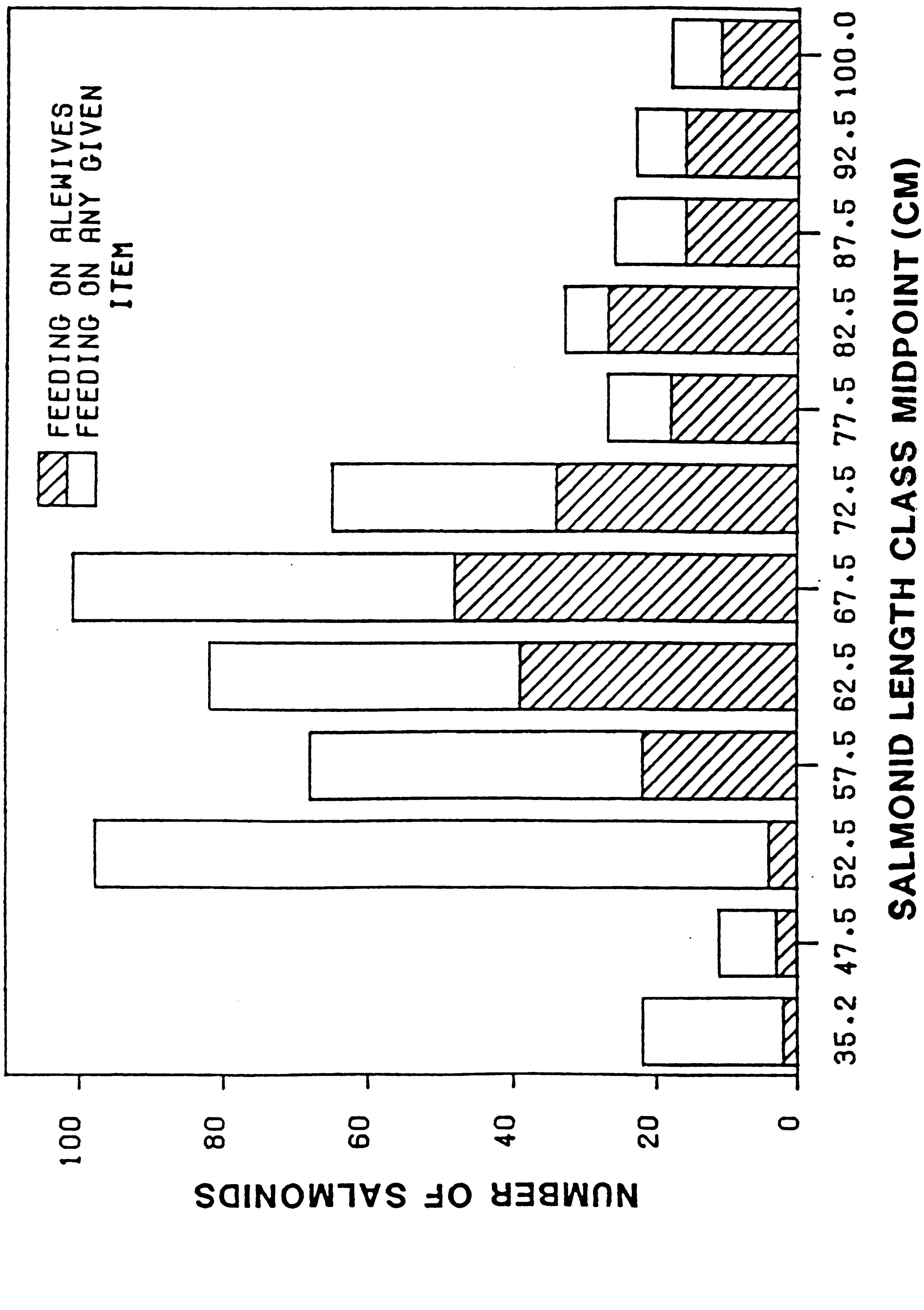
consumed by the predator. Error occurring from averaging widely separated length measurements was presumed minimal because of adults and juveniles occupying different strata (Janssen and Brandt, 1980; Brandt et al., 1980; Crowder et al., 1981). Independent plots of chinook salmon, coho salmon, and lake trout total lengths versus mean total lengths of ingested alewife resulted in no significant correlations (r): chinook salmon .216, coho salmon .133, and lake trout -.02. A scatterplot, illustrating the lack of correlation for chinook salmon is presented as an example in Appendix C.

Graphing salmonid size class predation on alewives and salmonid predation on the various alewife size classes allows few observations:

1) larger salmonids (>75 cm) fed more often on alewife than did smaller salmonids (<75 cm), while smaller to medium sized salmonids (>50 and <75 cm) fed more frequently on prey items other than alewife (Figure 8);
2) the percent that alewives contributed to the "percent of diet" of chinook salmon (>65 cm) was fairly constant (60-81 %)(Figure 9);
3) lake trout showed no obvious size predation on alewives (Figure 10).

Salmonid species fed primarily upon larger alewives (Figure 11). Although species size distributions illustrate more large chinook salmon were sampled than lake trout (Appendix D), chinook salmon still appeared to show a

Figure 8.--Salmonid size class predation on alewife and other prey items in eastern Lake Michigan, 1983.



FEEDING ON ALEWIVES
FEEDING ON ANY GIVEN ITEM
SALMONID LENGTH CLASS MIDPOINT (CM)
NUMBER OF SALMONIDS
35.2
47.5
52.5
57.5
62.5
67.5
72.5
77.5
82.5
87.5
92.5
100.0
0
20
40
60
80
100

Figure 9.--Chinook salmon size class predation on alewife and other prey items in eastern Lake Michigan, 1983.

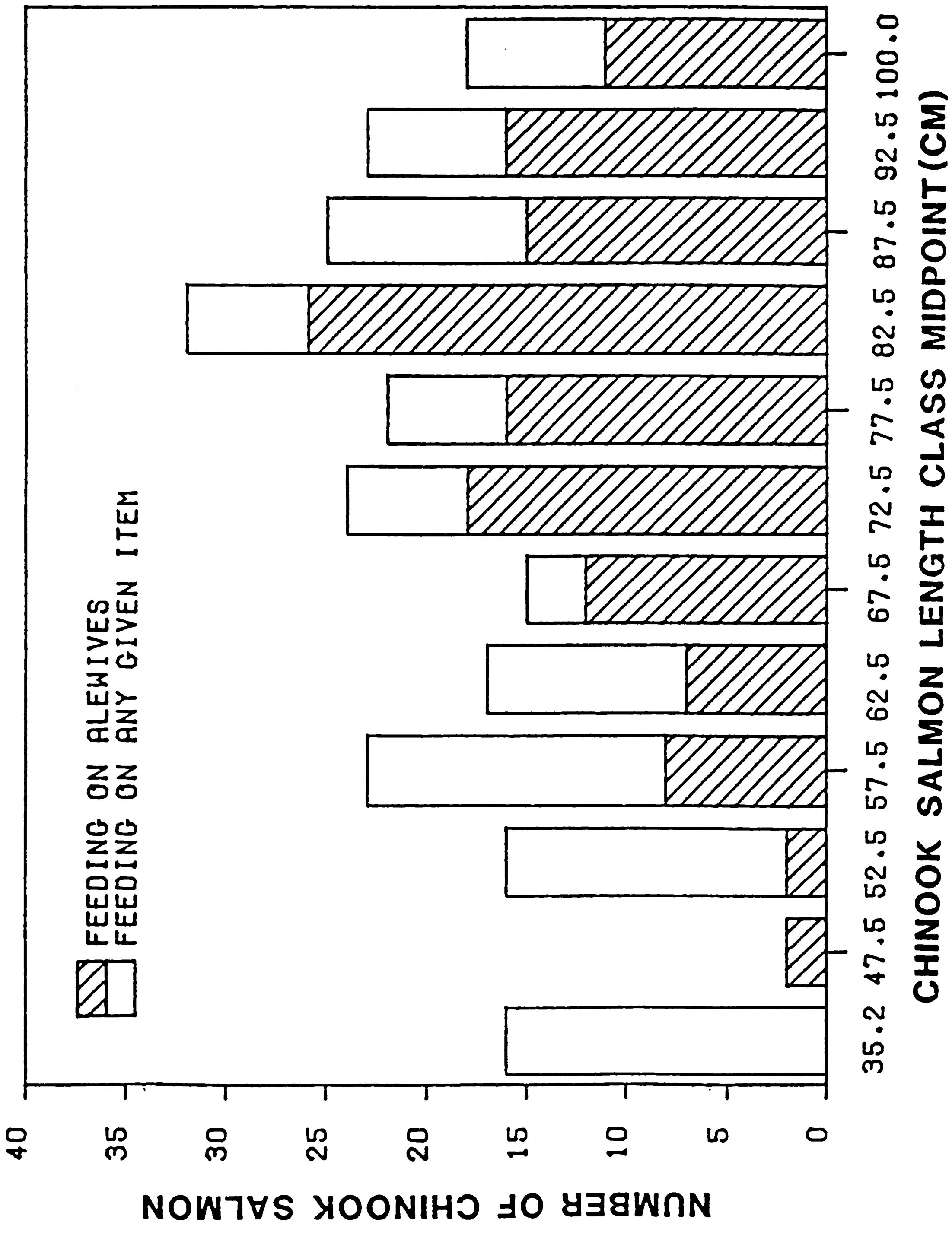

FEEDING ON ALEWIVES
FEEDING ON ANY GIVEN ITEM
CHINOOK SALMON LENGTH CLASS MIDPOINT (CM)
35.2 47.5 52.5 57.5 62.5 67.5 72.5 77.5 82.5 87.5 92.5 100.0
NUMBER OF CHINOOK SALMON
0 5 10 15 20 25 30 35 40

Figure 10.--Lake trout size class predation on alewife and other prey items in eastern Lake Michigan, 1983.

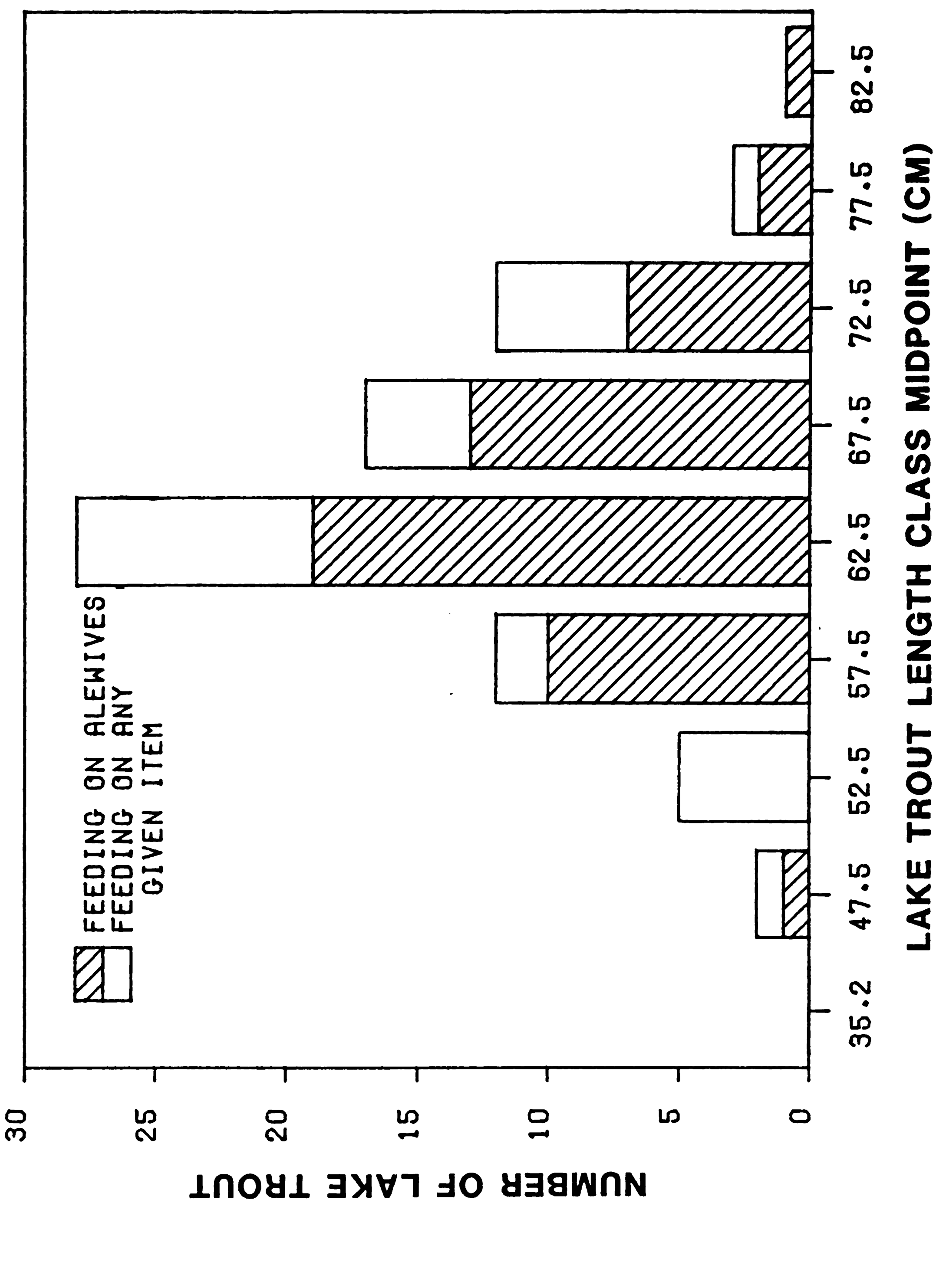
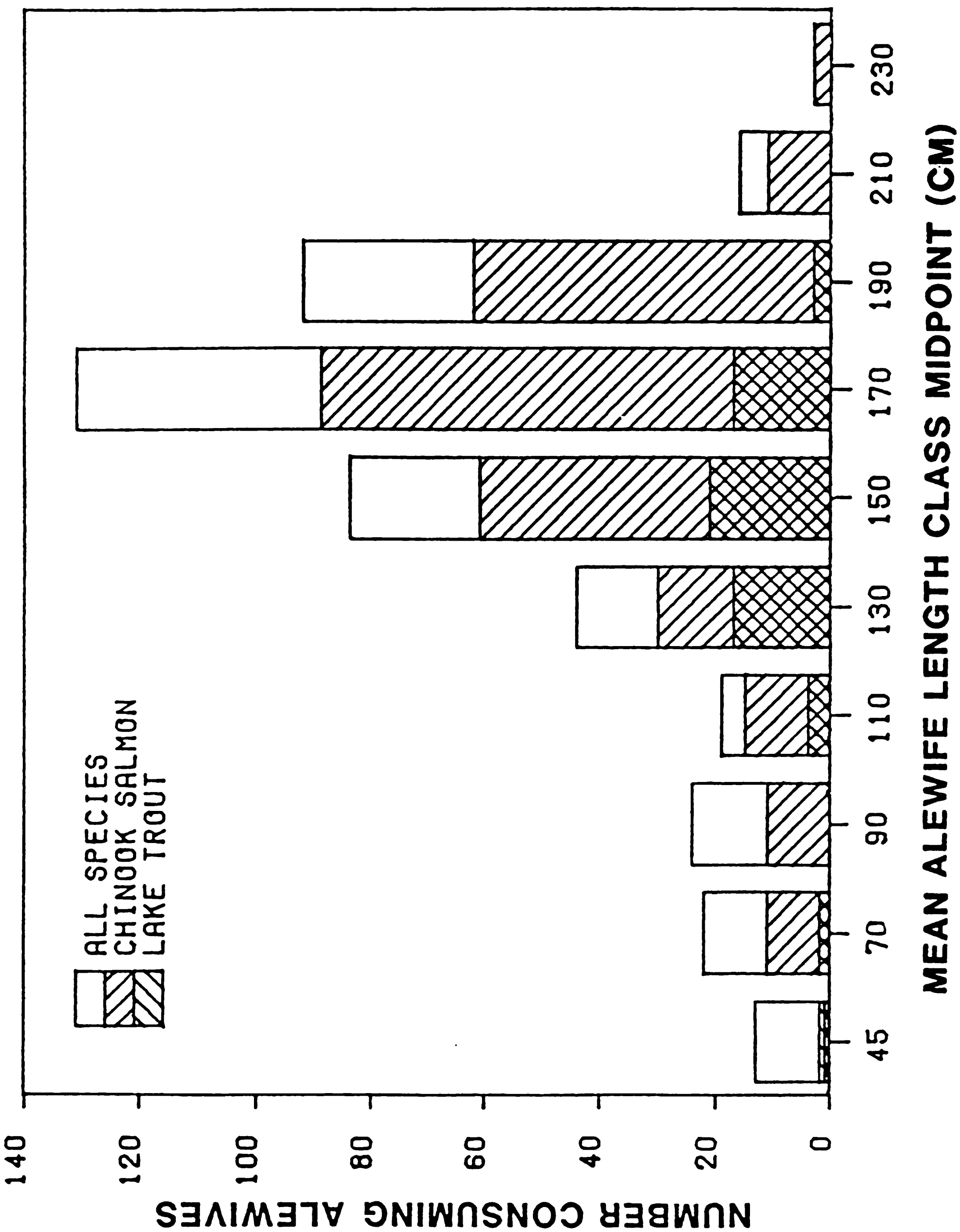
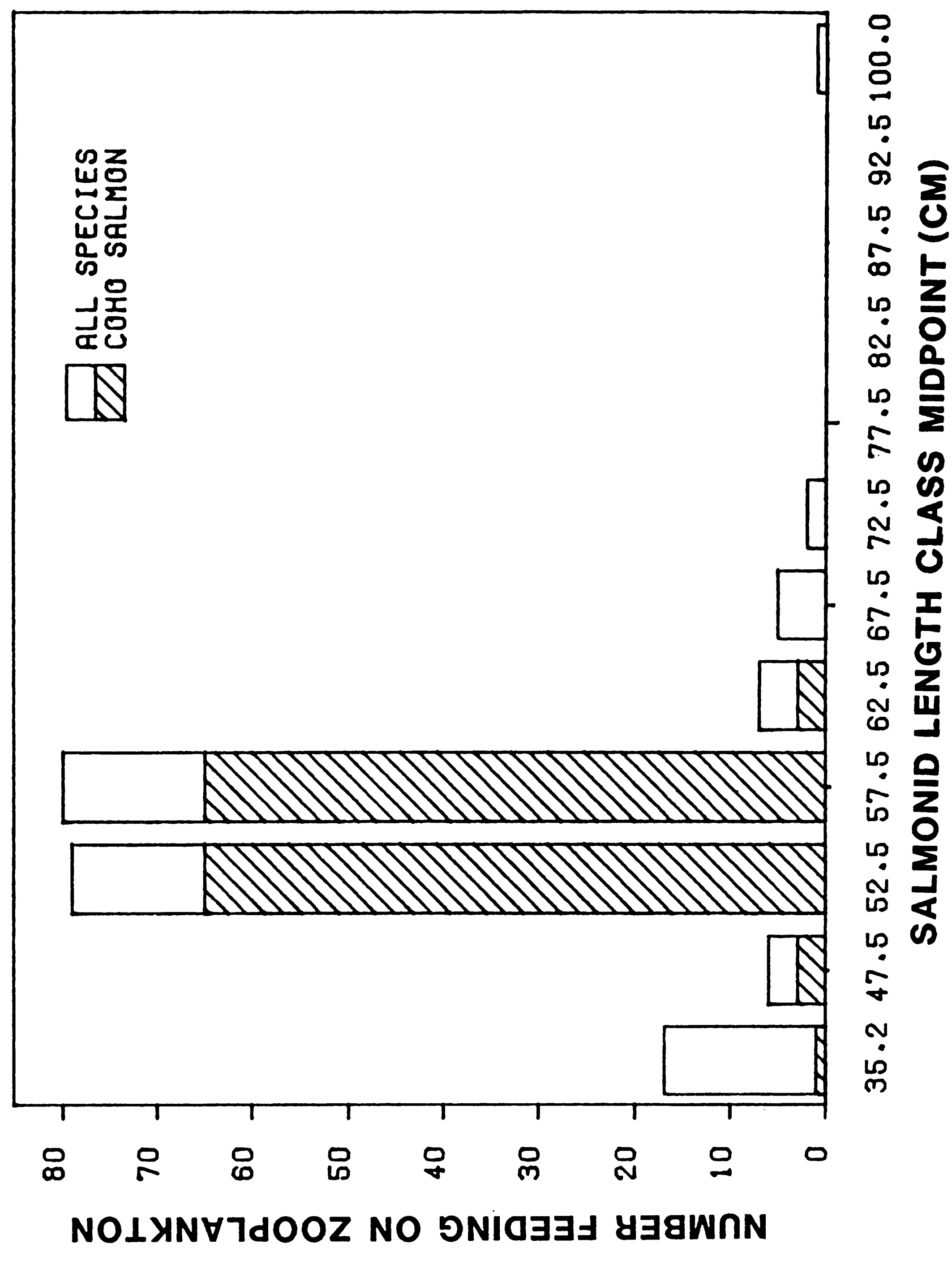

FEEDING ON ALEWIVES
FEEDING ON ANY GIVEN ITEM
NUMBER OF LAKE TROUT
0
5
10
15
20
25
30
35.2
47.5
52.5
57.5
62.5
67.5
72.5
77.5
82.5
LAKE TROUT LENGTH CLASS MIDPOINT (CM)

Figure 11.--Mean length of alewife consumed by salmonids of various size classes in eastern Lake Michigan, 1983.


NUMBER CONSUMING ALEWIVES
0
20
40
60
80
100
120
140
MEAN ALEWIFE LENGTH CLASS MIDPOINT (CM)
45
70
90
110
130
150
170
190
210
230
ALL SPECIES
CHINOOK SALMON
LAKE TROUT

higher affinity for larger alewives than lake trout. Fish between 50.1 and 60 cm in length consumed the majority of zooplankton found in the salmonid diets (Figure 12). Coho salmon fed more extensively upon organisms within the zooplankton category followed by steelhead and chinook salmon. In stream, lake, and river habitats rainbow trout at times have been reported to feed extensively on these zooplankters, especially *Daphnia* spp. (Gailbraith, 1967; Taylor and Gerking, 1979). No evidence of *Daphnia* spp. consumption by salmonids within Lake Michigan was found in the literature searched. The number of salmonids feeding on insects by size was random, with no evident pattern (Appendix E).

Figure 12.--Salmonid size class predation on organisms within the zooplankton category in eastern Lake Michigan, 1983.


ALL SPECIES
COHO SALMON
NUMBER FEEDING ON ZOOPLANKTON
0
10
20
30
40
50
60
70
80
35.2
47.5
52.5
57.5
62.5
67.5
72.5
77.5
82.5
87.5
92.5
100.0
SALMONID LENGTH CLASS MIDPOINT (CM)

GENERAL FEEDING HABITS, 1984

The stomachs of 2,705 salmonids were examined for food contents in 1984. Food items were found in 1,255 (46.41 %) of the stomachs, while 1,449 (53.59 %) were empty. Species sampled varied with respect to percent feeding (Table 11).

Table 11.--Percent (number feeding/sample size) of feeding salmonid species caught in eastern Lake Michigan, 1984.

	CHINOOK S.	COHO S.	LAKE T.	STEELHEAD	BROWN T.	ATLANTIC S.
%	35.55	47.90	63.06	73.40	54.67	100.00
	(449)/(1263)	(330)/(689)	(366)/(582)	(69)/(94)	(41)/(75)	(1)/(1)

ALL SPECIES: 46.51 (1256)/(2705)

These values differed significantly from chinook and coho salmon percentages obtained in 1983. There was an average 38.42 % decrease in salmonids feeding from 1983 to 1984. Chinook salmon decreased 72.1 %, coho salmon, 43.3 %; and lake trout, 1.08 %. The two following observations further typify a decline in feeding fish : 1) increased state of decomposition of prey items in salmonid stomachs and; 2) a decrease in stomach fullness from 1983 to 1984. Reasons for the apparent decline in feeding salmonids could be related to a declining forage base, an increased number of stocked salmonids, or a combination of both.

The major food items of salmonids in Lake Michigan were again fish (91.6 %), primarily alewives, smelt, and bloater (Figure 13). Zooplankton did not constitute a significant portion of the diet as it did in 1983. The decline of zooplankton in salmonid diets may be explained by the majority of fishing occurring in deeper water during 1984 than in 1983. This resulted in catches of more pelagic than littoral salmonids. Forage fish-zooplankton interactions occurring within the lake should result in larger zooplankton populations following a decline in planktivorous predators (e.g. alewife) (Stewart et al., 1981). Leading to the prediction of zooplankton becoming a potential prey item. Sample collections in late fall 1984 have shown the dietary reoccurrence of zooplankton. Their proportion and frequency is still in the analysis stage (Nurse, personal communication). Future sampling should result in a better understanding of zooplankton in salmonid diets.

Occurrence of various prey items in salmonid diets are listed in Table 12, as well as the percent that each item contributes to the salmonid species diet. Organisms comprising insect, zooplankton, and other categories, including miscellaneous items found in salmonid stomachs, are shown in Table 13.

The frequency of bloaters and perch in salmonid diets increased noticeably from 1983 to 1984, while alewives and smelt decreased. These numbers indicate a shift in salmonid feeding habits towards a diet which better reflects the

Figure 13.--Percentage of each major prey item contributing to the diet of salmonids in eastern Lake Michigan, 1984.

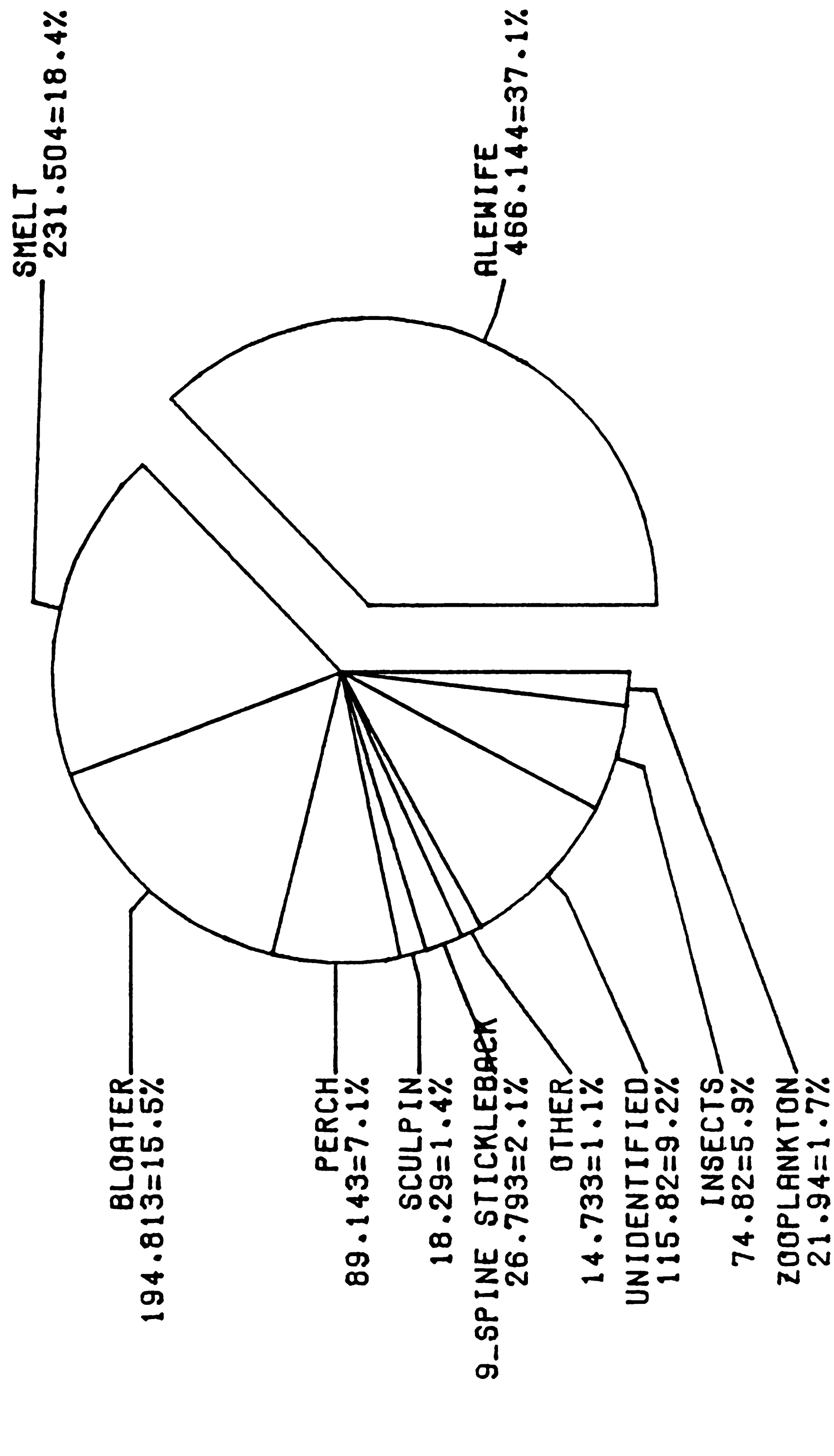

SMELT
231.504=18.4%
ALEWIFE
466.144=37.1%
BLOATER
194.813=15.5%
PERCH
89.143=7.1%
SCULPIN
18.29=1.4%
9_SPINE STICKLEBACK
26.793=2.1%
OTHER
14.733=1.1%
UNIDENTIFIED
115.82=9.2%
INSECTS
74.82=5.9%
ZOOPLANKTON
21.94=1.7%

Table 12.--Frequency of occurrence of prey items in the salmonid diets in 1984 (percent of diet in parentheses).

	CHINOOK S.	COHO S.	LAKE T.	STEELHEAD	BROWN T.
ALEWIVES	37.50	19.00	51.30	21.74	41.46
	(38.18)	(17.30)	(58.26)	(14.08)	(39.02)
SMELT	16.21	29.45	11.47	17.40	17.07
	(15.53)	(33.52)	(10.04)	(12.91)	(14.84)
BLOATERS	23.63	12.83	10.82	7.25	4.88
	(25.94)	(11.41)	(9.68)	(2.21)	(4.88)
PERCH	6.05	10.45	4.98	17.40	26.83
	(5.63)	(8.90)	(4.70)	(12.50)	(21.75)
SCULPINS	0.00	1.66	4.33	2.90	0.00
	0.00	(1.50)	(3.55)	(0.83)	(0.00)
9-SPINES	1.76	3.56	1.73	2.90	0.00
	(1.60)	(3.86)	(1.60)	(1.41)	(0.00)
OTHER	0.78	2.85	1.95	1.45	0.00
	(0.49)	(2.58)	(1.09)	(0.11)	(0.00)
UNIDENT-IFIED FISH	9.38	10.21	10.39	4.35	9.76
	(0.92)	(10.6)	(9.17)	(3.18)	(9.76)
INSECTS	0.98	7.60	2.60	60.87	7.32
	(0.77)	(8.04)	(1.77)	(51.32)	(7.32)
ZOO-PLANKTON	3.71	2.38	0.43	1.45	2.44
	(2.65)	(2.31)	(0.12)	(1.44)	(2.44)

Table 13.--Frequency of occurrence of organisms making up the pooled categories - insects, zooplankton, and other fish species, as well as miscellaneous items consumed, 1984.

	FREQUENCY OF OCCURRENCE
Invertebrates	
Crustacea	
Amphipoda	
Pontiporeia	1.52
Cladocera	
Daphnia pulex	.72
D. retrocurva	.08
D. longiremis	.08
Hyallela azteca	.08
Leptodora kindtii	.16
Copepoda	
Cyclops spp.	.08
Calanoid	.08
Decapoda	.08
Mysidacea	
Mysis oculata relicta	.32
Insecta	
Coleoptera	6.45
Carabidae	2.47
Chrysomelidae	.56
Coccinellidae	.64
Curculionidae	.24
Dytiscidae	.64
Elateridae	.24
Gyrinidae	.08
Haliplidae	.08
Hydrophilidae	.08
Lampyridae	.72
Diptera	.96
Muscidae	.72
Syrphidae	.08
Tabanidae	.08
Tipulidae	.08
Ephemeroptera	
Ephemeridae	
Hexagenia spp.	.08
Hemiptera	1.35
Corixidae	.32
Pentomatidae	1.19
Homoptera	
Cicadellidae	.24
Lepidoptera	
Noctuidae	2.23
Orthoptera	
Tettigoniidae	.08
Trichoptera	
Brachyceridae	.08

Table 13 (cont'd).

	FREQUENCY OF OCCURRENCE
Fish	
Clupeidae	
Alosa cerepedianum	.48
Centrachidae	
Lepomis macrochirus	.08
Cyprinidae	
Notropis spp.	.32
Percidae	
Etheostoma nigrum	.40
Percopsis omiscomaycus	.24
Salmonidae	
Salvelinus namaycus	.08
Corigoninae	
Coregonus clupeaformis	.24
Miscellaneous items consumed	
Cigarette butts	.16
Soil (dirt clot)	.08
Plastic	.16
Sticks	.08
Wood	.08

present forage base.

The forage base in Lake Michigan has undergone major species shifts within the past 20 years. Alewife populations have undergone reductions in number as well as changes in size class distribution (Jester, personal communication) possibly resulting from salmonid predation and inter-specific competition (Stewart et al., 1981; Crowder and Magnuson,1982; Crowder and Binkowski, 1983). These changes in the alewife population should results in a decline in numbers and sizes consumed. The frequency of larger alewife size classes ingested by salmonid predators declined from 1983 to 1984.

An increase in perch in salmonid diets was seen from 1983 to 1984. Future predation on perch seems evident with any further decline in alewife populations. However, misrepresentation of perch as a major prey item may have occurred in 1984 due to a large year class. Perch have been shown to undergo large population fluctuations (Eshenroder, 1977; Nelson and Walburg, 1977; Smith, 1977).

The rate at which salmonid feeding habits have changed in relation to a declining alewife population is not well understood. Evidence of a lag time between salmonid predators in response to a changing forage base may exist. This is based on lake trout's continued predation on alewives compared to coho and chinook salmon's increased predation on bloaters and perch. Lack of change might also be explained by lake trout's presumed selective preference for alewife.

A realistic approach in viewing the consumption of various prey species by salmonids was by viewing species distribution overlap. Lake trout inhabit a deep water benthic strata of the lake as compared to chinook and coho salmon which are more pelagic. The large occurrence of alewives in lake trout was understandable because of adult alewives mainly concentrating on the bottom during the day (Brandt et al., 1980; Janssen and Brandt, 1980; Crowder et al., 1981). The majority of fish sampled were caught between 6:30 a.m. and 9:00 p.m.. Coho salmon fed more extensively on smelt, bloaters, perch and juvenile alewives which were more pelagic and littoral. These findings and observations of salmonid and forage species juxtaposition in the lake exemplify the salmonids opportunistic nature for feeding on the most abundant and available prey items. Numerous studies by Murdoch (1969 and 1975) have shown "switching" to occurr, increased feeding, by a predator, on prey items which are higher in relative abundance.

Opportunistic feeding is further substantiated by the occurrence of various forage species ingested at different locations and depths within the lake. Specific cases include occurrence of: 1) gizzard shad (Dorosoma cepedianum (Lesseur)) in salmonids caught at the mouths of rivers flowing into Lake Michigan; 2) trout-perch, 9-spine sticklebacks, sculpins, and mysids at deeper depths primarily in lake trout and; 3) insects in steelhead and coho salmon taken at or near the surface.

FEEDING HABITS BY REGION AND SEASON

A more diversified sampling scheme in 1984 allowed for regions and seasons to be independently analyzed. In the southern and northern regions of Lake Michigan, fewer feeding fish were found (sampled fish containing food) than in the middle region (Table 14). These values contrasted those of 1983 where the opposite occurred, fewer feeding fish in the middle region. Sampling in early spring occurred more frequently in the southern region, resulting from largers number of anglers present at that time. Practically 90 % of the early spring fish sampled were empty, contributing to a low southern region (mostly spring) percentage. Efforts to reduce the bias included extending the spring sampling season by two weeks, in order to compensate for the two week difference in feeding intensity (Table 1). And secondly, sampling as soon as possible in the other regions during spring once their fishing began.

Anglers pursued the larger, mature chinook salmon in the fall, mostly in the northern region. Because of mature salmonids exhibiting spawning behavior, the frequency of empty stomachs greatly increased. In spite of spawning behavior salmonids were still caught by anglers. This may have resulted from a split allocation of energy by salmonids towards spawning and food location. In observing the deterioration of the digestive tract in snagged, mature

Table 14.--Relative percent of feeding salmonid species by region (sample sizes inparentheses), 1984.

SPECIES	SOUTH	MIDDLE	NORTH	ALL REGIONS
CHINOOK S.	33.10	46.10	34.30	35.60
	(492)	(191)	(581)	(1264)
COHO S.	42.00	63.20	48.70	47.90
	(286)	(95)	(308)	(689)
LAKE T.	52.90	63.30	70.00	62.90
	(223)	(89)	(270)	(582)
STEELHEAD	63.80	95.00	81.30	73.40
	(58)	(20)	(16)	(94)
BROWN T.	60.50	44.40	50.00	54.70
	(38)	(9)	(28)	(75)
ATLANTIC S.	00.00	00.00	100.00	100.00
	(0)	(0)	(1)	(1)
ALL SPECIES	42.00	56.90	47.00	46.50
	(1097)	(404)	(1204)	(2705)

chinook salmon it was presumed that the majority of mature salmonids, prior to spawning, allocated more energy towards spawning while still opting for an available meal. A decline in fall feeding fish reflected a reduction in forage availability from 1983 to 1984.

The relative percent of feeding salmonids by season followed the above pattern with the exception of trout (lake trout, steelhead and brown trout). They tended to feed more extensively in the spring, declining towards the fall (Table 15). This feeding habit was discussed in a previous section (Wright, 1968; Frantz and Cordone, 1970; Chiotti, 1973).

Among feeding fish, smelt were the most abundant forage fish consumed followed by alewives, bloaters, and perch. However, lake trout continued to have alewife as its most numerous prey. Absence of a sufficient sample size for lake trout in the fall resulted from the imposed 0 creel limit after August 15, 1984. Consumption of forage species, alewives and smelt, by chinook and coho salmon, fluctuated with the season in relation to their distribution. Alewife were more abundant when salmonids were primarily pelagic (middle region - summer) and smelt more abundant when salmonids were more littoral (spring and fall - southern and northern regions) (Tables 16 and 17). Nine-spine sticklebacks and sculpins were most numerous during summer in the northern region.

Occurrence of various prey items within the diets

Table 15.--Relative percent of feeding salmonid species by season (sample sizes in parentheses), 1984.

SPECIES	SPRING	SUMMER	FALL	ALL SEASONS
CHINOOK S.	28.10	46.60	32.20	35.60
	(466)	(432)	(366)	(1264)
COHO S.	42.50	72.50	44.70	47.90
	(292)	(102)	(295)	(689)
LAKE T.	65.20	62.60	50.00	63.10
	(89)	(491)	(2)	(582)
STEELHEAD	81.30	67.70	60.00	73.40
	(48)	(31)	(15)	(94)
BROWN T.	62.10	45.90	66.70	54.67
	(29)	(37)	(9)	(75)
ATLANTIC S.	0.00	0.00	100.00	100.00
	(0)	(0)	(1)	(1)
ALL SPECIES	40.00	56.80	38.80	46.50
	(924)	(1093)	(688)	(2705)

Table 16.--Percent frequency of occurence, by region, of the various prey items consumed by the three major salmonids in eastern Lake Michigan, 1984.

	SOUTH			MIDDLE			NORTH			ALL REGIONS		
PREY	CHINOOK	COHO	LAKE T.	CHINOOK	COHO	LAKE T.	CHINOOK	COHO	LAKE T.	CHINOOK	COHO	LAKE T.
ALEWIFE	33.13	17.50	65.25	36.36	36.67	59.32	53.27	24.67	66.14	42.67	24.24	64.58
SMELT	18.40	45.00	19.49	11.36	15.00	13.56	21.61	40.67	11.64	18.44	37.58	14.44
BLOATER	31.29	.83	5.08	44.32	26.67	22.03	20.60	24.67	16.40	29.11	16.36	13.62
PERCH	11.04	15.00	7.63	7.95	31.67	20.34	3.02	4.67	1.06	6.89	13.33	6.27
SCULPIN	0.00	0.00	1.69	0.00	0.00	5.08	0.00	4.67	7.94	0.00	2.12	5.45
9-SPINE	0.00	0.00	0.00	0.00	0.00	0.00	4.52	10.00	4.23	2.00	4.55	2.18
OTHER	0.00	0.00	3.39	1.14	15.00	1.69	1.51	2.00	2.12	.89	3.64	2.45
UNIDENT.	9.20	18.33	11.02	10.23	5.00	18.64	12.06	12.00	12.70	10.67	13.03	13.08
INSECTS	1.23	16.67	.85	0.00	11.67	3.39	1.51	3.33	4.76	1.11	9.70	3.27
MICRO-CRUST.	4.29	8.33	0.00	10.23	0.00	1.69	1.51	0.00	.53	4.22	3.03	.54

Table 17.--Percent frequency of occurence, by season, of the various prey items consumed by the three major salmonids in eastern Lake Michigan, 1984.

	SPRING			SUMMER			FALL			ALL SEASONS		
PREY	CHINOOK	COHO	LAKE T.	CHINOOK	COHO	LAKE T.	CHINOOK	COHO	LAKE T.	CHINOOK	COHO	LAKE T.
ALEWIFE	52.67	14.52	60.34	32.34	55.41	65.58	49.15	15.91	0	42.67	24.24	64.58
SMELT	25.19	52.42	31.03	9.45	0.00	11.04	26.27	44.70	100	18.44	37.58	14.44
BLOATER	5.34	.81	5.17	44.78	17.57	15.26	28.81	30.30	0	29.11	16.36	13.62
PERCH	12.98	8.06	8.62	4.48	29.73	5.84	4.24	9.09	0	6.89	13.33	6.27
SCULPIN	0.00	0.00	5.17	0.00	8.11	5.52	0.00	.76	0	0.00	2.12	5.45
9-SPINE	0.00	0.00	0.00	4.48	17.57	2.60	0.00	1.52	0	2.00	4.55	2.18
OTHER	1.53	0.00	1.72	.50	1.35	2.60	.85	8.33	0	.89	3.64	2.45
UNIDENT.	12.21	15.32	12.07	11.44	13.51	13.31	7.63	10.61	0	10.67	13.03	13.08
INSECTS	0.00	20.16	3.45	1.99	4.05	3.25	.85	3.03	0	1.11	9.70	3.27
MICRO-CRUST.	8.40	8.06	1.72	3.98	0.00	.32	0.00	0.00	0	4.22	3.03	.54

(Tables 18 and 19) parallel observations from the number of prey species consumed (Tables 16 and 17). Further examination of frequency of occurrence (Tables 18 and 19) showed alewife and bloaters were dominant prey species for chinook salmon, as contrasted to alewife and smelt for coho salmon and lake trout. Bloaters showed a marked increase of 300 % in the frequency of occurrence in combined species from 1983 to 1984.

Regions were again employed to determine the percent that each prey item contributed to the various salmonid diets. Regions were used for reasons stated in 1983, with the exception of similarity between regions and seasons (Figures 14-16). The major observations from Figures 14-16 were the smaller percentage of alewife and larger percent of bloater and perch in the 1984 diets. These percentages differed from previous studies mentioned and that found in 1983.

The major presumption for the marked changes in feeding habits were due to regional and seasonal differences among forage species' populations. Statistical differences between 1983 and 1984 were insignificant ($p \geq .10$) with the exception of larger numbers of zooplankton being consumed during spring of 1984.

FISH SIZE AND PREY SELECTION

No significant correlations were found in 1984 between predator and mean alewife lengths. Correlations (r) obtained included: .190, .064, and .297 for chinook salmon, Table .--Total prey items consumed, by region, by the three major salmonids in eastern Lake Michigan, 1984.

	SOUTH			MIDDLE			NORTH			ALL REGIONS		
PREY	CHINOOK	COHO	LAKE T.	CHINOOK	COHO	LAKE T.	CHINOOK	COHO	LAKE T.	CHINOOK	COHO	LAKE T.
ALEWIFE	76	33	138	71	50	76	252	80	300	399	163	514
SMELT	105	99	32	13	26	14	384	517	44	502	642	90
BLOATER	93	2	7	72	45	17	82	88	63	247	135	87
PERCH	24	31	21	12	89	35	7	9	2	43	129	58
SCULPIN	0	0	18	0	0	4	0	16	21	0	16	43
9-SPINE	0	0	0	0	0	0	39	73	15	39	73	15
OTHER	0	0	4	2	13	1	3	4	5	5	17	10
UNIDENT.	20	44	18	9	8	18	33	29	38	62	81	74
TOTAL	318	209	238	179	231	165	800	816	488	1297	1256	891
ALL SPECIES		765			575			2104			3444	

Table .--Total prey items consumed, by season, by the three major salmonids in eastern Lake Michigan, 1984.

PREY	SPRING CHINOOK	SPRING COHO	SPRING LAKE T.	SUMMER CHINOOK	SUMMER COHO	SUMMER LAKE T.	FALL CHINOOK	FALL COHO	FALL LAKE T.	ALL SEASONS CHINOOK	ALL SEASONS COHO	ALL SEASONS LAKE T.
ALEWIFE	178	31	80	109	85	434	112	47	0	399	163	514
SMELT	65	113	27	85	0	62	352	529	1	502	642	90
BLOATER	13	2	6	167	39	81	67	94	0	247	135	87
PERCH	25	12	20	11	51	38	7	66	0	43	129	58
SCULPIN	0	0	4	0	15	39	0	1	0	0	16	43
9-SPINE	0	0	0	39	71	15	0	2	0	39	73	15
OTHER	2	0	1	1	1	9	2	16	0	5	17	10
UNIDENT.	24	41	9	26	17	65	12	23	0	62	81	74
TOTAL	307	199	147	438	279	7[illegible]3	552	778	1	1297	1256	891
ALL SPECIES		653			1460			1331			3444	

Figure 14.--Percentage of each major prey item contributing to the diet of shinook salmon in eastern Lake Michigan, 1984.

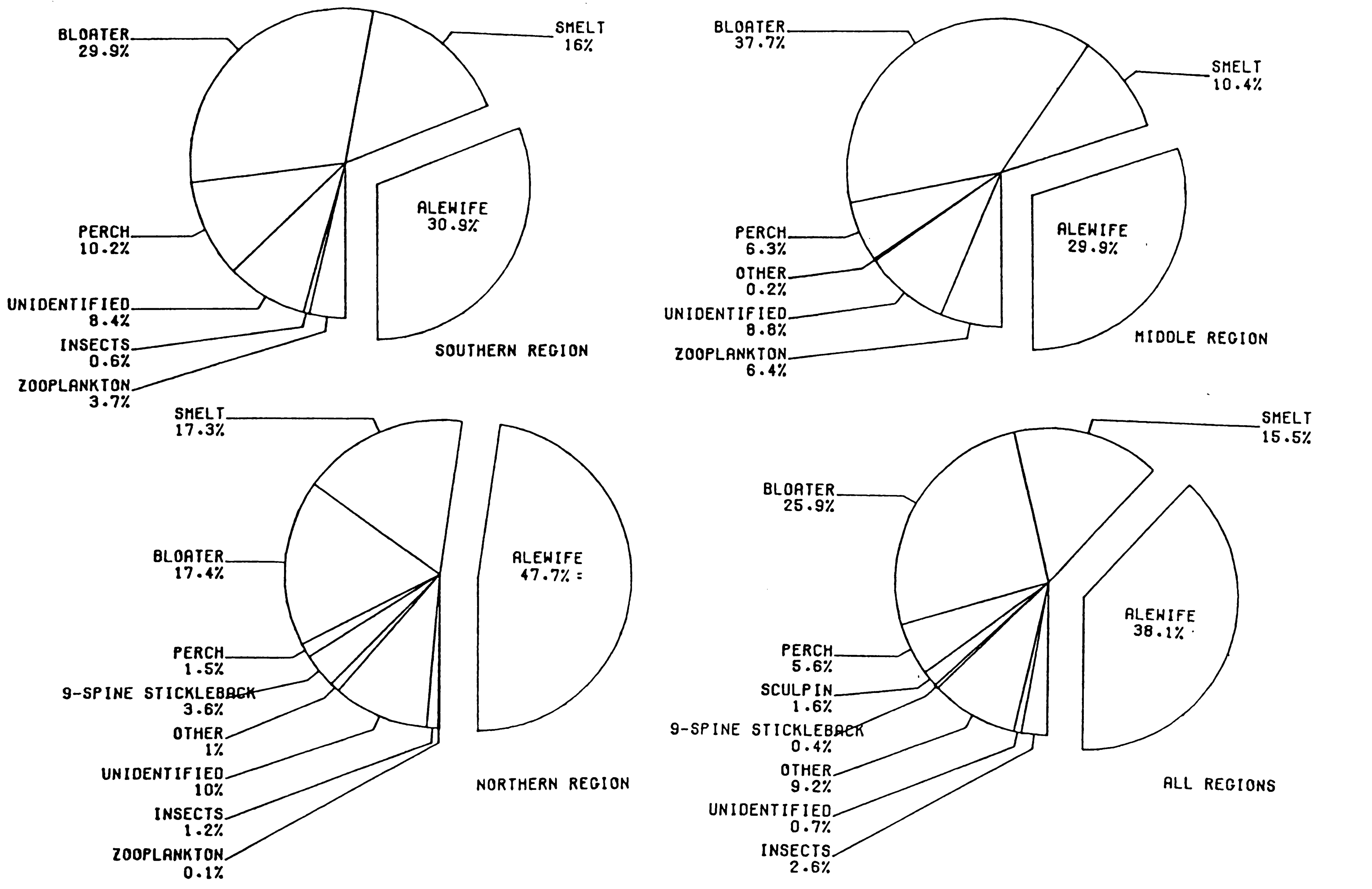

BLOATER 29.9%
SMELT 16%
ALEWIFE 30.9%
PERCH 10.2%
UNIDENTIFIED 8.4%
INSECTS 0.6%
ZOOPLANKTON 3.7%
SOUTHERN REGION
BLOATER 37.7%
SMELT 10.4%
ALEWIFE 29.9%
PERCH 6.3%
OTHER 0.2%
UNIDENTIFIED 8.8%
ZOOPLANKTON 6.4%
MIDDLE REGION
SMELT 17.3%
BLOATER 17.4%
ALEWIFE 47.7%
PERCH 1.5%
9-SPINE STICKLEBACK 3.6%
OTHER 1%
UNIDENTIFIED 10%
INSECTS 1.2%
ZOOPLANKTON 0.1%
NORTHERN REGION
SMELT 15.5%
BLOATER 25.9%
ALEWIFE 38.1%
PERCH 5.6%
SCULPIN 1.6%
9-SPINE STICKLEBACK 0.4%
OTHER 9.2%
UNIDENTIFIED 0.7%
INSECTS 2.6%
ALL REGIONS

Figure 15.--Percentage of each major prey item contributing to the diet of coho salmon in eastern Lake Michigan, 1984.

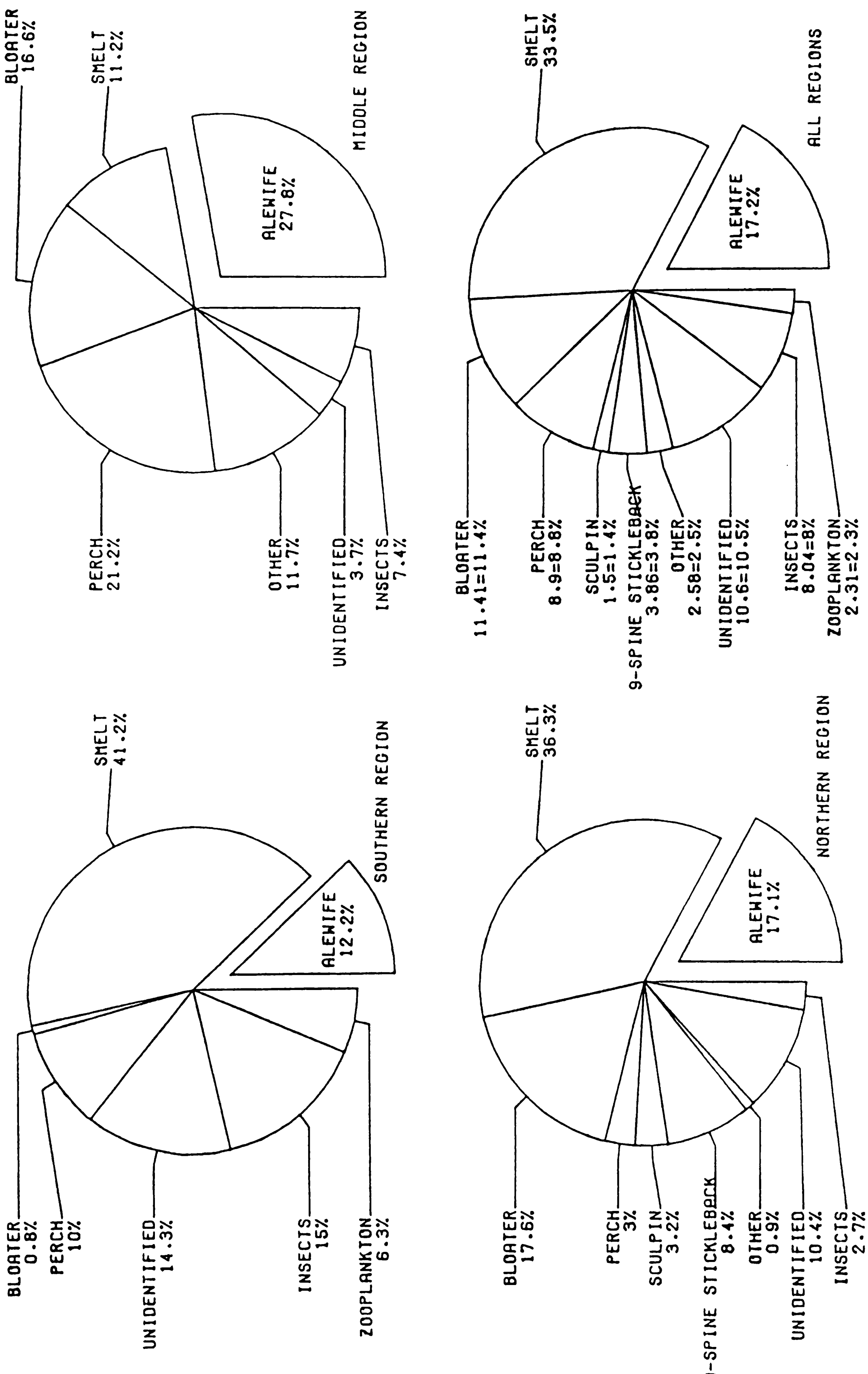
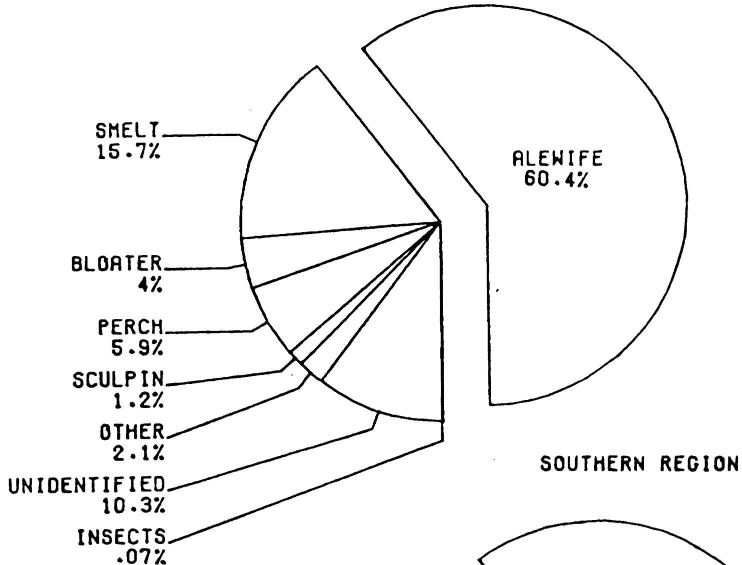
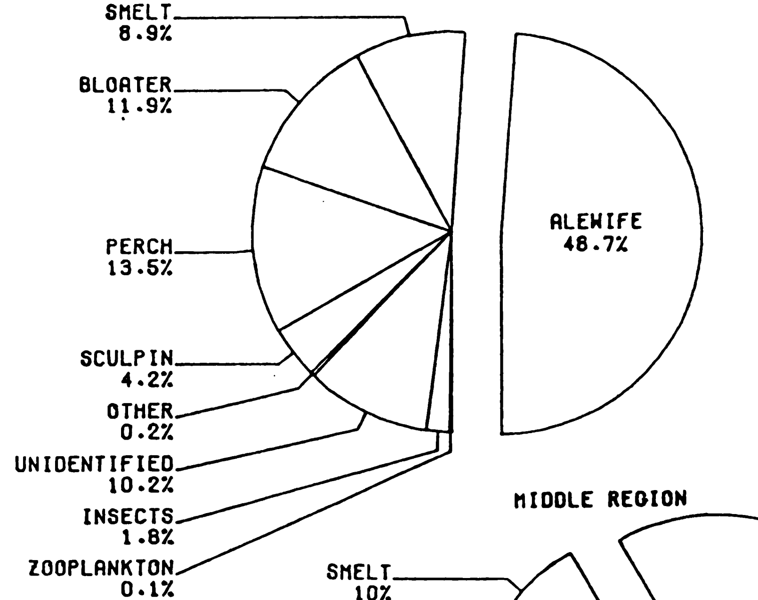
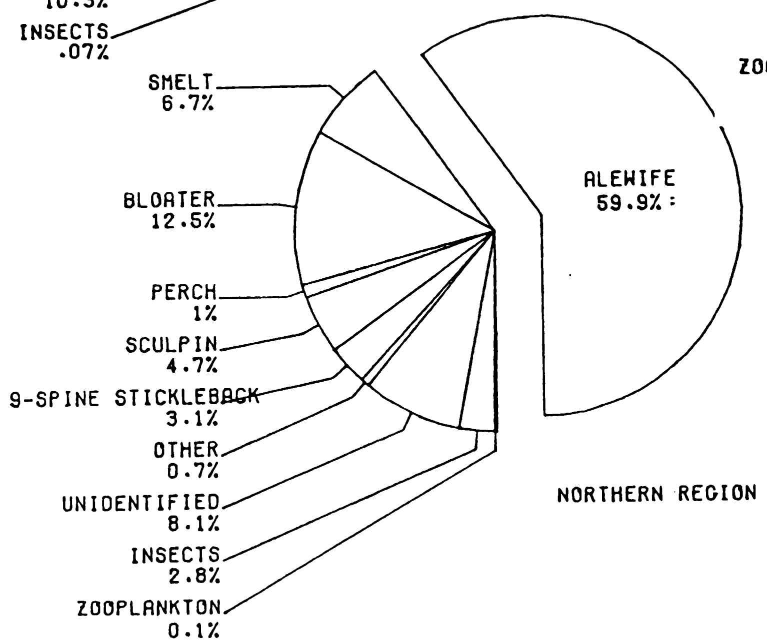
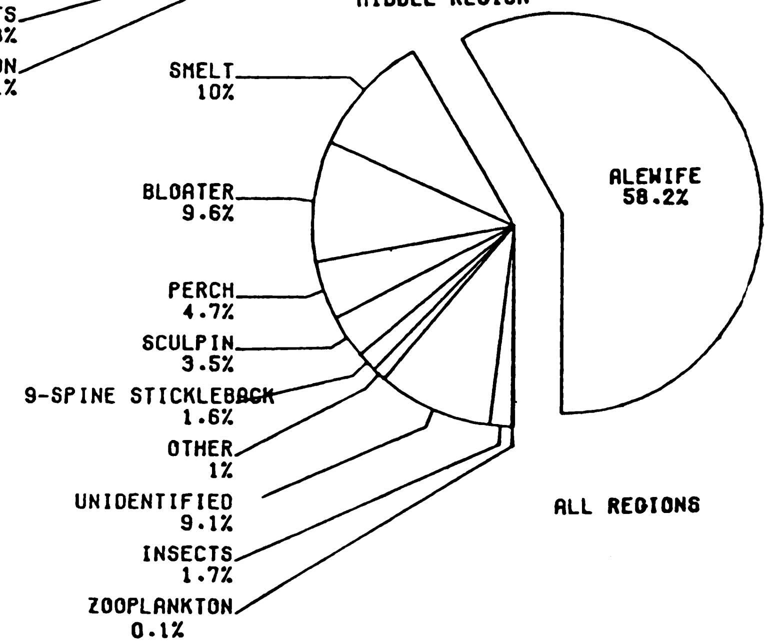

SOUTHERN REGION
SMELT 41.2%
ALEWIFE 12.2%
BLOATER 0.8%
PERCH 10%
UNIDENTIFIED 14.3%
INSECTS 15%
ZOOPLANKTON 6.3%
MIDDLE REGION
BLOATER 16.6%
SMELT 11.2%
ALEWIFE 27.8%
PERCH 21.2%
OTHER 11.7%
UNIDENTIFIED 3.7%
INSECTS 7.4%
NORTHERN REGION
SMELT 36.3%
ALEWIFE 17.1%
BLOATER 17.6%
PERCH 3%
SCULPIN 3.2%
9-SPINE STICKLEBACK 8.4%
OTHER 0.9%
UNIDENTIFIED 10.4%
INSECTS 2.7%
ALL REGIONS
SMELT 33.5%
ALEWIFE 17.2%
BLOATER 11.41=11.4%
PERCH 8.9=8.8%
SCULPIN 1.5=1.4%
9-SPINE STICKLEBACK 3.86=3.8%
OTHER 2.58=2.5%
UNIDENTIFIED 10.6=10.5%
INSECTS 8.04=8%
ZOOPLANKTON 2.31=2.3%

Figure 16.--Percentage of each major prey item contributing to the diet of lake trout in eastern Lake Michigan, 1984.


SMELT
15.7%
BLOATER
4%
PERCH
5.9%
SCULPIN
1.2%
OTHER
2.1%
UNIDENTIFIED
10.3%
INSECTS
.07%
ALEWIFE
60.4%
SOUTHERN REGION


SMELT
8.9%
BLOATER
11.9%
PERCH
13.5%
SCULPIN
4.2%
OTHER
0.2%
UNIDENTIFIED
10.2%
INSECTS
1.8%
ZOOPLANKTON
0.1%
ALEWIFE
48.7%
MIDDLE REGION


SMELT
6.7%
BLOATER
12.5%
PERCH
1%
SCULPIN
4.7%
9-SPINE STICKLEBACK
3.1%
OTHER
0.7%
UNIDENTIFIED
8.1%
INSECTS
2.8%
ZOOPLANKTON
0.1%
ALEWIFE
59.9%
NORTHERN REGION


SMELT
10%
BLOATER
9.6%
PERCH
4.7%
SCULPIN
3.5%
9-SPINE STICKLEBACK
1.6%
OTHER
1%
UNIDENTIFIED
9.1%
INSECTS
1.7%
ZOOPLANKTON
0.1%
ALEWIFE
58.2%
ALL REGIONS

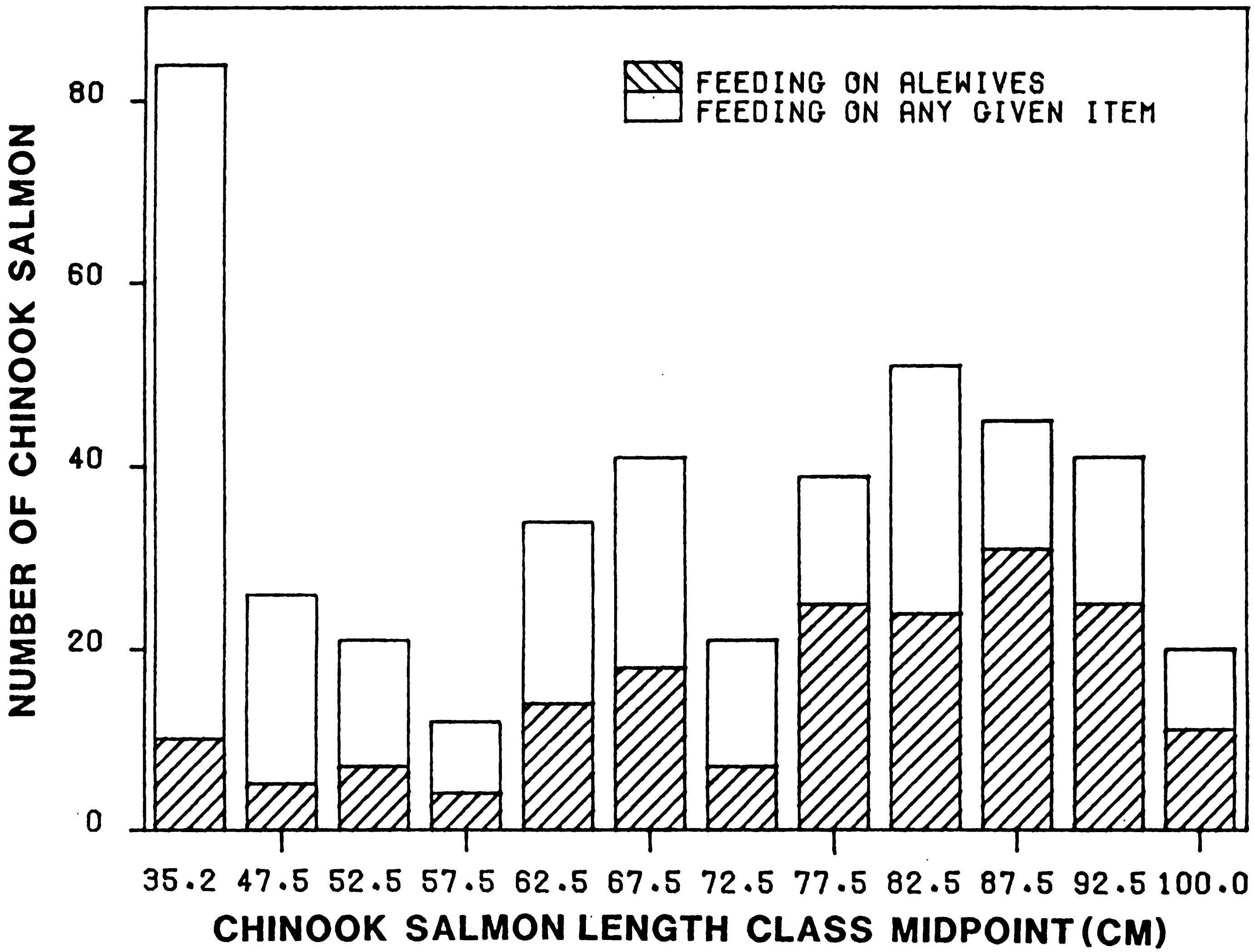
coho salmon, and lake trout, respectively. Scatterplots depicting lack of correlation for chinook salmon and lake trout are illustrated in Appendix D. Although no significant correlations were found, a few generalizations can be made from the number of salmonids (per size category) consuming alewives (Figures 17-18). Chinook salmon between 70 and 108 cm more frequently consumed alewives than those 50 to 70 cm, and especially those from 25.4 to 50 cm (Figure 17). The number of chinook salmon consuming alewives was shown to increase with increasing salmonid length. Lake trout showed fewer alewives being consumed between predator lengths of 50 and 75 cm (Figure 18).

Further examination of predator-alewife interactions reveal a large consumption of 120 to 200 mm alewife by all salmonids, with larger alewife (180-240 mm) being consumed primarily by chinook salmon (Figure 19). Lake trout, however, show a tendency to feed more on slightly smaller alewives (<200 mm)(Figure 20). In considering the size distribution of predator species sampled, no difference in alewife size classes consumed was evident.

Predation on zooplankton increased as salmonid size decreased (Figure 21). In many samples, the diets of smaller salmonids (25.4-45 cm) were packed with microcrustaceans, especially Daphnia spp.

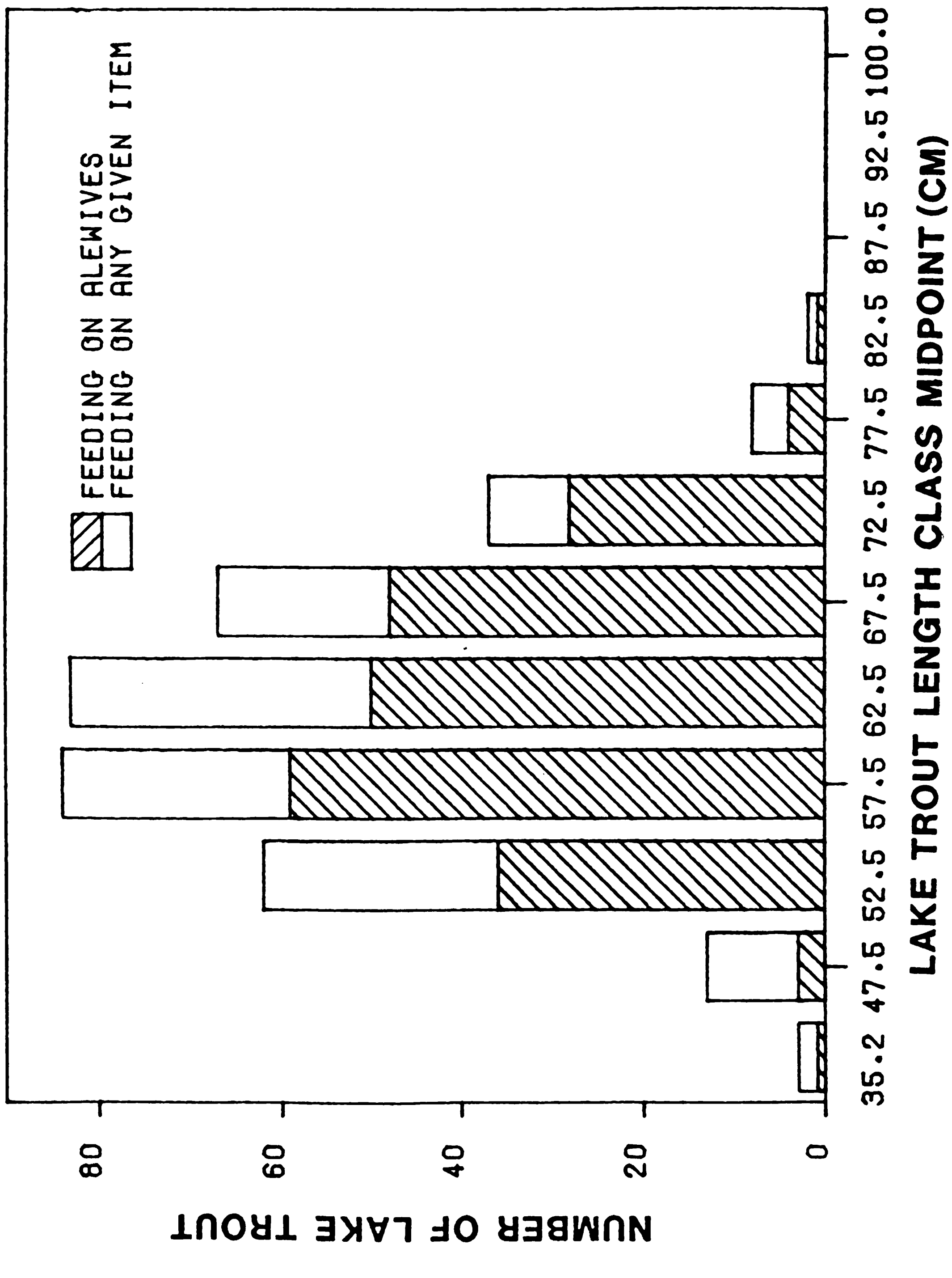
Stomach content analysis of steelheads showed that insects, while present throughout the size range, were preyed on primarily by larger individuals (60-95 cm)(Figure

Figure 17.--Chinook salmon size class predation on alewife and other prey items in eastern Lake Michigan, 1984.



FEEDING ON ALEWIVES
FEEDING ON ANY GIVEN ITEM
NUMBER OF CHINOOK SALMON
0
20
40
60
80
35.2
47.5
52.5
57.5
62.5
67.5
72.5
77.5
82.5
87.5
92.5
100.0
CHINOOK SALMON LENGTH CLASS MIDPOINT (CM)

Figure 18.--Lake trout size class predation of alewife and other prey items in eastern Lake Michigan, 1984.



FEEDING ON ALEWIVES
FEEDING ON ANY GIVEN ITEM
NUMBER OF LAKE TROUT
0
20
40
60
80
35.2
47.5
52.5
57.5
62.5
67.5
72.5
77.5
82.5
87.5
92.5
100.0
LAKE TROUT LENGTH CLASS MIDPOINT (CM)

Figure 19.--Mean length of alewife consumed by chinook salmon of various size classes in eastern Lake Michigan, 1984.

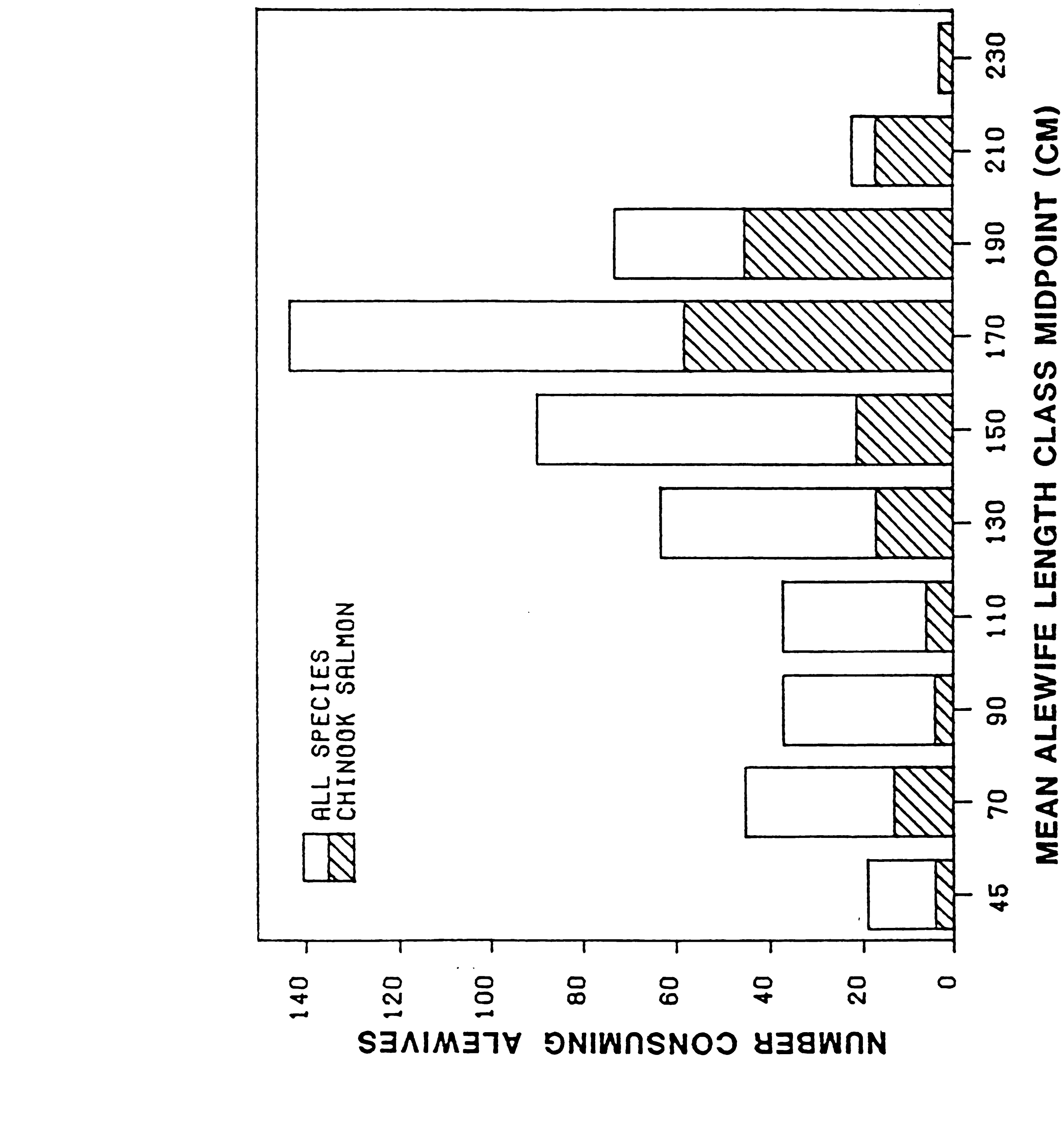

ALL SPECIES
CHINOOK SALMON
NUMBER CONSUMING ALEWIVES
140
120
100
80
60
40
20
0
45
70
90
110
130
150
170
190
210
230
MEAN ALEWIFE LENGTH CLASS MIDPOINT (CM)

Figure 20.--Mean length of alewife consumed by lake trout of various size classes in eastern Lake Michigan, 1984.

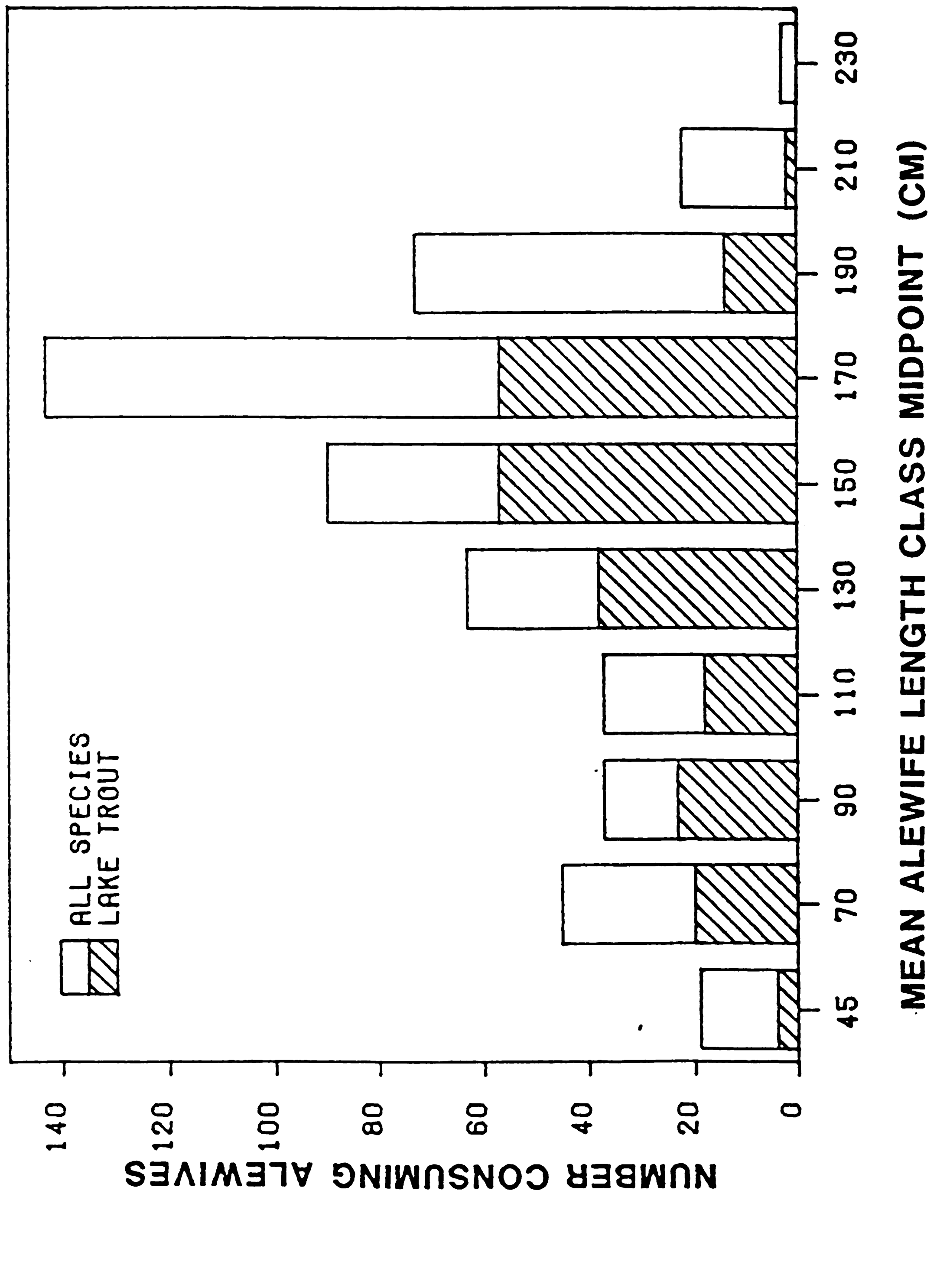
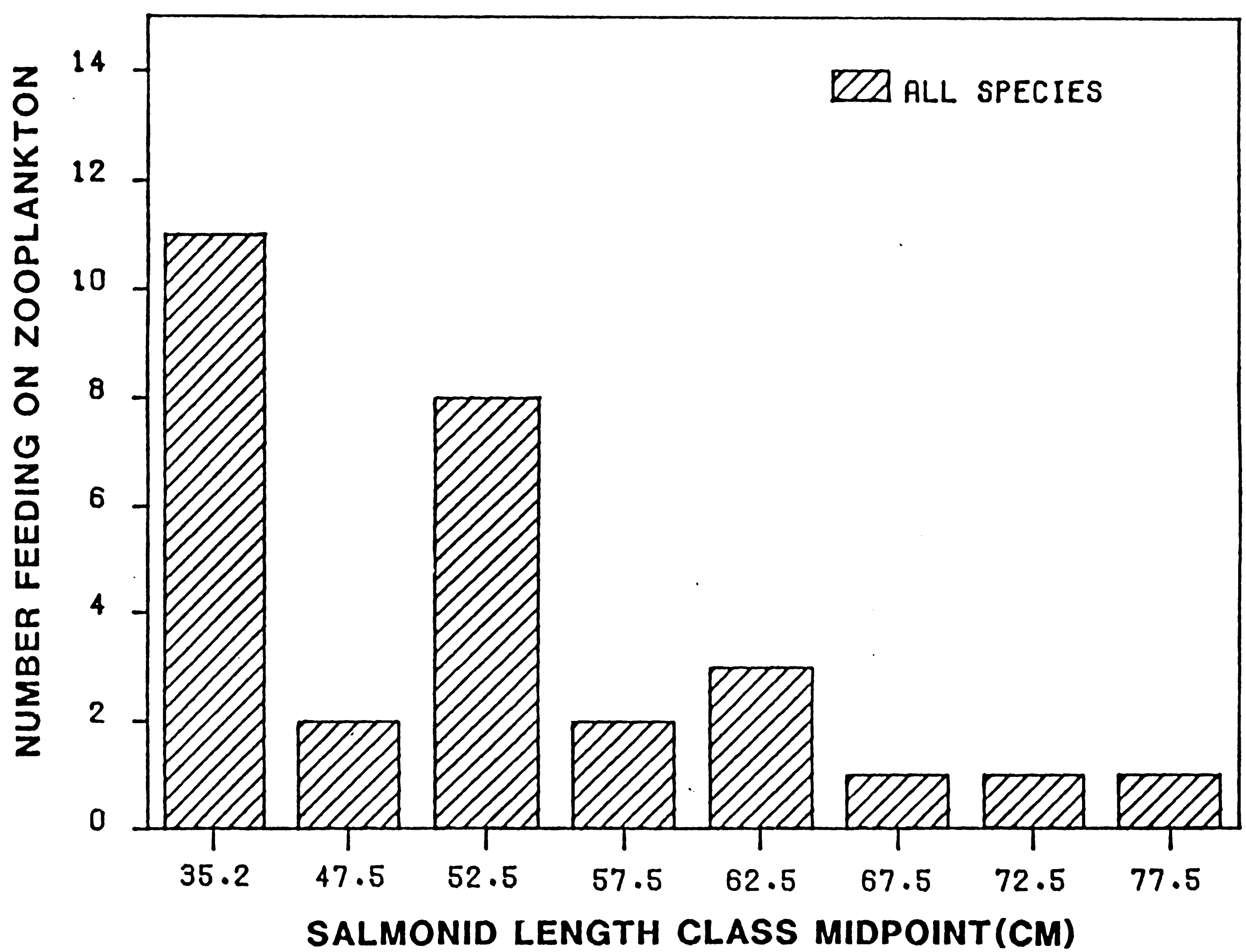

ALL SPECIES
LAKE TROUT
NUMBER CONSUMING ALEWIVES
0
20
40
60
80
100
120
140
45
70
90
110
130
150
170
190
210
230
MEAN ALEWIFE LENGTH CLASS MIDPOINT (CM)

Figure 21.--Salmonid size class predation on organisms within the zooplankton category in eastern Lake Michigan, 1984.


ALL SPECIES
NUMBER FEEDING ON ZOOPLANKTON
0
2
4
6
8
10
12
14
35.2
47.5
52.5
57.5
62.5
67.5
72.5
77.5
SALMONID LENGTH CLASS MIDPOINT(CM)

22). Conversely, coho salmon between 50 and 60 cm in length showed a larger percent feeding on insects (Figure 23).

FEEDING HABITS BY WATER DEPTH

The majority of fish examined were caught between 0 and 40 meters of water. Lake trout and chinook salmon were mostly taken from deeper water correlated to their population dynamics and physiological needs (Sommers et al. 1981; Eck and Wells 1982). The distribution of salmonids feeding on alewife and smelt followed its prey; chinook and coho salmon fed more extensively on smaller alewife (<85 mm) and smelt (30-180 mm) in the shallower regions than in deeper waters where more larger alewife (>85 mm) were consumed (Tables 20 and 21). Larger numbers of smaller fish were consumed in shallower waters because of their greater abundance and relatively larger numbers needed to satisfy a salmonid feeding.

In shallower regions diversity among prey species ingested was highest resulting from numerous forage species inhabiting the region. Forage fish fed primarily on zooplankton and invertebrates which were most abundant in these areas.

Figure 22.--Steelhead size class predation on insects in eastern Lake Michigan, 1984.

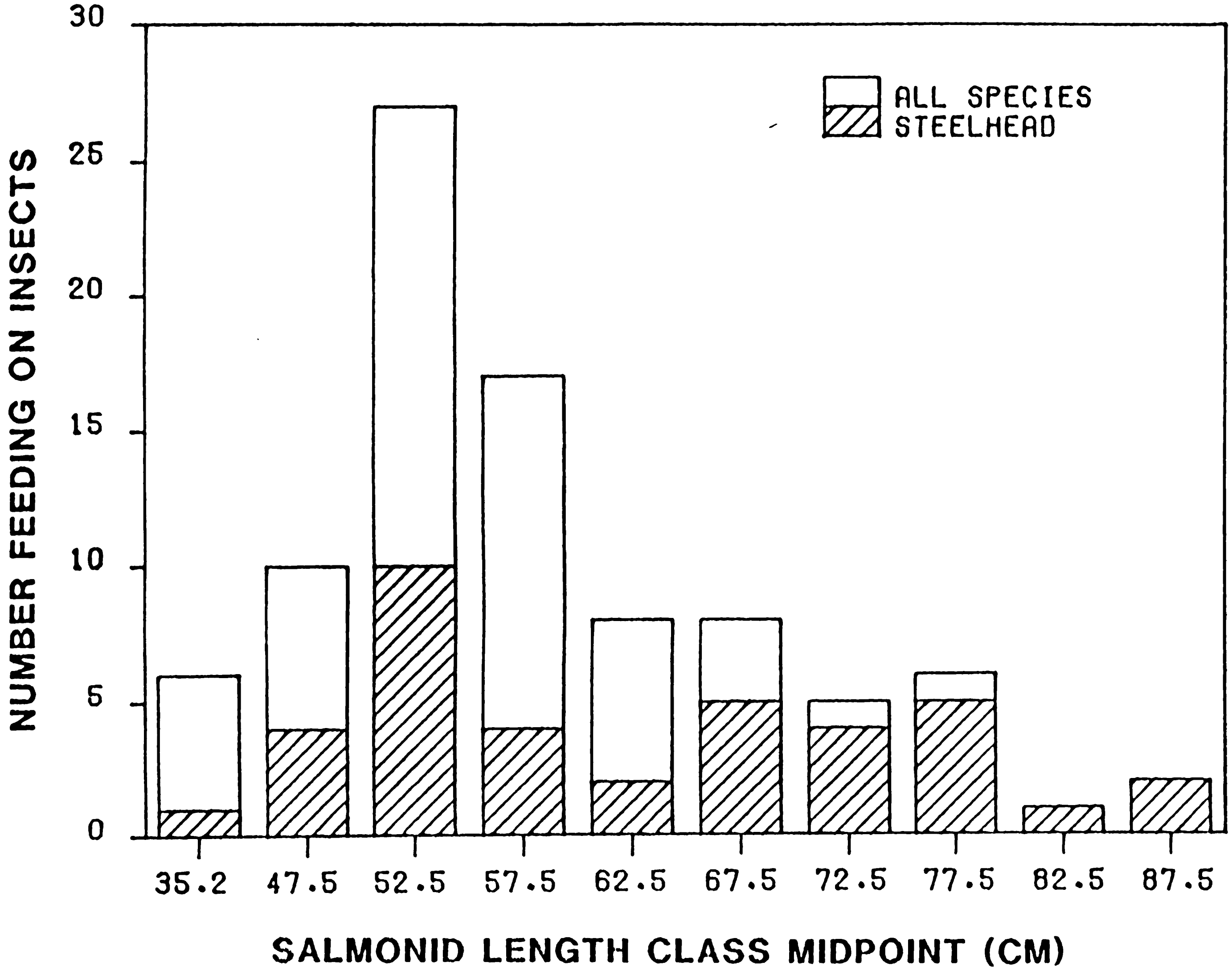

ALL SPECIES
STEELHEAD
NUMBER FEEDING ON INSECTS
30
25
20
15
10
5
0
35.2
47.5
52.5
57.5
62.5
67.5
72.5
77.5
82.5
87.5
SALMONID LENGTH CLASS MIDPOINT (CM)

Figure 23.--Coho salmon size class predation on insects in eastern Lake Michigan, 1984.

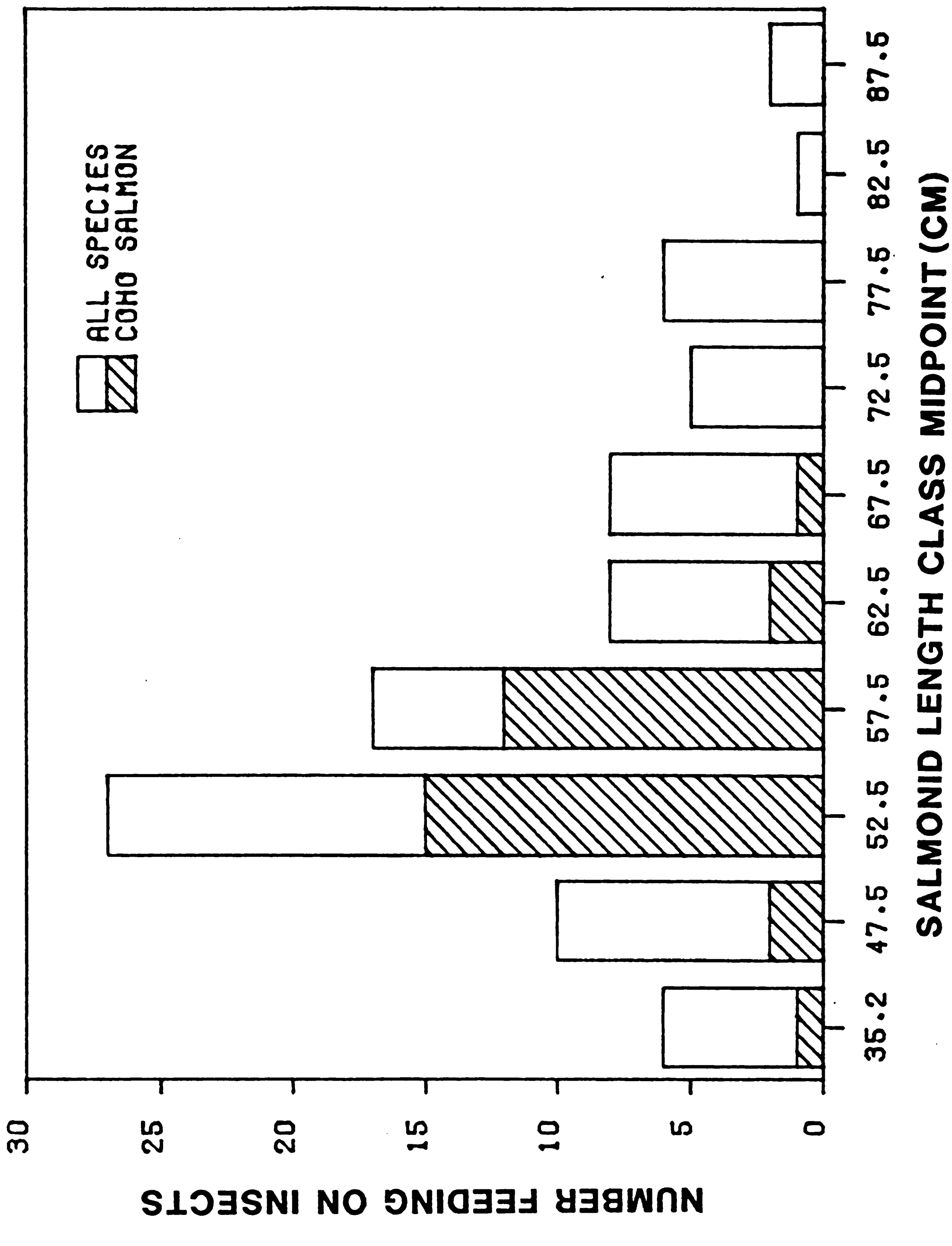

ALL SPECIES
COHO SALMON
NUMBER FEEDING ON INSECTS
0
5
10
15
20
25
30
35.2
47.5
52.5
57.5
62.5
67.5
72.5
77.5
82.5
87.5
SALMONID LENGTH CLASS MIDPOINT (CM)

Table 20.--Salmonid distribution and predation on alewives (ALW) by depth in eastern Lake Michigan, 1984 (numbers consumed in parentheses).

WATER DEPTH	CHINOOK	W/ALW	COHO	W/ALW	LAKE T.	W/ALW
0-10 feet	2	0 (0)	5	0 (0)	0	0 (0)
11-20	19	1 (1)	0	0 (0)	0	0 (0)
21-30	64	6 (9)	87	15 (35)	2	1 (1)
31-40	79	16 (28)	33	6 (25)	9	5 (14)
41-50	78	12 (40)	21	8 (14)	39	12 (19)
51-60	85	11 (28)	18	7 (12)	71	38 (96)
61-70	68	14 (16)	11	4 (7)	71	34 (81)
71-80	85	10 (11)	46	0 (0)	68	36 (73)
81-90	61	12 (18)	45	3 (5)	39	12 (22)
91-100	41	7 (15)	46	0 (0)	28	10 (17)
101-110	33	2 (3)	5	1 (1)	41	7 (11)
111-120	48	11 (13)	10	4 (9)	21	7 (13)
121-130	9	0 (0)	2	2 (4)	11	5 (6)
131-140	0	0 (0)	0	0 (0)	1	0 (0)
141-150	11	2 (2)	0	0 (0)	5	2 (2)
151-160	14	1 (1)	0	0 (0)	5	3 (6)

Table 20 (cont'd).

161-170	2	0 (0)	0	0 (0)	1	0 (0)
171-180	13	2 (5)	1	0 (0)	8	3 (4)
181-190	4	0 (0)	1	1 (1)	4	0 (0)
191-200	0	0 (0)	0	0 (0)	1	0 (0)
. . .						
221-230	10	5 (16)	1	0 (0)	1	0 (0)
231-240	0	0 (0)	1	1 (1)	0	0 (0)
241-250	3	0 (0)	0	0 (0)	0	0 (0)
. . .						
261-270	1	0 (0)	2	0 (0)	0	0 (0)
. . .						
291-300	1	1 (1)	0	0 (0)	0	0 (0)
. . .						
381-390	1	0 (0)	0	0 (0)	0	0 (0)
. . .						
531-540	1	0 (0)	0	0 (0)	0	0 (0)
UNKNOWN	531	89 (192)	342	27 (49)	157	62 (147)

Table 21.--Salmonid distribution and predation on smelt (SMLT) by depth in eastern Lake Michigan, 1984 (number consumed in parentheses).

WATER DEPTH	CHINOOK	W/SMLT	COHO	W/SMLT	LAKE T.	W/SMLT
* 0-10	49	2 (3)	61	5 (7)	0	0 (0)
11-20	19	1 (1)	0	0 (0)	0	0 (0)
21-30	64	6 (11)	87	8 (30)	2	0 (0)
31-40	99	8 (266)	33	6 (83)	9	1 (2)
41-50	78	4 (6)	21	4 (10)	39	1 (2)
51-60	85	3 (67)	18	2 (4)	71	7 (9)
61-70	68	5 (6)	11	3 (6)	71	5 (14)
71-80	85	3 (5)	46	14 (227)	68	11 (17)
81-90	61	7 (20)	45	4 (39)	39	1 (1)
91-100	41	2 (2)	46	8 (63)	28	0 (0)
101-110	31	2 (30)	5	0 (0)	41	3 (11)
111-120	46	2 (4)	22	6 (46)	21	0 (0)
121-130	9	0 (0)	2	0 (0)	11	1 (1)
131-140	0	0 (0)	0	0 (0)	1	0 (0)
141-150	11	0 (0)	0	0 (0)	5	0 (0)
151-160	3	0 (0)	0	0 (0)	5	1 (2)

Table 21 (cont'd).

161-170	2	0 (0)	0	0 (0)	1	0 (0)
171-180	13	1 (1)	1	0 (0)	8	1 (1)
181-190	4	0 (0)	1	0 (0)	4	1 (1)
191-200	0	0 (0)	0	0 (0)	1	0 (0)
. . .						
221-230	10	0 (0)	0	0 (0)	1	0 (0)
231-240	0	0 (0)	1	0 (0)	0	0 (0)
241-250	3	1 (1)	2	1 (1)	0	0 (0)
. . .						
261-270	1	0 (0)	0	0 (0)	0	0 (0)
. . .						
291-300	1	0 (0)	0	0 (0)	0	0 (0)
. . .						
381-390	1	0 (0)	0	0 (0)	0	0 (0)
. . .						
531-540	1	0 (0)	0	0 (0)	0	0 (0)
UNKNOWN	*	* (*)	*	* (*)	*	* (*)

GRAND TRAVERSE BAY

GENERAL FEEDING HABITS, 1983-84

In 1983, the stomachs of 57 salmonids from Grand Traverse Bay, predominantly lake trout (94.74%), were examined for food contents.

Smelt was the major prey item consumed (89.13%) while alewife and bloater occurred respectively in 10.87% and 2.7% of the salmonids representing 8.15% and 0.54% of total diet (Table 22). Analysis of 121 salmonids in 1984 showed similar feeding habits to those found in 1983 with lake trout again dominating the sample (93.39%)(Table 23).

Smelt constituted the major portion of the diet (76.73%) occurring in 82.05% of the fish sampled in 1984 (Table 22). This value significantly correlated (r=.99) with 82% in 1983. The only noticeable differences between the two years were: 1) a larger proportion of sublegal lake trout taken in 1983 correlating with a larger percent of feeding fish in 1983 and; 2) the occurrence of a whitefish in a 1984 lake trout stomach. A large percent of insects in the 1984 diets correlated with a *Hexagenia* hatch at the time of sampling. These comprised 95% of the insects consumed.

Because of small sample sizes, and large variability, little can be postulated about feeding habits, with the exception of smelt dominated diets in 1983 and 1984. Furthermore, diversity of prey items ingested reflected the opportunistic nature of feeding salmonids.

Table 22.--Percent frequency of occurrence of various prey items consumed by Grand Traverse Bay salmonids, 1983-84 (percent of diet in parentheses).

	ALL SPECIES-1983	ALL SPECIES-1984
ALEWIFE	10.87	10.26
	(8.15)	(6.52)
SMELT	89.13	82.05
	(85.33)	(76.73)
BLOATERS	2.17	1.28
	(0.54)	(1.28)
OTHER	0.00	1.28
	(0.00)	(0.43)
UNIDENTIFIED	8.70	10.26
	(5.98)	(6.63)
INSECTS	0.00	12.82
	(0.00)	(8.41)

Table 23.--Species distribution of Grand Traverse Bay salmonids, 1983-84.

	CHINOOK SALMON	COHO SALMON	LAKE TROUT
1983	3	0	54
	5.26 %	0	94.74 %
1984	6	2	113
	4.96 %	1.65 %	93.39 %

LAKE SUPERIOR

GENERAL FEEDING HABITS, 1983-84

Between 1983 and 1984, the stomach contents of 158 salmonids from Lake Superior were examined, with 113 (71.52 %) containing prey items. This value, however, does not illustrate the percentage of feeding fish in Lake Superior because of selective analysis on only feeding fish in 1983 and one major sample collection in the fall of 1984. The latter resulted in 45 (50.56 %) feeding fish and 44 (44.49 %) non-feeding fish (empty). A better estimate for the percent of feeding fish between 1983 and 1984 was 10-20 % (Kinnunen and local anglers, personal communication).

Stomach contents from Lake Superior salmonids showed a high diversity among prey items consumed. The wide array and presence of prey items found in salmonid diets from 1983 and 1984 are illustrated in Table 24. High diversity among diets refelct Lake Superior's smaller forage base (Lawrie and Rahrer 1972).

In 1983, 9-spine sticklebacks showed the highest frequency of occurrence in diets with 37.5 % followed by smelt 33.33 % and insects 29.17 % (Table 24); insects were most prevalent in coho salmon and steelhead. Chinook salmon and lake trout fed more on bottom dwelling species such as mysids, sculpins, and 9-spine sticklebacks.

In 1984, smelt was the most frequently consumed prey item (53.93%) followed by insects (21.35%) and mysids (12.36%) (Table 23).

Table 24.--Percent frequency of occurrence of various prey items consumed by Lake Superior salmonids, 1983-84.

	ALL SPECIES-1983	ALL SPECIES-1984
ALEWIVES	12.50	0.00
SMELT	33.33	53.93
BLOATERS	0.00	2.25
LAKE HERRING	0.00	1.12
SCULPINS	12.50	10.11
9-SPINE STICKLEBACKS	37.50	8.99
BURBOT	4.17	3.37
LAKE WHITEFISH	8.33	2.25
ROUND WHITEFISH	0.00	2.25
COHO SALMON	4.17	0.00
BROWN TROUT	0.00	1.12
LAKE TROUT	8.33	2.25
UNIDENTIFIED	8.33	4.49
MYSIDS	4.17	12.36
INSECTS	29.17	21.35

Several sport and commercially fished species were represented in the diets, namely coregonids and salmonids.

The data indicates that a more diverse forage base, as represented by the larger array of species consumed, exists in Lake Superior than in Lake Michigan. In Lake Michigan four fish species (alewife, smelt, bloater, and perch) constituted the majority of salmonid diets as compared to Lake Superior with seven species (alewife, smelt, sculpins, 9-spine sticklebacks, lake whitefish, and lake trout).

SUMMARY AND CONCLUSIONS

Study of salmonid feeding habits in eastern Lake Michigan led to the following conclusions.

Salmonids fed more often during spring and summer of 1983 than of 1984. The majority of fish found feeding in the fall were immature. From 1983 to 1984 there was a decrease in number of feeding salmonids; chinook salmon declined 72.1%; coho salmon, 43.3%, and lake trout, 1.08%.

The major food of salmonids was fish, with the exception in spring 1983 for coho salmon and in 1984 for steelhead. Cohos fed primarily on zooplankton, *Daphnia* spp., and steelhead on insects.

Alewife and smelt made up the majority (73.2 %) of salmonid diets in 1983, while large quantities of zooplankton in coho salmon and in smaller chinook salmon constituted an additional 21.5 %.

In 1983, alewife and smelt made up the bulk of chinook salmon diets (77.12 %), lake trout diets (82.47 %), and coho salmon diets (41.52 %). Zooplankton in the spring represented 40.07 % of the coho diet.

Four fish species (alewife, smelt, bloater, and perch) made up the bulk (78.1 %) of 1984 salmonid diets.

Salmonids ate fewer alewife in 1984 than in 1983 with frequency of occurrence in chinook salmon being 64.24% during 1983 and 37.50% in 1984; coho salmon, 20.70% compared to 19.00%, and lake trout 69.72% compared to 51.30%.

Organisms within the zooplankton category showed a significantly higher frequency of occurrence in 1983 (23.72%) than in 1984 diets (2.63%).

In 1983 and 1984, seasonal shifts of species consumed indicated more littoral fish and zooplankton being taken in spring (smelt and Daphnia spp.), pelagic fish in summer (alewives, bloaters and perch), and a mixture of littoral, pelagic and benthic species in the fall (alewives, smelt, bloaters, perch, sculpins, 9-spine sticklebacks). A higher diversity of prey items consumed was seen in the fall.

Regional shifts of species consumed correlated with seasonal shifts in 1983. Higher frequency of occurrence of sculpins, 9-spine sticklebacks, and whitefish were reported in salmonids of the northern region. Larger numbers of smelt were consumed in spring of 1983 coinciding with a large spawning smelt run occurring at the same time in the southern region of Lake Michigan.

From 1983 to 1984, an increase in the consumption of bloaters and perch was found to occurr throughout the lake with larger numbers being ingested in the middle region.

Lack of correlation between salmonid length and alewife length reflects salmonids opportunistic feeding behavior, in addition to on-going changes in alewife population dynamics. Kitchells' (1984) forage base models predict that with a decline in forage base, prey populations will be dominated by smaller, younger fish. Furthermore these fish will show up in salmonid diets giving predator - prey length correlations 0 to negative values.

Forage base structure in eastern Lake Michigan is believed to be moving towards a higher abundance of smaller prey species, i.e. more juvenile alewife.

Chinook salmon in 1983 showed a higher affinity for consuming larger size classes (>67.5 cm) of alewife, while chinook salmon in 1984 consumed a broader size range of alewife.

Lake trout showed no significant change in size range of alewife consumed from 1983 to 1984.

Mean alewife lengths consumed in 1983 were not significantly different from those consumed in 1984 ($p>.05$), although a larger abundance of smaller, juvenile alewife were consumed in 1984.

In 1983, predation on organisms within the zooplankton category was primarily by coho salmon (50 - 60 cm) in spring (mostly southern region). An inverse relationship between the occurrence of zooplankton in salmonid diets and predator length was found.

Steelhead, regardless of size, ate insects; however, insects were found more frequently in steelhead from 65 to 90 cm.

The majority of smelt and smaller alewife were consumed by salmonids caught between 3 and 15 meters below the surface of the water and in 7-40 meters of water. Larger alewife were consumed in deeper waters correlated with their distribution.

Grand Traverse Bay salmonids fed predominantly on smelt and illustrated their opportunistic nature to feed on any available prey items.

Coho salmon showed a quicker response (more opportunistic behavior) to the changing forage base than did lake trout, which may have been more selective on various species (e.g. sculpins and alewife).

Study of salmonid feeding habits in southern Lake Superior led to the following conclusions. Salmonids reflected Lake Superiors' smaller forage base, in comparison to that of Lake Michigan. Smelt were the predominate prey item. Lake trout dominated the samples and reflected its benthic nature by consuming relatively large numbers of 9-spine sticklebacks and sculpins.

Changes in salmonid feeding behavior appears to reflect changes in the forage base. The decline in alewife as a predominant prey item in eastern Lake Michigan salmonids may depict a reduction in the alewife population. Furthermore with increasing diversity and numbers of other prey items consumed.

Fewer feeding salmonids were recorded in 1984 than in 1972 (Chiotti, 1973) and 1983. This reduction in predator-prey encounters may indicate a decline in forage availability. Thus the question of forage exploitation by salmonid predators arises and future reduction in salmonid size. Several biologists and I feel this has been the trend. Further study will be necessary to better assess the salmonid fishery as well as answering the question: Do we want a quality or quantity fishery?

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APPENDIX A

To determine total length from caudal peduncle (CP) length the following derived equations were utilized:

<u>ALEWIFE</u>

For CP:	>70	Total length = 13.5068 + 1.482 (CP)
	<50	Total length = 10 + 1.482 (CP)
	<70	Total length = 6 +1.482 (CP)

<u>SMELT</u>

For CP:	>50	Total length = 3.61 + 1.38 (CP)
	<50	Total length = 3 + 1.38 (CP)
	<30	Total length = 1.5 + 1.38 (CP)

<u>BLOATER</u>

For CP:	>50	Total length = -1.6 + 1.59 (CP)
	<50	Total length = -3 + 1.59 (CP)

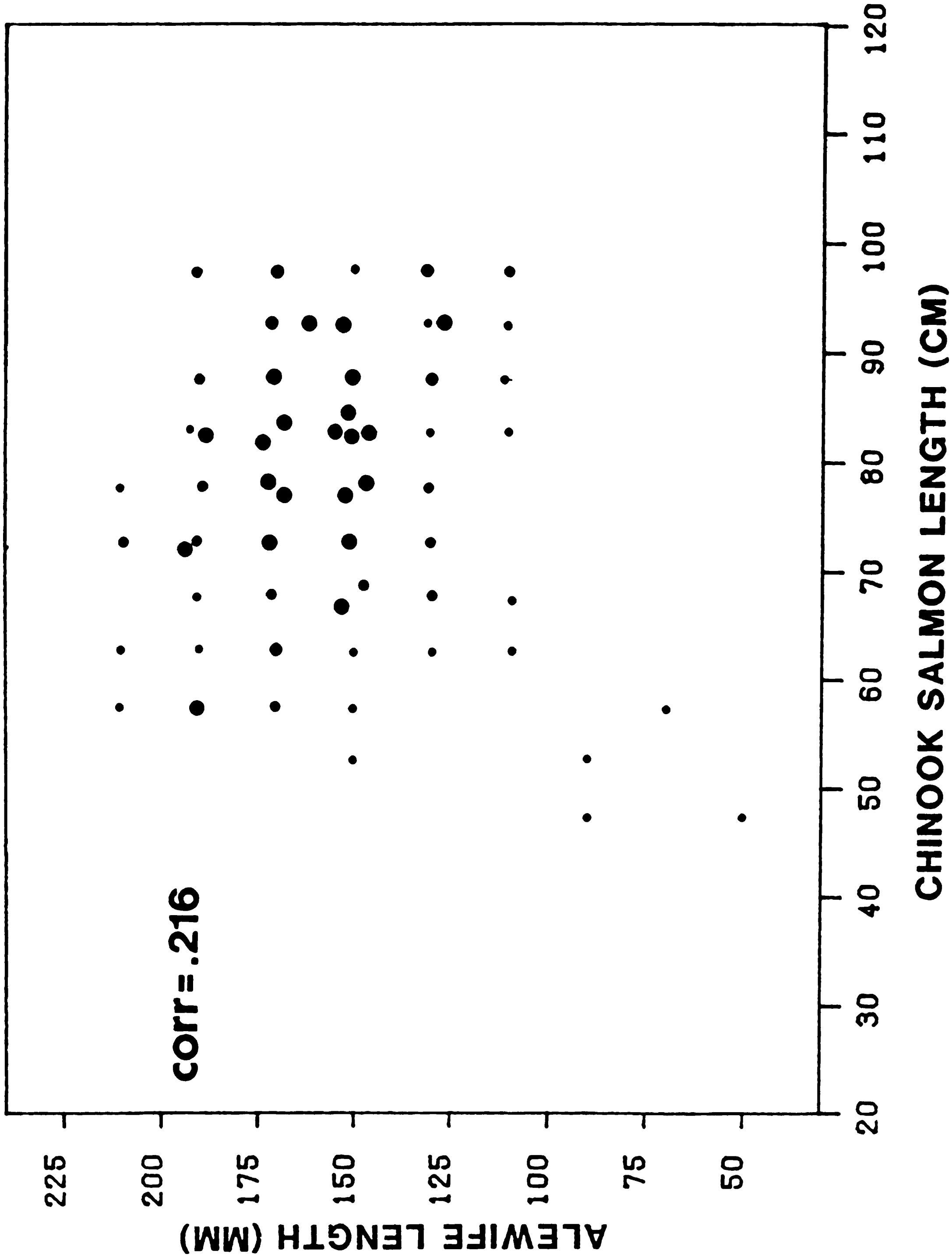
<u>UNIDENTIFIED</u>

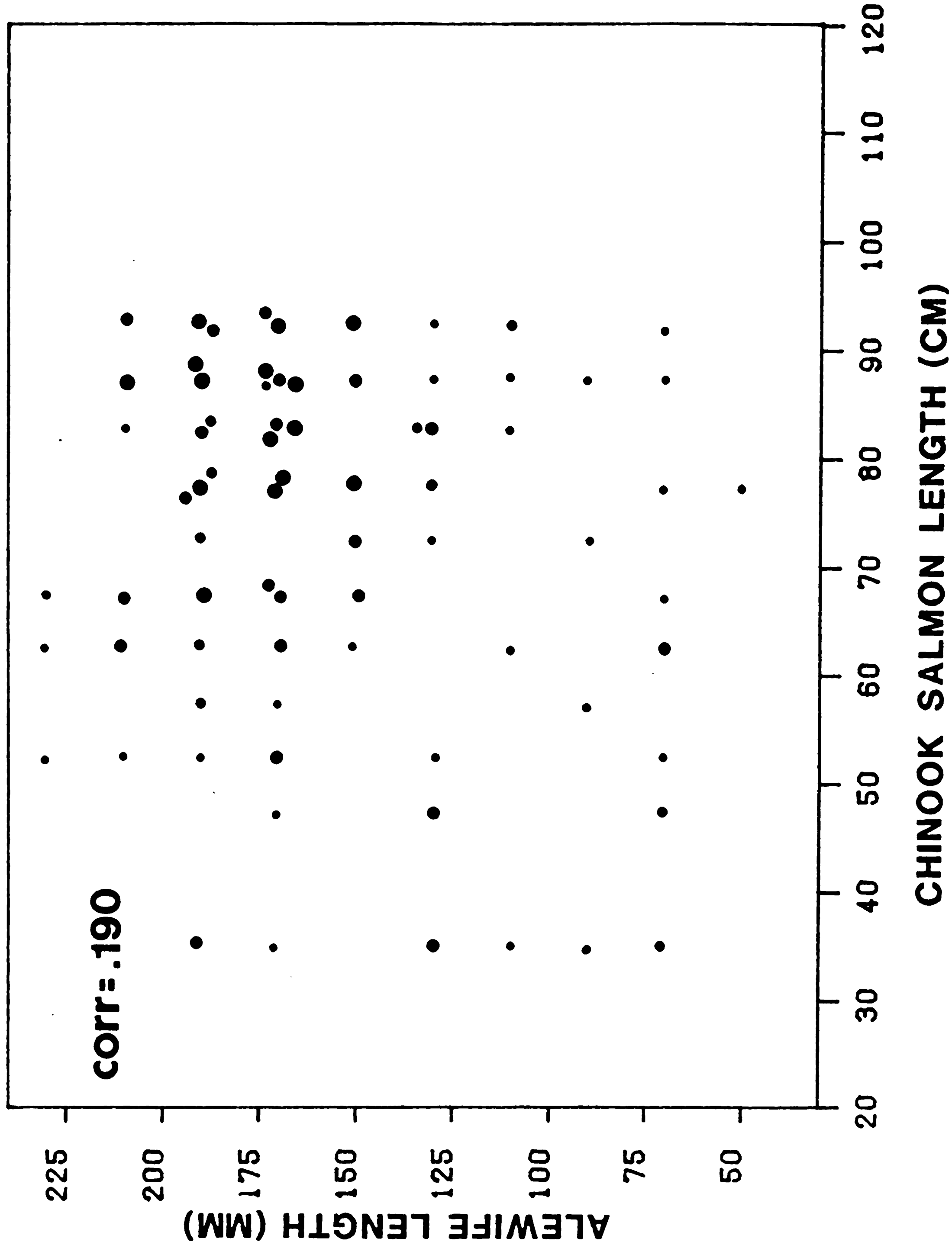
For CP:	>50	Total length = 5.172 + 1.484 (CP)
	<50	Total length = 3 + 1.48 (CP)

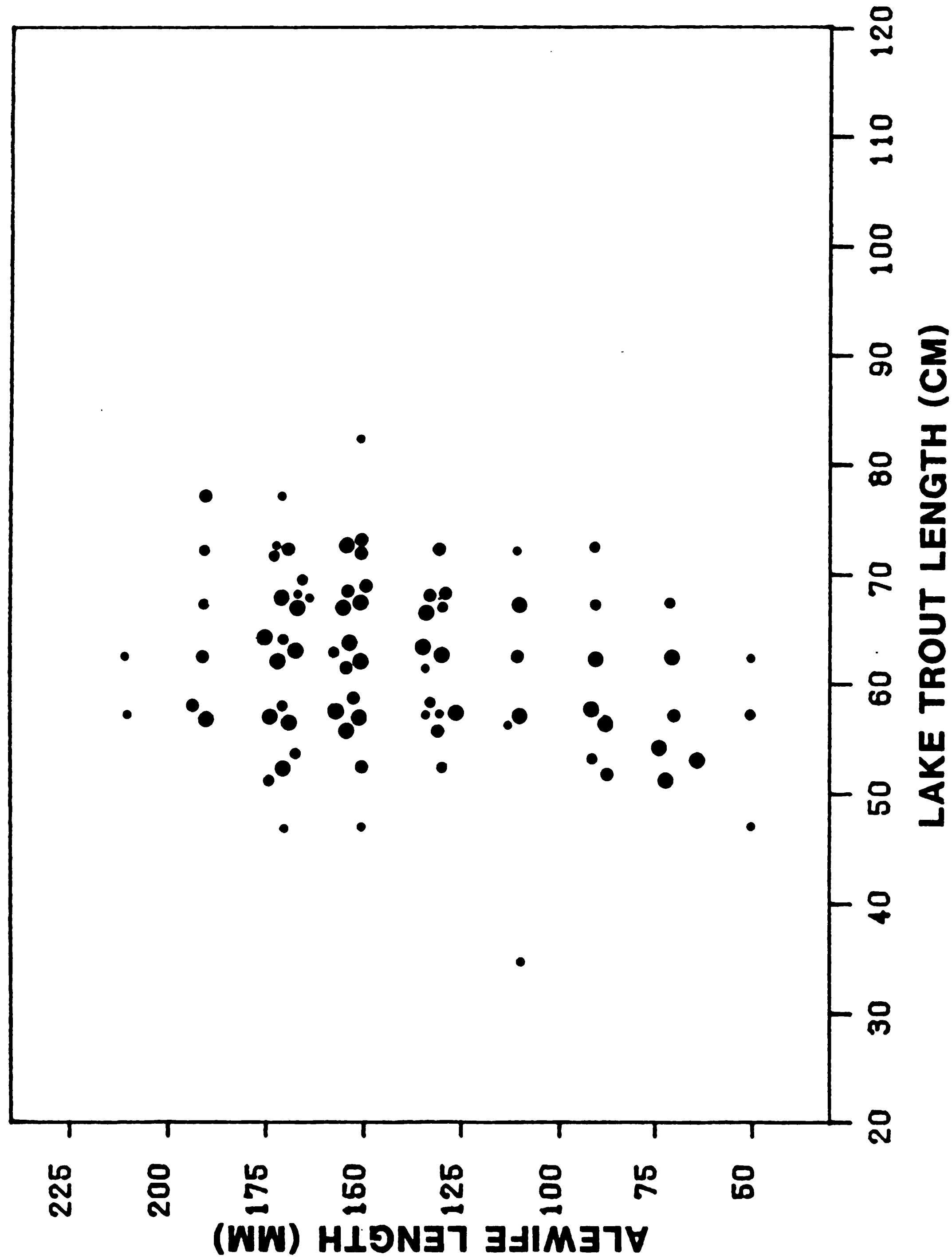
Appendix B.--Estimated biomass (thousands of metric tons) of forage species available to bottom trawls in Lake Michigan, fall 1973-82; confidence intervals are shown in parentheses (Wells and Hatch, 1982).

Year of sampling	Alewives		Smelt		Slimy Sculpins	Total forage
	Adult	Young-of-the-year	Adult	Young-of-the-year		
1973	114.4 (97.7-131)	3.9 (1.9-6.0)	14.3 (8.3-20.3)	0.25 (0.15-0.36)	0.99 (0.59-1.39)	134 (109-159)
1974	92.1 (78.5-106)	30.9 (19.4-42.4)	12.0 (9.2-15.8)	0.50 (0.27-0.73)	1.37 (0.80-1.94)	137 (107-166)
1975	108.8 (86.0-132)	13.3 (7.5-19.1)	13.1 (8.3-18.0)	0.59 (0.19-0.99)	2.39 (1.50-3.29)	138 (104-173)
1976	49.3 (38.7-52.7)	7.2 (3.9-10.4)	10.5 (6.9-14.2)	0.57 (0.38-0.76)	2.11 (1.32-2.90)	70 (51-89)
1977	44.9 (37.0-52.7)	6.9 (3.1-10.7)	11.8 (7.1-16.6)	0.18 (0.12-0.25)	0.93 (0.58-1.29)	65 (48-81)
1978	76.6 (52.4-95.8)	14.4 (8.6-20.2)	15.6 (11.3-20.0)	0.62 (0.45-0.79)	0.62 (0.42-0.82)	108 (78-138)
1979	86.5 (63.1-110)	5.1 (2.6-7.5)	15.2 (10.5-20.0)	0.70 (0.47-0.92)	1.01 (0.69-1.33)	109 (77-139)
1980	47.5 (31.9-63.2)	14.0 (6.0-22.0)	16.7 (12.6-21.0)	2.48 (1.75-3.20)	1.02 (0.52-1.52)	82 (53-111)
1981	71.6 (58.3-84.9)	22.0 (13.6-30.4)	27.6 (19.1-36.1)	2.56 (1.52-3.59)	0.89 (0.19-1.59)	125 (93-157)
1982	40.9 (24.1-57.8)	3.9 (1.2-6.5)	30.8 (19.8-41.8)	1.97 (1.16-2.78)	0.38 (0.17-0.60)	78 (46-110)

Appendix C.--Scatterplots of 1983 chinook salmon, 1984 chinook salmon, and 1984 lake trout versus alewife length, respectively.


corr=.216
ALEWIFE LENGTH (MM)
225
200
175
150
125
100
75
50
CHINOOK SALMON LENGTH (CM)
20
30
40
50
60
70
80
90
100
110
120


corr=.190
ALEWIFE LENGTH (MM)
225
200
175
150
125
100
75
50
CHINOOK SALMON LENGTH (CM)
20
30
40
50
60
70
80
90
100
110
120


LAKE TROUT LENGTH (CM)
20 30 40 50 60 70 80 90 100 110 120
ALEWIFE LENGTH (MM)
225 200 175 150 125 100 75 50

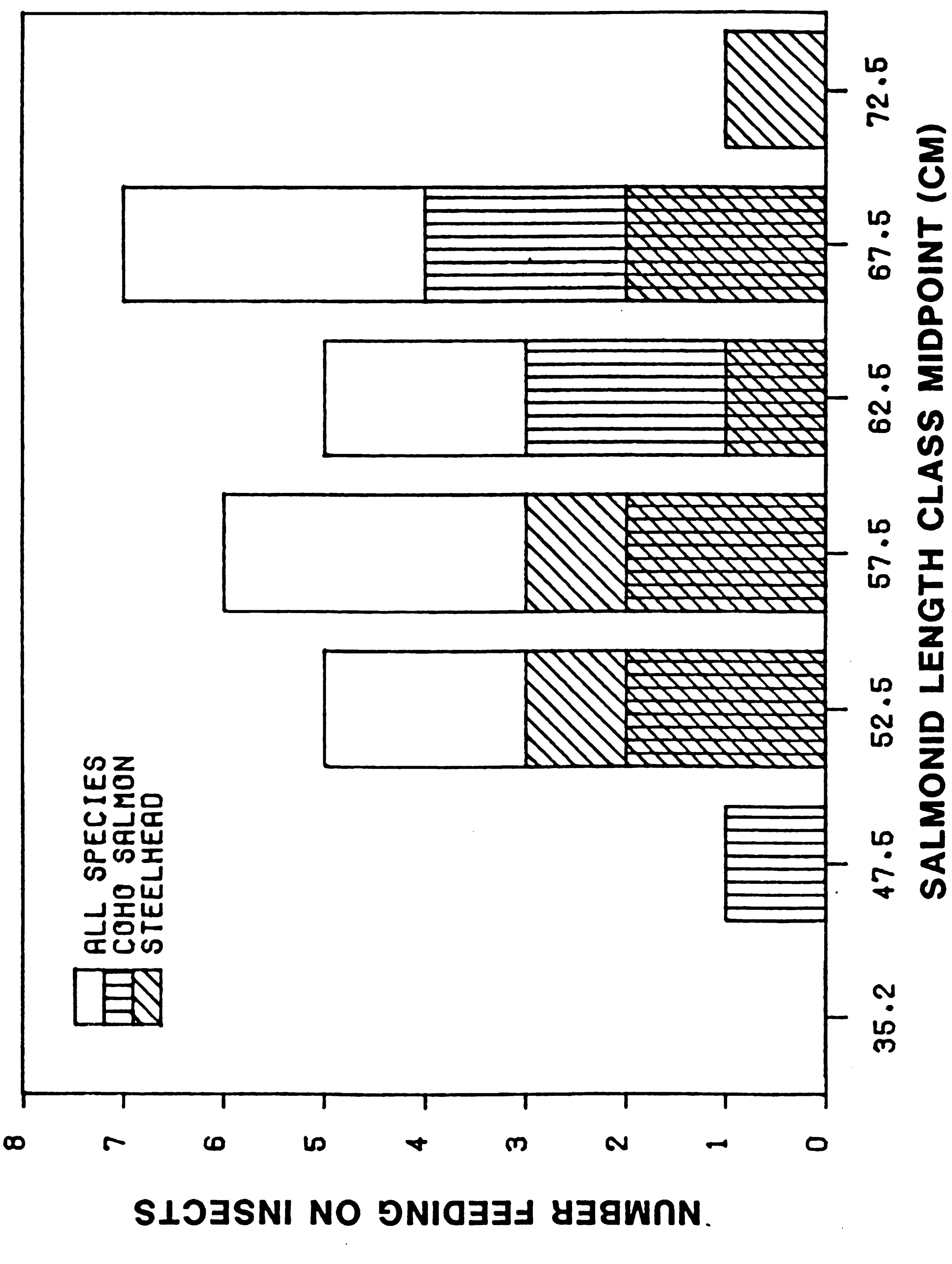
Appendix D.--Size distribution of the various salmonids in eastern Lake Michigan, 1983.

	PREDATOR LENGTH (CM)												
	25.4-45	45-50	50-55	55-60	60-65	65-70	70-77	75-80	80-85	85-90	90-95	95-108	ALL
CHINOOK S.	22	4	22	36	27	29	32	35	50	45	45	30	377
SPRING	16	1	17	30	20	16	13	25	28	8	4	0	178
SUMMER	6	3	1	4	5	3	3	4	7	7	3	2	48
FALL	0	0	4	2	2	10	16	6	15	30	38	28	151
COHO S.	10	9	83	37	66	136	36	3	0	1	0	0	381
SPRING	5	8	81	35	4	2	0	0	0	0	0	0	135
SUMMER	0	1	2	0	6	3	0	0	0	0	0	0	12
FALL	5	0	0	2	56	131	36	3	0	1	0	0	234
LAKE T.	2	2	6	17	37	25	19	5	3	0	0	0	116
SPRING	0	2	4	10	25	17	16	3	2	0	0	0	79
SUMMER	2	0	2	7	11	5	2	2	0	0	0	0	31
FALL	0	0	0	0	1	3	1	0	1	0	0	0	6
STEELHEAD	0	1	7	5	2	3	2	0	0	0	1	1	22
SPRING	0	1	7	4	1	2	1	0	0	0	0	0	16
SUMMER	0	0	0	1	0	0	1	0	0	0	1	1	4
FALL	1	0	0	0	0	0	0	1	0	0	0	0	2
BROWN T.	1	1	0	3	1	0	0	0	0	0	0	0	6
SPRING	1	1	0	1	0	0	0	0	0	0	0	0	3
SUMMER	0	0	0	1	0	0	0	0	0	0	0	0	1
FALL	0	0	0	1	1	0	0	0	0	0	0	0	2

Appendix D.--Size distribution of the various salmonids in eastern Lake Michigan, 1984.

	PREDATOR LENGTH (CM)												
	25.4-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-108	ALL
CHINOOK S.	155	50	39	62	110	106	78	110	162	156	119	83	1230
SPRING	50	8	12	40	71	56	37	55	62	39	24	8	462
SUMMER	96	28	18	15	27	35	27	27	46	48	27	19	413
FALL	9	14	9	7	12	15	14	28	54	69	68	56	355
COHO S.	10	45	208	128	179	74	14	3	1	1	0	0	663
SPRING	3	43	198	41	6	0	0	0	1	0	0	0	292
SUMMER	3	0	5	39	36	9	3	1	0	0	0	0	96
FALL	4	2	5	48	137	65	11	2	0	1	0	0	275
LAKE T.	4	23	99	137	124	102	59	14	7	2	0	1	572
SPRING	1	1	7	7	20	18	26	3	3	1	0	0	87
SUMMER	3	22	92	130	104	84	32	11	4	1	0	1	484
FALL	0	0	0	0	0	0	1	0	0	0	0	0	1
STEELHEAD	1	4	17	7	4	9	14	18	7	7	1	0	89
SPRING	1	4	14	3	3	4	7	5	3	2	0	0	46
SUMMER	0	0	2	1	0	3	5	10	3	4	0	0	28
FALL	0	0	1	3	1	2	2	3	1	1	1	0	15
BROWN T.	14	20	25	12	1	1	0	0	0	0	0	0	73
SPRING	2	15	6	4	0	1	0	0	0	0	0	0	28
SUMMER	9	4	15	7	1	0	0	0	0	0	0	0	36
FALL	3	1	4	1	0	0	0	0	0	0	0	0	9

Appendix E.--Salmonid size predation on insects in eastern Lake Michigan, 1983.


ALL SPECIES
COHO SALMON
STEELHEAD
NUMBER FEEDING ON INSECTS
0
1
2
3
4
5
6
7
8
35.2
47.5
52.5
57.5
62.5
67.5
72.5
SALMONID LENGTH CLASS MIDPOINT (CM)