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ECOLOGY OF FORAGE FISH FOLLOWING
CESSATION OF OVERHARVEST OF WALLEYE
IN HENDERSON LAKE, ONTARIO

by

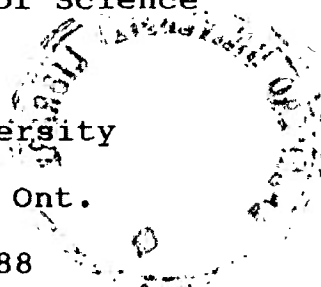
KEVIN TRIMBLE ©

A thesis submitted to the Department of Biology in partial
fulfillment of the requirements for the
degree of Master of Science.

Lakehead University

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ABSTRACT

I examined the forage base of Henderson Lake, Ontario following collapse of its walleye stock due to overexploitation, and an inexplicable decline of the ninespine stickleback population. In response to these events a very large yellow perch year class was produced. Subsequently, adult perch density increased while growth, mortality, size at maturity and fecundity decreased. Continued stunting in young yellow perch could not be attributed to direct interspecific competition with abundant shiners. As northern pike activity increased shiner activity declined but yellow perch remained active and available as prey. Thus, small perch occurred much more frequently in the diets of northern pike than did shiners. The large numbers of stunted yellow perch may provide excellent forage for enhancing the recovery of the walleye population.

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Dave Reid, Sandra McIver and Sue Trimble probably still wake up at night to visions of tubs full of slimy, striped, dead data illuminated by lanterns through a cloud of budworms and mosquitos. I thank them for their assistance, tolerance and sanity in the field.

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GENERAL INTRODUCTION

An experimental "pulse fishing" management scheme is being tested on the walleye (Stizostedion vitreum vitreum) population of Henderson Lake, a small boreal percid community in northwestern Ontario. At least 90% of the fish were removed between 1980 and 1982, simulating a deregulated fishery. The fishery was then closed to determine the extent of walleye recovery, and timing of subsequent pulses. Large numbers of YOY walleye did not enter the population until three years later in 1985 (Reid and Momot 1985; K. Trimble, unpublished data). During this entire period neither common white sucker (Catostomus commersoni) nor northern pike (Esox lucius) increased in adult numbers. Initially (1977) sticklebacks (Pungitius pungitius), and to a lesser extent, yellow perch (Perca flavescens) formed the main forage for walleye and pike (Nunan 1983). However, stickleback populations unexpectedly collapsed in 1981. Since then, perch under 90mm in length have formed the principal forage for pike and walleye (Reid 1985).

The yellow perch and shiner populations were monitored between 1981 and 1985. My objectives were primarily to assess responses of the perch population to the walleye removal, and secondarily to determine the potential effects of these responses on walleye recovery. In reaction to decreased predation and competition yellow perch could either have increased in growth to become top predators, or increased in density to produce a large, fecund, slow growing forage population (Johnson 1977; Botsford 1981; Laarman and Schneider 1986; Green 1986). While the former

may have impeded walleye recovery, the latter may have enhanced it.

The role of the large shiner (Notropis heterolepis and N. volucellus) populations in the Henderson Lake community is unclear. However, factors regulating forage fish populations may be important in top predator population dynamics (Shephard and Cushing 1979; Forney 1980). I therefore initiated pilot feeding studies to determine the potential for competition between stunted young-of-year yellow perch and adult shiners.

Adult shiners have also been underutilized as forage by northern pike, the remaining top predator in the lake (Reid 1985). Northern pike are not size selective in Henderson Lake (Reid 1985) and readily accept shiners as prey in other systems (Nursall and Pinsent 1969; Beyerle and Williams 1968; Hess and Heartwell 1978). This apparent avoidance was hypothesized to be the result of availability of adult shiners relative to alternate prey. By sampling all fish species in a small bay throughout the daylight period I hoped to assess the presence and activity of potential forage species during peak feeding periods of pike.

YELLOW PERCH POPULATION DYNAMICS

INTRODUCTION

The response of a forage species to overexploitation of its predators may help us understand the reasons for collapse of target species (Colby 1984; Lawler 1965). If a strong relationship between predator and prey exists this may heighten a response in numbers or growth of forage populations (Nielsen 1980; Walters and Hillborn 1978). Successful management therefore demands that we understand which mechanisms regulate dynamics of both predator and prey populations as well as their interactions (Ware 1980).

The walleye (Stizostedion vitreum vitreum) population of Henderson Lake was "pulse" fished between 1980 and 1982. At least 90% of the fish were removed during this period, simulating a deregulated fishery. Following closure of the fishery to allow walleye recovery, large numbers of YOY walleye did not enter the population until three years later in 1985 (Reid and Momot 1985; K. Trimble, unpublished data). During this entire period neither common white sucker (Catostomus commersoni) nor northern pike (Esox lucius) increased in adult numbers. Initially (1977) sticklebacks (Pungitius pungitius), and to a lesser extent, yellow perch (Perca flavescens) formed the main forage for walleye and pike (Nunan 1983). However, stickleback populations unexpectedly collapsed in 1981. Since then, perch under 90mm in length have formed the principal forage for pike and walleye (Reid 1985).

In 1981 we began the study of yellow perch (Perca flavescens) in Henderson Lake (Ritchie 1984). Additional gill

netting and seining in 1984 and 1985 monitored both yellow perch and shiner (Notropis volucellus and Notropis heterolepis) populations. This allowed examination of responses of this forage base to the decreases in walleye caused by overexploitation.

METHODS AND MATERIALS

Henderson Lake is a 150ha boreal percid lake in northwestern Ontario. Mean and maximum depths are 2.5 and 5.5m respectively. Other physical parameters are summarized by Reid and Momot (1985).

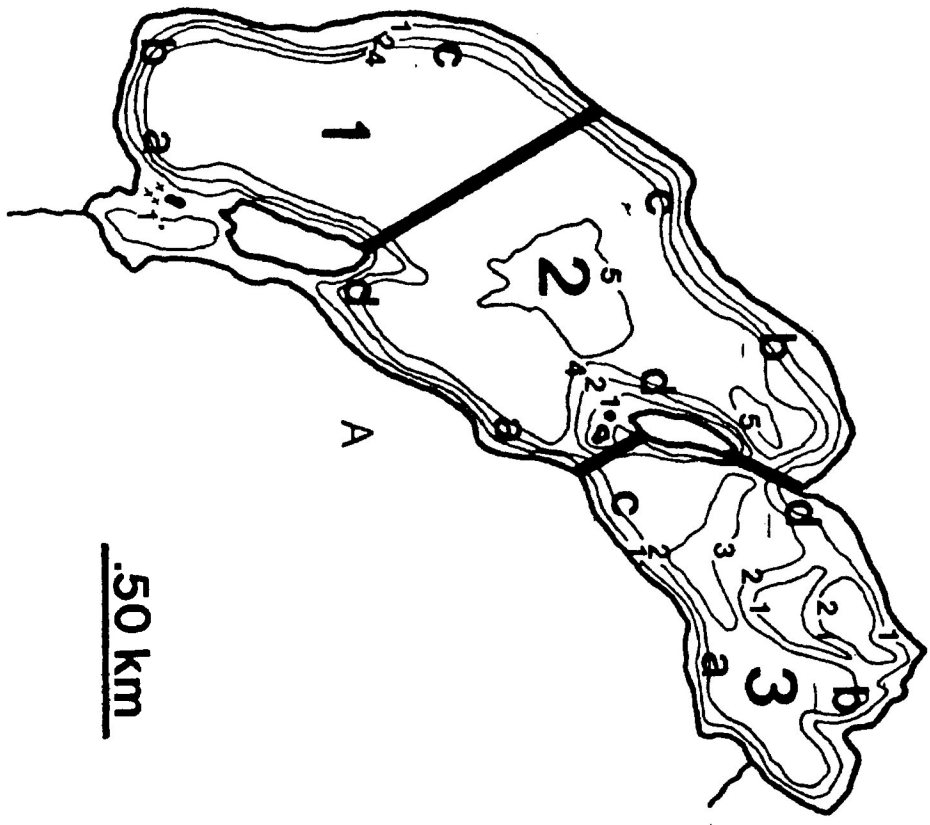
Beginning in 1981, a beach seining program was carried out at nine marked sites on Henderson Lake (Fig. 1.1). YOY yellow perch are most vulnerable to this gear from late June through August on calm, sunny afternoons (Ritchie 1984). In order to maintain consistency with previous data collections, six seine hauls per station were made in 1984, and four hauls in 1985, at each of the nine sites (Fig. 1.1).

A bag seine measuring 18.2m by 1.2m deployed parallel to shore was hauled in with 30.8m ropes attached at each end. The area covered by one such sample was .047 ha. The bag was comprised of 3.2mm square mesh, while that of the wings measured 6.5mm.

All individuals of each species were sorted and counted. Subsamples were then preserved in 10% formalin with a small quantity injected directly into the body cavity and gut, for subsequent growth and feeding studies.

Annual trends in forage fish abundance were examined by calculating the percent composition by species and the mean

Figure 1.1. Gillnet (A) and beach seine (B) sampling locations in Henderson Lake. The lake was divided into three gillnetting zones (1-3) shown in A, within which there were four sampling sites (a-d). Nine stations shown in B were used for beach seining (1-9).



number of each species per hectare seined. Abundance of YOY yellow perch, was also ranked relative to the year of maximum abundance.

Owing to a relatively limited data set and because there were no correlations between YOY perch abundance and growing-degree-days ($>15^{\circ}\text{C}$) or precipitation (Ritchie 1984), climatic factors were not emphasized in this study.

Subsamples of YOY yellow perch were soaked in water for twelve hours, then weighed (nearest 0.1g) and measured (nearest millimetre). Total length regressed on sampling date provided estimates of seasonal growth, as well as trends in abundance and temperature.

Green monofilament gill nets 2.4m wide, consisting of four 15.2m long panels of 19.1mm, 25.4mm, 38.1mm and 50.8mm stretched mesh were utilized to sample juveniles and adults. A randomly chosen site (of a possible four) was fished in each of three areas of the lake (Fig. 1.1) on each sampling day. Samples consisting of three concurrent gill net sets were taken on a minimum of ten dates from June through August during dawn (0400-0800hrs) and dusk (2000-2400hrs) periods. At least thirty sets were made for each of 1984 and 1985, during the periods of peak yellow perch activity (Helfman 1981; Hasler and Bardach 1949; Engel and Magnuson 1976). This allowed estimates of adult yellow perch relative abundance based on catch-per-unit-effort of effectively recruited fish. Total length of all fish was measured to the nearest millimetre. Northern pike, walleye and common white suckers were weighed (nearest 20.0g) and

immediately released. Perch and other small fish were weighed (nearest 0.1g) and sex determined by gonad inspection.

Opercles and otoliths were removed from a stratified subsample (Ketchen 1950; Ricker 1975), cleaned with warm water and stored in scale envelopes for age determination analysis. Yellow perch specimens preserved in 10% formalin were retained for subsequent feeding analyses.

Annual length frequency histograms helped determine the size of effective recruitment (Ricker 1975; Ritchie 1984). All CPUE samples were combined for each time period (4:00 to 8:00 and 20:00 to 24:00) since Ritchie (1984) found no seasonal change within periods. Mean annual CPUEs were compared with a Kruskal-Wallis analysis of variance (Sokal and Rohlf 1981).

Age determination was performed from stratified subsamples (Ketchen 1950) of yellow perch from 1981 to 1985 using the methods of J. Tost (1984, pers. comm.), Chilton and Beamish (1982), Bardach (1955), Le Cren (1947), and Williams and Bedford (1974). Opercles and otoliths, collected during index gill net programs, were used as the primary and secondary tissues respectively. The "break and burn" technique was used on otoliths.

Age determinations from both tissues were verified by several readers including J. Babuluk (DFO, Winnipeg) as cited in Ritchie (1984), J. Tost (OMNR, Thunder Bay), and S. McClelland (DFO, Pacific Biological Station, Nanaimo, B.C.).

Annual mean length at age was calculated for each sex, by employing otoliths and opercles in 1984 and 1985. To measure

growth changes and sex differences annual length at age regressions were compared through analysis of covariance. Length-weight regressions, performed on 1984 and 1985 data, were compared with those of previous years.

Fecundity and maturity were analyzed from fall samples made on 3 October, 1984 and 16 September, 1985. However, because of the small number of perch caught, 1984 was omitted from the analysis. Each fish was measured (nearest 1.0mm), weighed (nearest 0.1g), and its ovary was stored in 10% formalin.

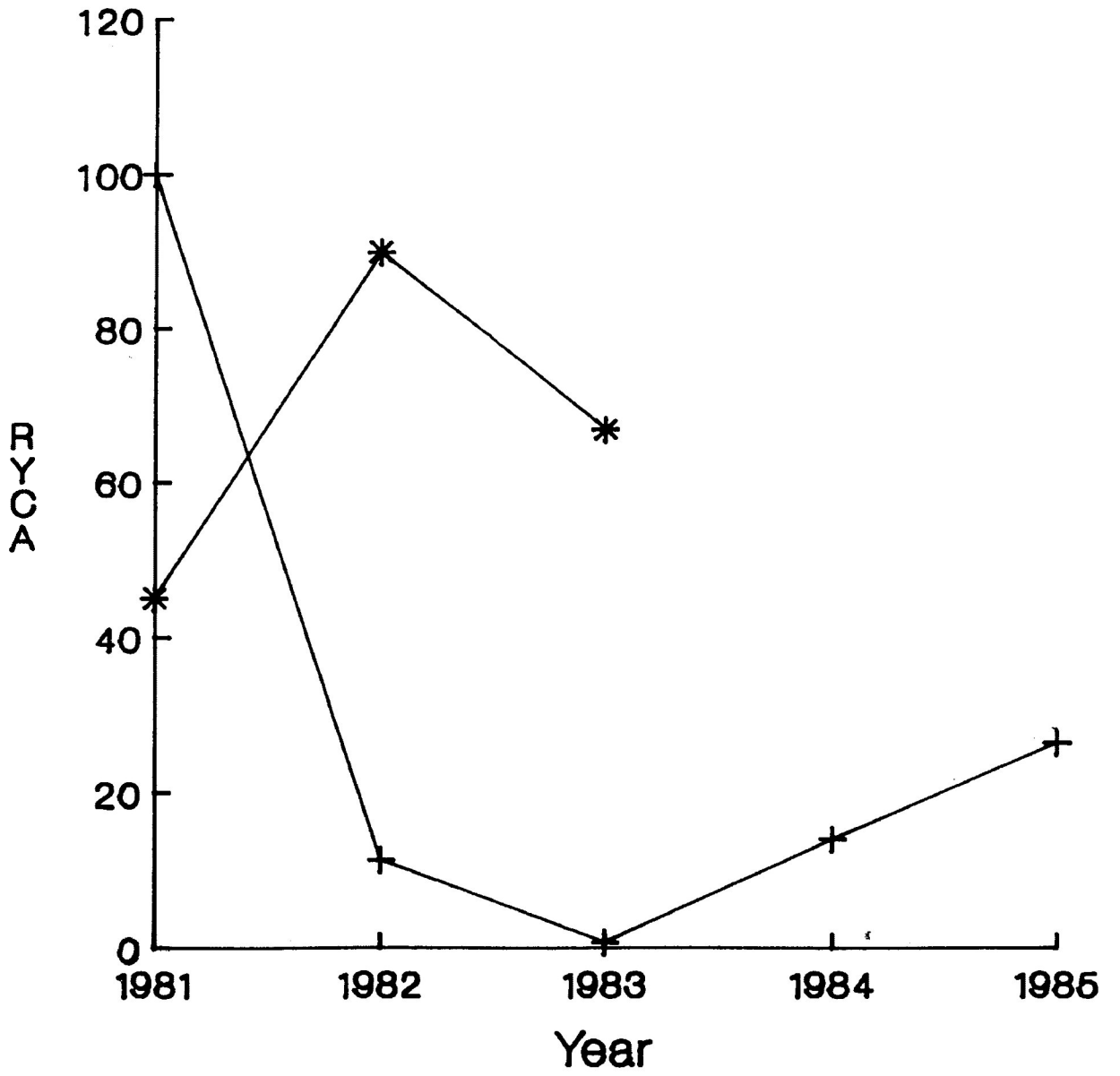
Percent maturity was recorded by 1cm length intervals, and owing to the abrupt delineation of resultant distributions, no further analyses were performed.

Absolute fecundity was determined using the gravimetric method described by Bagenal (1978), Weber and Les (1982) and Ritchie (1984). The ovary was blotted dry, weighed (nearest 0.01g) and three subsamples were removed and weighed. The mean egg count from the three subsamples was then used to determine absolute fecundity of the entire ovary. Absolute fecundity regressed against total fish length was compared with earlier data (Ritchie, 1984) through analysis of covariance.

RESULTS

The largest hatch of young-of-year yellow perch during the study period was produced in 1981 (Fig. 1.2). YOY abundance then declined dramatically until 1983 when it attained only 0.8% of the 1981 level. In 1984 and 1985 the relative abundance climbed from the low levels of 1983 (Fig. 1.2) to about 26% of the 1981 abundance. Further, in 1981, catches were comprised mainly of

Figure 1.2. Relative year class abundance (RYCA) of young-of-year yellow perch, expressed as a percentage of the year of maximum abundance, in Henderson and Savanne lakes, July, 1981 to 1985.



+ Henderson L. * Savanne L.

YOY yellow perch, but by 1983 juveniles and adults were more abundant (Fig. 1.3). Mimic and Blacknose shiners dominated the forage fish assemblage in 1982, 1984 and 1985.

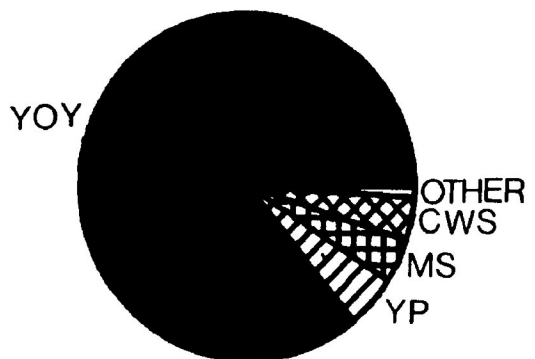
The species encountered in Henderson Lake can be seined efficiently (Lyons 1984; Forney 1971). Efficiency does not vary with fish density, but inherent variability of abundance estimates must nevertheless be accepted (Lyons 1984). Such variability is evident from the wide range of annual abundance estimates for YOY yellow perch (Table 1.1). Estimates of juvenile perch abundance were even more variable. Therefore, resultant mortality calculations (YOY to juvenile) yielded several negative values, indicating incomplete recruitment to the gear, and were of limited value.

The YOY to juvenile mortality estimate for 1982 was omitted. Estimates for the remaining three years followed perch abundance trends during their first growing season. Mortality may thus be density dependent, decreasing in years of low relative perch abundance (Table 1.1).

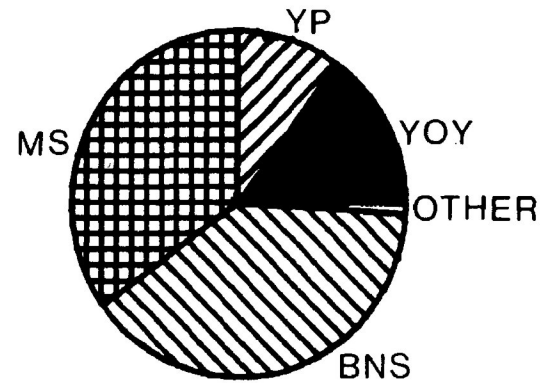
No relationships between YOY perch abundance, growth and growing-degree-days were apparent. Both good and poor growth and high and low abundance occurred in warm years such as 1981 and 1982 (Table 1.1). In contrast, young perch also experienced good growth in cold years (1983). Poor growth was experienced at both the highest and lowest abundance levels, 1981 and 1983 respectively.

In nearby Savanne Lake, water temperatures and climatic trends were similar to those of Henderson Lake (Ritchie 1984).

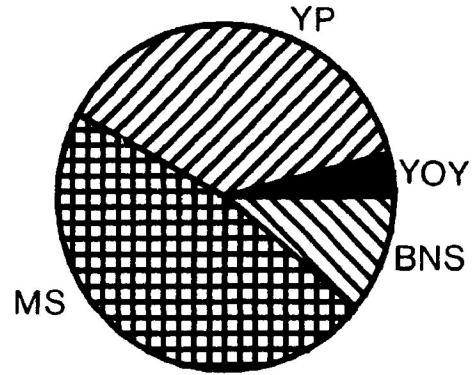
Figure 1.3. Percent composition of young-of-year yellow perch (YOY), juvenile and adult yellow perch (YP), blacknose shiners (BNS), mimic shiners (MS) and common white suckers (CWS) in beach seine catches, July, 1981 to 1985.



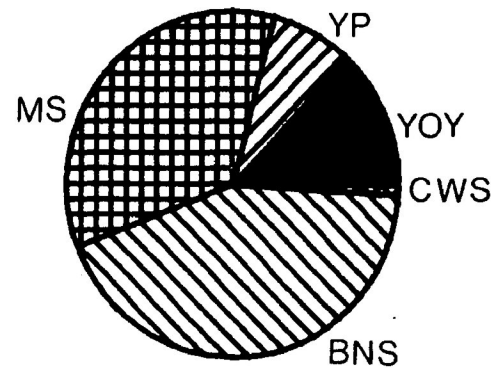
1981



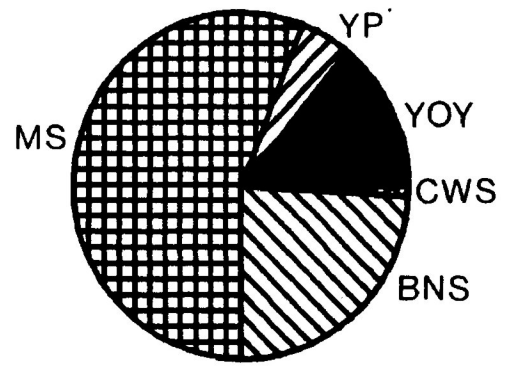
1982



1983



1984



1985

Table 1.1. Annual relative abundance, growth and mortality of young-of-year yellow perch, and growing degree days in Henderson Lake.

Year	N	Period	Relative Abundance		Rel. Yr.Cl. Abund.*	Growth mm/day	Mortality Z	GDD>15°C	
			Range	Mean				May17- May30	May17- June30
1981	30	May23-Aug24	5647-34788	19,122	100.0	0.22	2.50	20.3	105.3
1982	54	June6-Aug24	401-4004	2,147	11.4	0.53	-0.55	25.3	80.6
1983	81	July1-Aug16	2-409	147	0.8	0.25	0.25	0.0	NA
1984	52	Jun29-Aug23	815-4690	2,658	14.0	0.35	1.07	0.0	39.4
1985	22	Jun30-Jul31	140-3147	5,080	26.6	NA	NA	0.0	2.7

*Relative year class abundance (%).

While YOY perch relative year class abundance remained at less than 50% of peak levels in Savanne Lake it peaked in Henderson Lake (Ritchie 1984; Fig. 1.2). These levels were maintained in Savanne Lake but they subsequently plummeted in Henderson Lake (Fig. 1.2).

Mean total length remained below 11cm and did not change between 1981 and 1985 (Fig. 1.4). Most of the catch consisted of a single length class in 1984 and 1985, suggesting year class dominance.

The length of effective recruitment was provided by Figure 1.4. From these modes, mean annual catch-per-unit-effort of yellow perch for both dawn and dusk were calculated. In 1981 and 1982 dusk CPUE levels were similar, as were those of 1984 and 1985 (Kruskal-Wallis ANOVA, $P > 1.0$). During the latter two years levels increased significantly over those of the first two years ($P < 0.05$, Table 1.2).

Annual yellow perch growth was compared by analyzing length at age regressions using analysis of covariance. Regressions of otolith against opercle age determinations resulted in correlation coefficients of at least 90%, with slopes not significantly different than one.

Good agreement between various individual ageing technicians occurred for both otolith and opercle age determinations. The only significant difference, using the Wilcoxon matched-pairs signed ranks test, was with opercle age assigned by J. Babuluk ($P = .047$), who tended to underage such samples by approximately a year. This difference was considered negligible.

Figure 1.4. Length-frequency histograms showing percent composition (%) of gillnetted yellow perch length classes, 1981 to 1985.

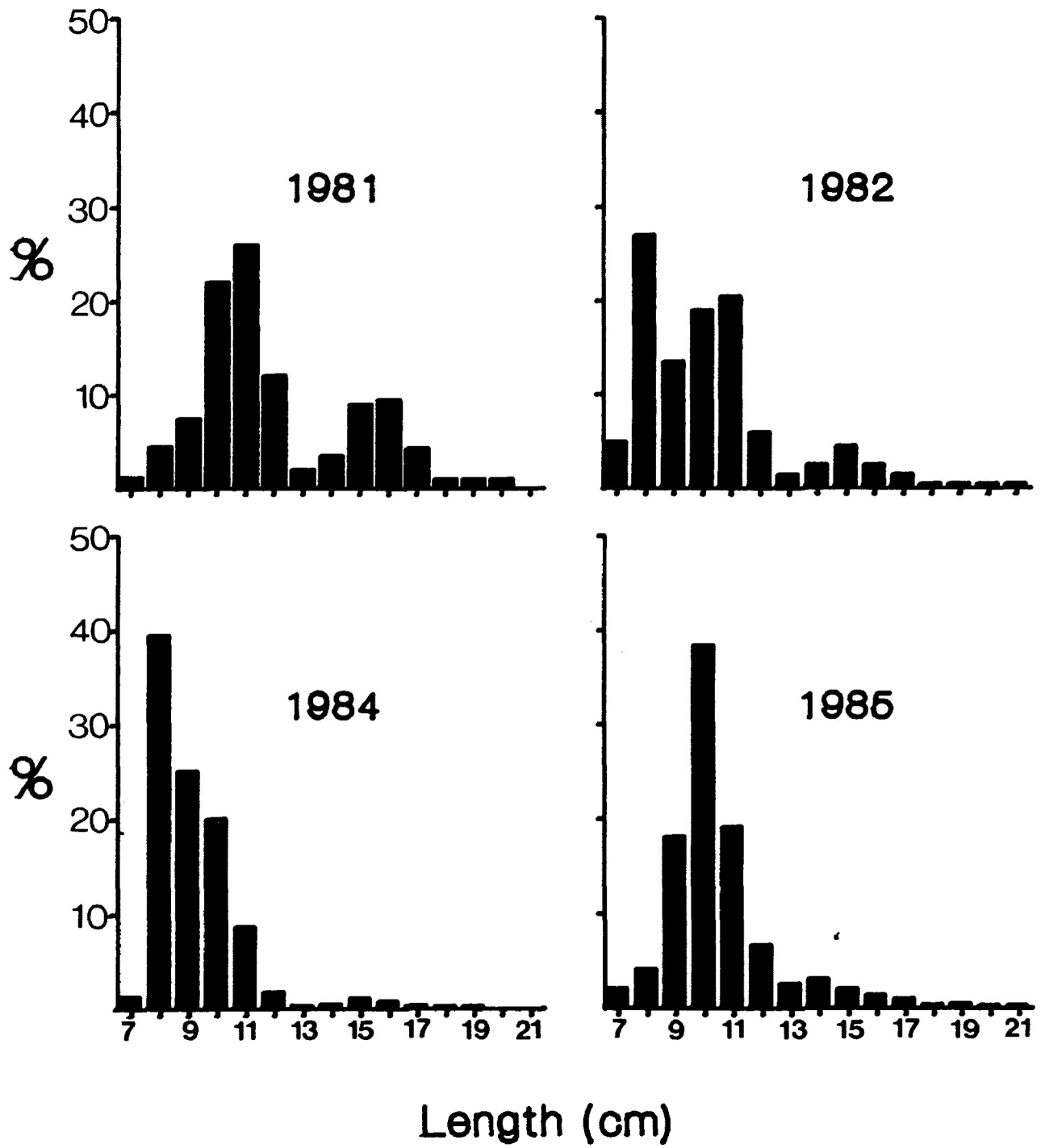


Table 1.2. Yellow perch
CUE^a by year and sampling
period.

Time of day	Year	CUE ^a	S.E. ^b
AM	1981	6.61	1.40
	1982	7.93	2.00
	1984	52.60	8.80
	1985	34.97	5.10
PM	1981	7.94	1.10
	1982	9.06	2.46
	1984	78.39	22.62
	1985	71.06	14.40

^aNumber of fish per hour.

^bStandard error.

Differences between sexes occurred in both slopes and intercepts of length at age regressions in 1984 and 1985 (ANCOVA $P < .001$), but data for the three preceding years could be pooled. No growth trends were evident until 1983 and 1984 (Table 1.3, Fig. 1.5). From 1981 to 1985 the overall trend suggests reduced growth in length at age ($P < .001$, Table 1.3).

Annual age composition was constructed from total gill net catches each year, using age-length keys (FAO 1981). Note that three year old perch consistently dominated the age structure each year and that this age group made up about 70% of the population in 1984, confirming that the large 1981 year class had become dominant (Fig. 1.6). Mortality estimates in 1985 reflect the strength of this year class. Mean instantaneous mortality rates of all recruited age groups decreased from 1.67 to 0.53 during the study period.

In 1985 when males matured at lengths of 8 to 10cm all females matured at 10 to 11cm (Table 1.4). Compared with length at maturity in 1981 and 1982 an obvious reduction occurred (Table 1.5). Males consistently matured at age three while females were three to four years old (Table 1.5). Thus, Henderson Lake yellow perch matured at a fixed age, but at a smaller size as growth decreased.

Absolute fecundity regressed against total length of yellow perch was compared with earlier data (Ritchie 1984). All regressions were significant, with correlation coefficients of at least 92%. ANCOVA revealed that absolute fecundity differed significantly between years. Mean values, especially for fish

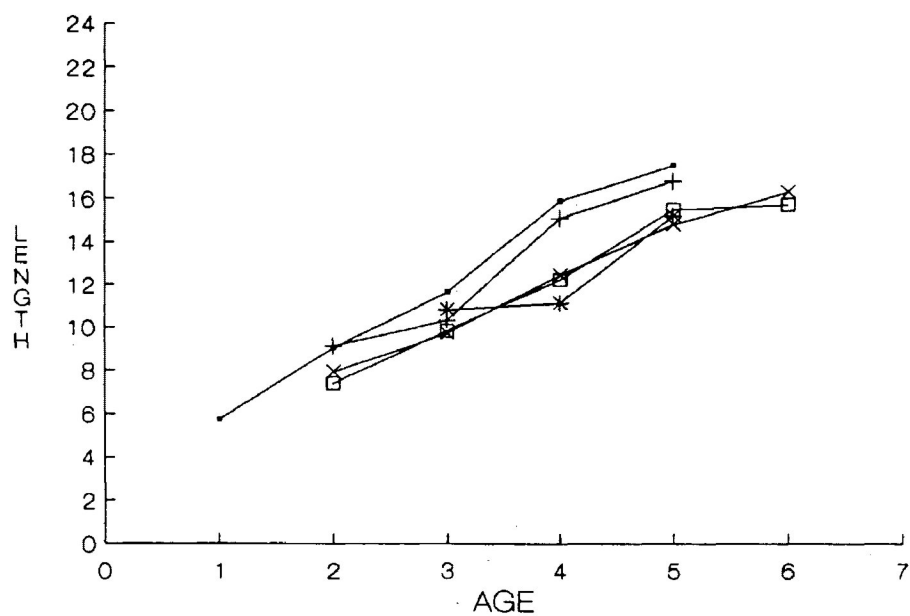
Table 1.3. Mean total length (cm) at age of male and female yellow perch from Henderson Lake by year.

Sex	Year	Age					
		I	II	III	IV	V	VI
Males	1981	5.7*	9.0	11.6	15.9	17.5	
	1982		9.1	10.3	15.1	16.8	
	1983			10.8	11.1	15.2	
	1984		7.4	9.8	12.2	15.5	15.7
	1985		7.9	9.7	12.4	14.8	16.3
Females	1981	5.2	8.9	11.5	16.6	18.0	20.6
	1982		8.7	11.0	15.7	19.2	
	1983			10.1	13.3	16.8	19.7
	1984		7.6	10.6	14.0	17.2	19.9
	1985		8.1	10.5	14.3	17.1	18.7

*mean total length (cm)

Figure 1.5. Growth of male and female yellow perch, expressed as mean total length (cm) at age, 1981 to 1985.

MALES



FEMALES

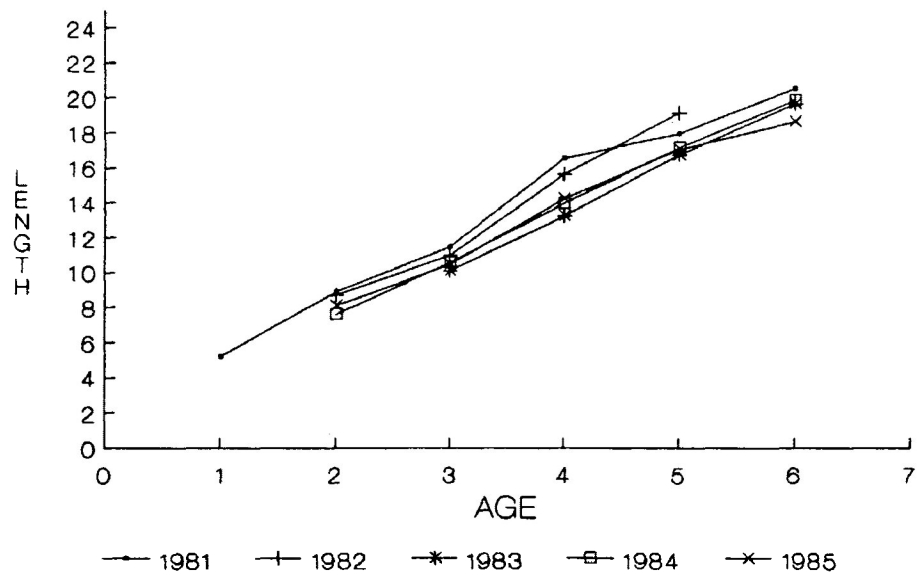


Figure 1.6. Age compositions showing percent relative abundance (%) of gillnetted yellow perch age classes, 1981 to 1985.

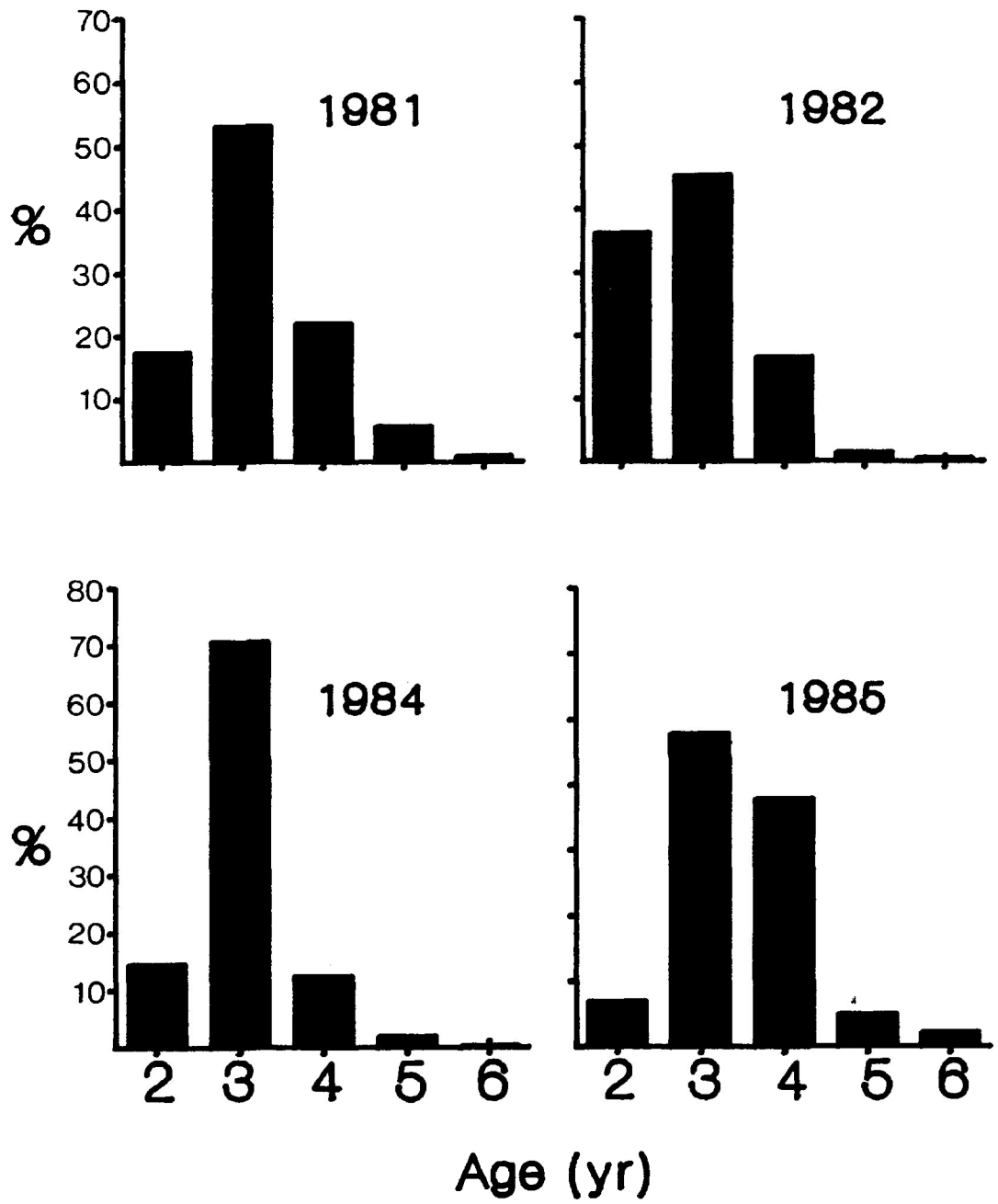


Table 1.4. Number and percent of mature yellow perch at length by sex, 1985.

Length (cm)	Males			Females		
	N ^a	number ^b	%	N ^a	number ^b	%
7	0			8	0	0
8	7	6	86	6	0	0
9	7	5	71	2	0	0
10	33	33	100	9	8	89
11	18	18	100	12	12	100
12	5	5	100	18	18	100
13	5	5	100	9	9	100
14	3	3	100	9	9	100
15	1	1	100	6	6	100
16	0			1	1	100

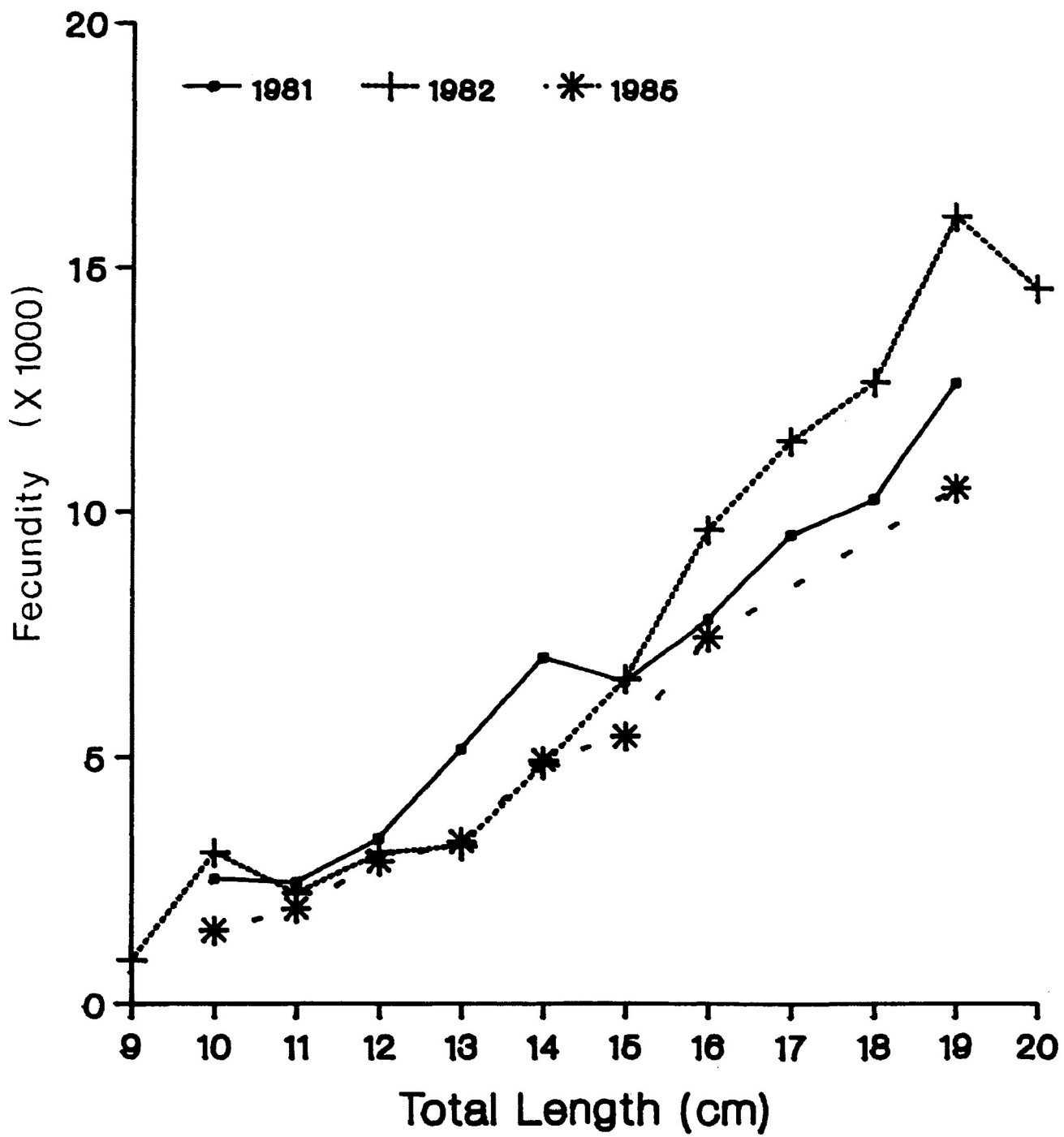
^aNumber sampled

^bNumber mature

Table 1.5. Size and age of maturity of yellow perch by sex and year.

Year	Males		Females	
	Length (cm)	Age	Length (cm)	Age
1981	11-11.9	3	13-13.9	3-4
1982	10-10.9	3	14-14.9	3-4
1985	8-10.0	2-3	10-11.0	3-4

Figure 1.7. Absolute fecundity of yellow perch length classes, 1981, 1982 and 1985.



greater than 15cm, at first increased from 1981 to 1982 but then fell in 1985 (Fig. 1.7).

DISCUSSION

The inexplicable collapse of the ninespine stickleback population resulted in increased predation pressure by northern pike and walleye on small yellow perch (Nunan 1983). These sticklebacks probably competed with, and preyed upon small pelagic perch (Olsen 1979; Wootton 1977). Stickleback diets often consist of larval insects, cladocerans and fish fry (Scott and Crossman 1973; Tompkins and Gee 1983). Conversely, sticklebacks were also preyed upon by large perch (>13cm) in 1981 as they were found in 20% of the stomachs examined (Ritchie 1984).

Walleye predation, can cause extensive mortality in young yellow perch, often affecting both abundance and recruitment (Swenson and Smith 1976; Nielsen 1980; Forney 1971; Lyons 1984).

The impact of concurrent reductions in walleye and stickleback on the yellow perch population is confounded. Thus, competitive and predatory pressures on yellow perch were drastically reduced in 1981, at the exact same time that a very large perch year class appeared (Fig. 1.2).

In 1984 catch-per-unit-effort of yellow perch increased dramatically. Age composition (Fig. 1.6) and length frequency analyses (Fig. 1.4) both suggest that this 1981 year class was very strong (Weatherly and Rogers 1978).

While yellow perch populations exhibit age class dominance (Schneider 1972; Ney 1978; Forney 1971), the percent composition of this dominant age class from year to year may reflect juvenile

survival to recruitment (Weber and Les 1982). For instance, the age III year class consistently dominated the Henderson Lake perch population (Fig. 1.6). However, the 1981 cohort was much larger than normal and catch levels were much higher in 1984. This further illustrates the successful recruitment of the 1981 cohort into the mature population.

Percent age composition can also be used to estimate year class strength (Mann 1973). Analyzing the perch year classes from 1977 to 1982 revealed the 1981 year class to be 30% larger than any other, and nearly twice as large as the 1982 cohort. This provides further support for the hypothesis suggesting that reduced predation and competition significantly affected perch year class strength in Henderson Lake.

Following production of the large 1981 year class, YOY yellow perch abundance fell dramatically in both 1982 and 1983. Ritchie (1984) observed a 25% increase in the incidence of cannibalism during these two periods. This diet shift was accompanied by, and attributed in part to similar reductions in the occurrence of stickleback as prey items, resulting from the catastrophic stickleback population crash. There 'being great numbers of juvenile perch present, potential for intense cannibalism increased (Schneider 1972; Holcik 1977). Dominant yellow perch year classes are known to suppress several subsequent year classes (Holcik 1977; Alm 1952), with cannibalism perhaps serving as an important determinant of yellow perch population structure (MacLean and Magnuson 1977; Schneider 1972; Ware 1980). Whether this happens depends on predatory

impacts, growth, and environmental influences. Above certain critical biomass levels, intense cannibalism can initiate an important compensatory response (Craig and Kipling 1983).

Compensatory population responses in adult Windermere perch were insufficient to eliminate fluctuations in recruitment caused by external factors, such as temperature and predation on young (Craig and Kipling 1983). Their stock-recruitment curve suggested that very large year classes may be produced at low stock density. Weber and Les (1982) and Kempinger et. al. (1975) showed great variation in yearly abundance of perch with large year classes occasionally produced by relatively small parental stocks. My study was consistent with a number of others (Koonce et al. 1977; Forney 1971; Weber and Les 1982) in failing to relate climatic variables to yellow perch population dynamics, although some maintain that temperature is important (Craig et al. 1979; Kipling 1984; Weber and Les 1982; Kitchell and Stewart 1977).

In 1984 and 1985 adults in Henderson Lake displayed a variety of responses to the events of the preceding five years. Population size increased while growth, mortality, size at maturity and fecundity all significantly decreased. These responses are typical of density changes (Botsford 1981; Craig and Kipling 1983), within small or shallow lake systems which are forage and habitat limited (Alm 1946). Depressed forage availability causes decreased growth rates which may be accompanied by lower mortalities in adults. Although individual fecundity may decrease, the overall population fecundity or

reproductive potential remains the same or increases (Craig and Kipling 1983), because of decreased size at maturity.

Mortality between hatch and recruitment may be a more important population regulator than density dependent changes in population fecundity (Craig and Kipling 1983; Cushing 1978). Parameters of the adult population fail to sufficiently compensate for a perturbation and may not be useful as predictors of year class strength, but rather, as indicators of perturbation in a stock. Colby (1984) suggested that increased stunting in prey populations serves as an indicator of an overharvested target species. A large, fecund, slow growing forage population may provide an optimal forage for the re-establishment of overexploited top predators. Such is the case in Henderson lake where the juvenile walleye population began to increase at the end of the study period.

Over the years the perch of Henderson Lake have become even more stunted relative to other north temperate and boreal populations (McComish 1981; Smith 1977; Deedler 1951; Craig 1974; Ney 1978). Interestingly, these fish stunt very early in their life cycle, suggesting that food availability for very young perch may critically determine growth patterns throughout their entire lives (Ney 1978, Persson 1987a).

Such stunting responses were noted by Colby (1984) for centrarchids, and by Hess and Heartwell (1978) for muskellunge. According to Botsford's theory of stable equilibrium levels (Botsford 1981), some change in density which affects the availability of forage to individuals in a population, may

become manifested in permanent growth changes and reproductive strategies of the population.

Decreased predation and competition might have produced one of two alternative responses in Henderson Lake perch. In reaction to the vacated niche of one top predator (walleye), which was not reoccupied by another predator (northern pike), the perch population could either have increased in growth and succeeded walleye as a top predator, or instead, increased in density and stunted (Johnson 1977; Schneider 1972; Botsford 1981; Eshenroder 1977). The stocking of predators and control of competitors has successfully increased growth of perch, resulting in the development of a number of perch fisheries (Laarman and Schneider 1986, Green 1986). In contrast, the removal of common white suckers from a Minnesota lake reduced competition for food between perch and suckers without increasing predation pressure (Johnson 1977). In this case perch density was not suppressed, and their growth further declined. Competition and predation on Henderson Lake perch both decreased. These factors exacerbated intense intraspecific competition and caused a stunting response, rather than a growth response.

As density decreases both habitat and resources become available. Since reproductive potential is undiminished, a very large year class may be produced if the environment is favorable. This year class then rapidly depletes resources. Growth decreases and subsequent year classes are suppressed through competition and cannibalism. Eventually the dominant cohort moves out of the population, allowing the cycle to begin again. Mechanisms which

created this cycle, and which regulate its frequency and amplitude remain largely unknown.

FORAGE FISH INTERACTIONS

INTRODUCTION

Forage availability plays an important role in community trophic dynamics (Mills and Forney 1981; Hess and Heartwell 1978; Persson 1987a,b). Prey abundance and predator feeding habits may form a density dependent control on the growth of predators such as yellow perch, Perca flavescens (Shephard and Cushing 1979). Growth regimes of yellow perch affect their vulnerability to top predators such as walleye (Stizostedion vitreum vitreum) and northern pike (Esox lucius). Moreover studies of feeding habits may help measure the degree of ecological segregation among predators (Moyle 1973, Hickey 1975). Therefore, assessment of the status of a fishery may necessitate investigation of forage fish feeding interactions.

Walleye were subjected to a 'pulse fishing' management scheme in Henderson Lake, Ontario. Between 1980 and 1982 90% of the walleye were removed. Following this removal the fishery was closed. Large numbers of young-of-year walleye did not enter the population until 1985, signalling recovery of the walleye population (Reid and Momot 1985; K. Trimble unpub. data). During this entire period neither common white sucker (Catostomus commersoni) nor northern pike increased in adult numbers.

In 1977 sticklebacks (Pungitus pungitus), and to a lesser extent, yellow perch were the main forage fishes of walleye and pike (Nunan 1983). However, stickleback populations unexpectedly collapsed in 1981. Since then perch under 90mm in length formed the principal forage for pike and walleye (Reid 1985).

Declines in walleye and stickleback populations have caused increases in abundance of yellow perch, and perch growth is now even more retarded (Trimble 1988). Stunting has often been attributed to either resource limitation or competition in fishes (Botsford 1981; Rask 1986; Persson 1987b). In Henderson Lake I felt that, in addition to intraspecific competition, interactions at the community level would of necessity further delineate which mechanisms regulate yellow perch (Ritchie 1984; Trimble 1988). Since the lake supports large populations of shiners (Notropis heterolepis and N. volucellus), and stunting begins during the earliest life stages of yellow perch, I hypothesized that interspecific competition from shiners may be important in determining the structure of the yellow perch population. Such relationships may then have ramifications within higher trophic levels through resultant patterns of resource availability as well as competition between forage fishes and various life stages of top predators. Ultimately these community interactions may influence the recovery and health of the walleye fishery.

Feeding studies were carried out on samples of shiners and young of the year yellow perch. I determined the extent of ecological overlap and the potential for interspecific competition between them.

In spite of the great abundance of shiners and a lack of size selectivity by northern pike, the latter do not prey heavily on shiners in Henderson Lake (Nunan 1983; Reid 1985). Northern pike accept minnows as forage in other lakes and prefer them in

laboratory environments (Nursall and Pinsent 1969, Beyerle and Williams 1968, Hess and Heartwell 1978). I therefore hypothesized that shiners are avoided by northern pike in Henderson Lake in the presence of alternate prey which are more available at times of peak northern pike feeding. By sampling all fish species in a small bay throughout the daylight period I hoped to assess the presence and activity of potential forage species during peak feeding periods of pike.

These studies served as an initial assessment of species interactions in a boreal percoid community. Through them I hoped to direct future research to assess the importance of considering forage species and community interactions in fisheries management.

METHODS AND MATERIALS

Forage Fish Diets

Henderson Lake is a 150ha boreal percoid lake in northwestern Ontario. Mean and maximum depths are 2.5 and 5.5m respectively. Other physical parameters are summarized by Reid and Momot (1985).

In 1984 a beach seining program was carried out at nine marked sites. Ritchie (1984) found YOY yellow perch most vulnerable to this gear from late June through August on calm, sunny afternoons. A bag seine measuring 18.2m by 1.2m was deployed parallel to shore and hauled in with 30.8m ropes attached at each end. The area covered by one such sample was

.047ha. The bag was comprised of 3.2mm square mesh while the wing mesh measured 6.5mm.

All individuals were sorted and counted by species. Subsamples were then preserved in 10% formalin (a small quantity was also injected directly into the body cavity and gut) for subsequent growth and feeding studies.

Feeding analyses were conducted on stomach samples collected from June 29 to July 13, 1984. This two week period was representative of rapid first year growth of yellow perch inhabiting the littoral zone after the Spring warming period.

A modified Brillouin's index of diet diversity was used to establish potential diet breadths for the predator groups and to determine sample size (Hair 1980). Hoffman (1979) felt that the point at which the cumulative diversity of pooled stomachs stabilizes indicates that examination of additional stomachs will not change prey species number or composition enough to increase uncertainty. Therefore, the cumulative diet at this point approximates that of the population. The equation was

$$H_k = 1/N_k (\log_{10} N_k! - \log_{10} N_{ki}!)$$

where H_k is the diversity in K pooled stomachs, N_k is the number of individuals in these stomachs and N_{ki} is the number of individuals of the i^{th} species in K pooled stomachs (Hair 1980; Hoffman 1979).

Entire intestinal tracts were removed, sliced open and emptied into petri dishes containing a small quantity of alcohol. Precise weight or volume measurements were precluded by numbers and size of prey, as well as the facilities available. Instead,

prey items were separated into ecologically sound taxa and ranked by relative volume occupied in the gut. These ranks were then used to generate a mean bulk index for each predator group (Saiki 1976). In addition, frequency of occurrence, mean percent composition of prey taxa by number, and size of at least fifty individuals of each taxum were recorded when available. This was accomplished using an ocular micrometer in a dissecting microscope at 25X power.

Predator-Prey Interactions

Between June 13 and July 31, 1985 northern pike feeding periodicity and forage fish availability were assessed in a small bay in Henderson Lake. Four panels of green monofilament gill net 2.4 X 15.2m with stretched mesh sizes ranging from 25.4mm to 62.5mm were deployed from shore to depths of 3 meters. Three diurnal periods (first light to 10:00, 10:00 to 19:00 and 19:00 to last light) were sampled at least 14 times each to record pike catch-per-unit-effort, length, weight and location in the water column.

Since gastric lavage as used by Reid (1985) produced high mortality of released fish and low confidence in the removal of all stomach contents, individual pike were sacrificed for gut contents. Stomachs were removed and stored in 70% alcohol for several days before being analyzed in the laboratory. Stomach contents were weighed (nearest .01g) and identified to derive frequency of occurrence of prey taxa and the feeding periodicity of pike. This was calculated as the weight of total stomach contents per gram body weight of pike (Keast and Welsh 1968).

Forage fish presence and activity were assessed concurrently with the pike netting program. Though transect swims and use of minnow traps had been designed to assess exact location of forage fishes in the bay, these were precluded by poor visibility and trap avoidance respectively. Instead, I extended my beach seining program in this bay to include twilight periods.

RESULTS

Diet diversity indices for YOY yellow perch and shiners stabilized at relatively low levels (Hoffman 1979) and at small sample sizes (Fig. 2.1). This suggests that either resources are limited or these predators are specialist feeders. Indices for young perch stabilized at higher levels than those for shiners (Fig. 2.1) indicating a wider potential diet breadth for young perch in early to mid summer. Perch stomach samples contained 16 forage categories (Fig. 2.2), 6 more than shiners. Stabilized diversity for samples from both predator groups indicated that sample sizes were sufficient.

Bosminids, Holopedium spp. and copepods were eaten in high numbers by a large proportion of the YOY yellow perch sampled (Figs. 2.2 and 2.3). Shiners concentrated on bosminids and ostracods. Several prey categories were utilized exclusively by each predator group while others were shared (Figs. 2.2 and 2.3). Mean bulk indices (Table 2.1) confirmed that copepods and most cladocerans eaten by young perch in early to mid summer of 1984 were important forage. Important prey of shiners included chydorids, bosminids and ostracods during the same period.

Figure 2.1. Relationship of the modified Brillouin's diet diversity index and sample size of YOY yellow perch and shiners caught in beach seines, 1984.

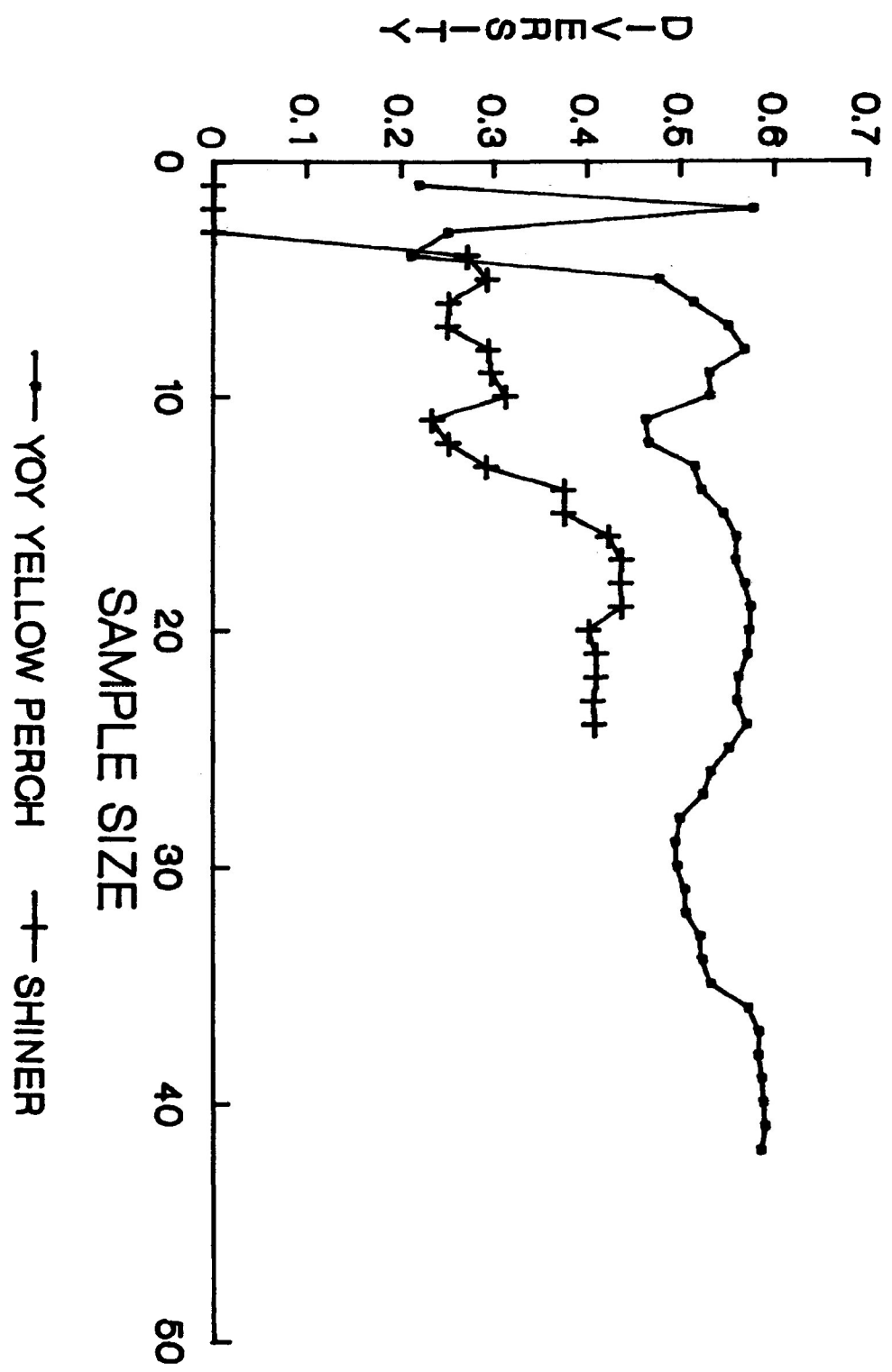


Figure 2.2. Percent frequency of occurrence of food taxa in the stomachs of YOY yellow perch and shiners, 1984.

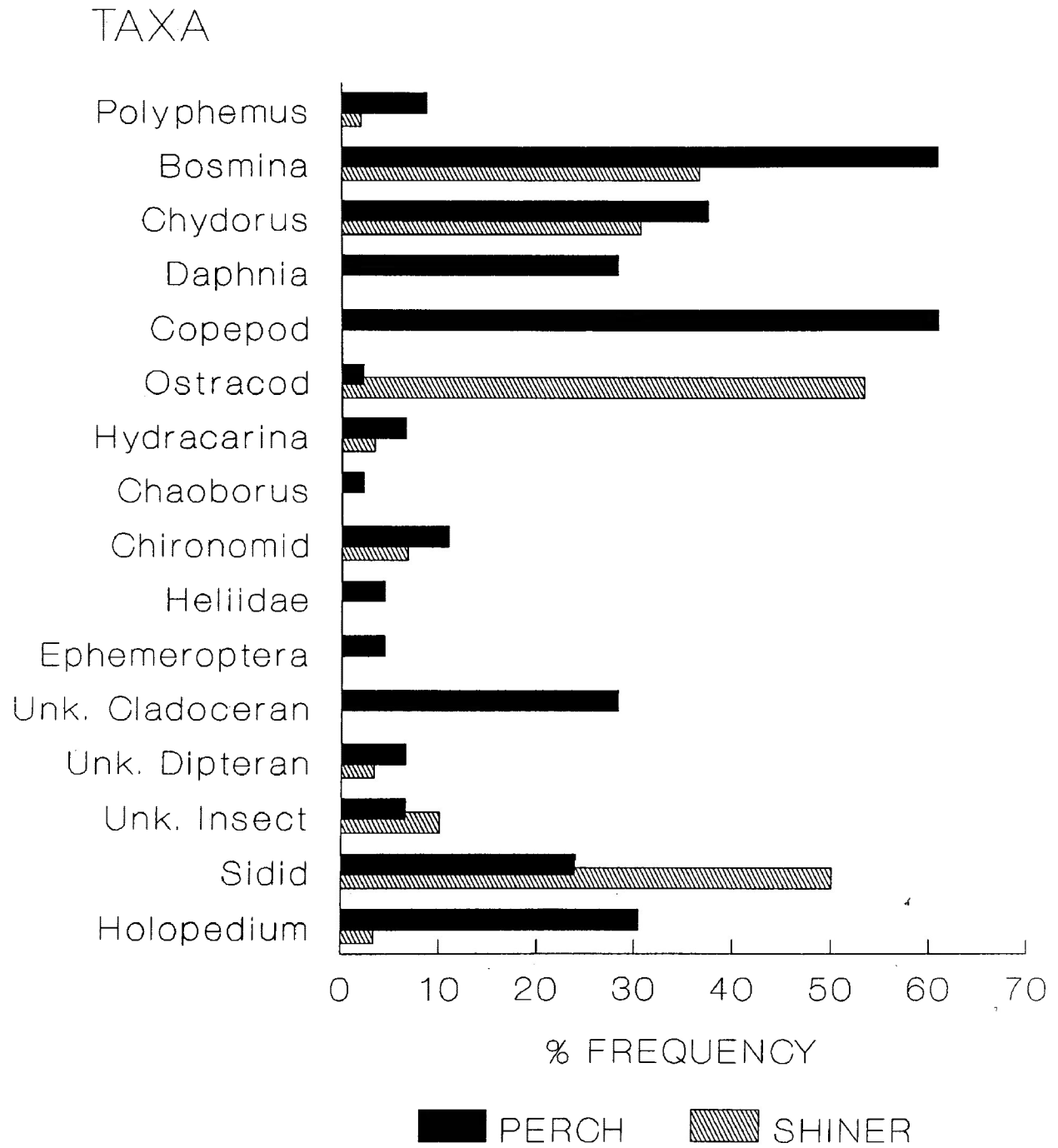


Figure 2.3. Percent of mean total number of food taxa in the stomachs of YOY yellow perch and shiners, 1984.

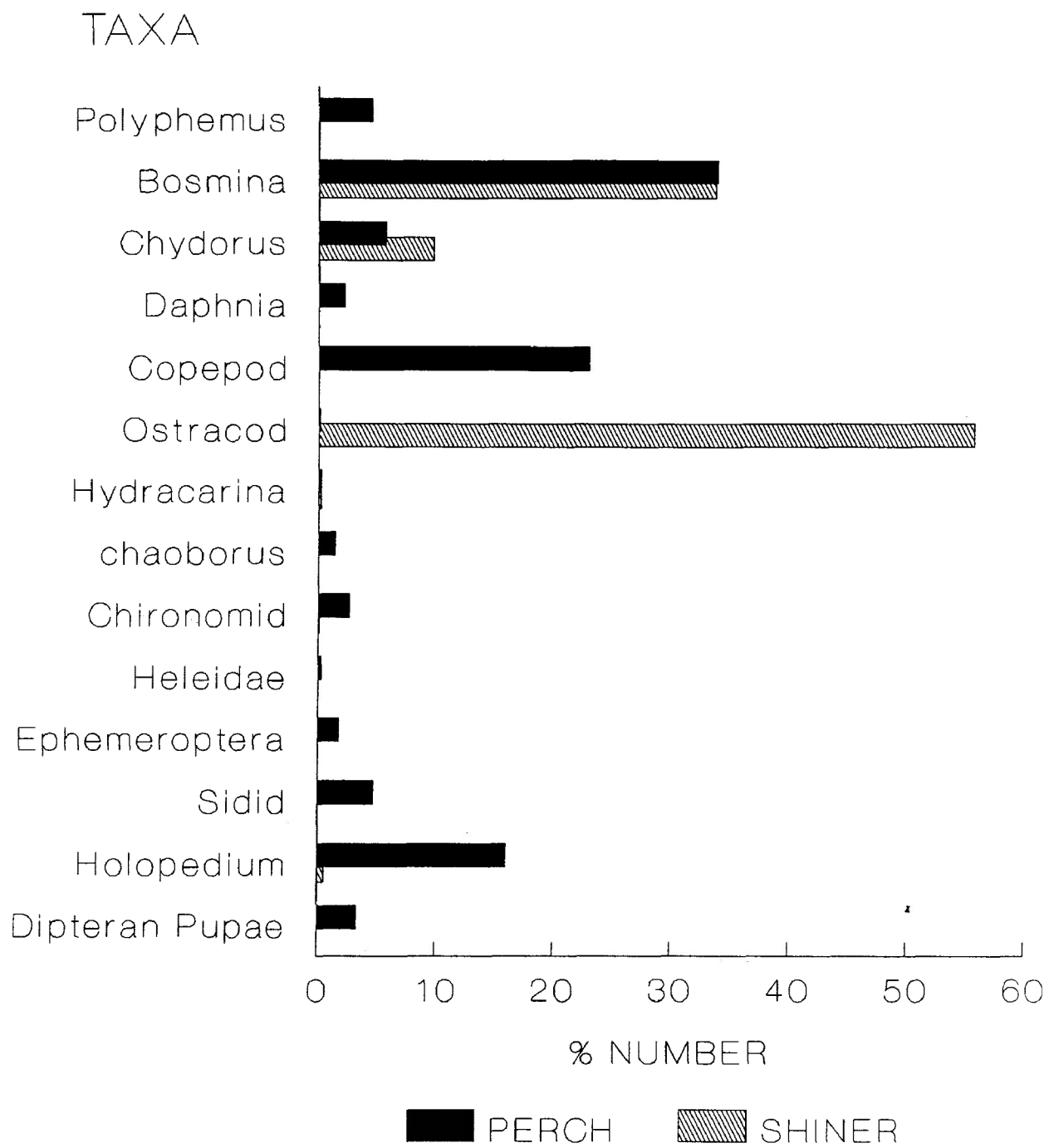


Table 2.1. Mean bulk indices for YOY yellow perch and shiners, 1984.

Taxum	Perch	Shiner	Difference
Polyphemus	16.7	18.0	1.3
Bosminids	8.0	12.0	4.0
Chydorids	13.0	13.2	0.2
Daphnids	13.8	18.0	4.2
Copepods	12.2	18.0	5.8
Ostracods	17.7	9.1	8.6
Hydracarina	17.2	17.5	0.3
Chironomids	16.3	17.1	0.8
Chaoborus	17.6	18.0	0.4
Heleidae	17.4	18.0	0.6
Ephemeropterans	17.4	18.0	0.6
Unk. cladoceran	13.9	18.0	4.1
Unk. dipterans	17.0	17.4	0.4
Unk. insects	17.1	16.4	0.7
Unkown items	12.3	10.0	2.3
Sidids	14.5	18.0	3.5
Holopedium	13.5	17.4	3.9

Neither Levin's (.28) nor Schoener's (.41) indices, assessed for numbers of prey consumed, showed high levels of overlap for these predator groups. In addition, mean size and size distributions of prey taxa shared by young perch and shiners were significantly different, further reducing the possibility of overlap.

Trends in catch-per-unit-effort indicated that pike activity peaked at dawn and dusk in Henderson Lake (Fig. 2.4). Ritchie (1984) found a similar pattern for yellow perch activity. Of all pike caught 26% had empty stomachs and most of the others contained very few individual items (Fig. 2.5). Reid (1985) and Nunan (1983) found no size selectivity in Henderson Lake pike and I detected no size dependent differences in diurnal activity. Therefore, all samples were pooled for frequency of occurrence analysis.

Even though minnows were found in 7% of the pike sampled, perch and insects formed most of the diet (Fig. 2.5). In addition small perch and insects occurred more frequently than large perch.

Evening seine sample size was too small to allow an assessment of statistical significance of observations because seining was conducted as a last resort, when other methods of determining forage fish diurnal activity failed. However, notably and without exception, young perch remained active as pike activity rose to twilight peaks. In contrast, shiner catches were either very low or non existent during the same time periods (Fig. 2.4).

Figure 2.4. CUE (number caught per hour) of gillnetted adult yellow perch at three hour intervals (Ritchie 1984) and northern pike during dawn, midday and dusk periods. Horizontal bars show diurnal periodicity in the presence (solid line) and decline (broken line) of young yellow perch and shiner activity.

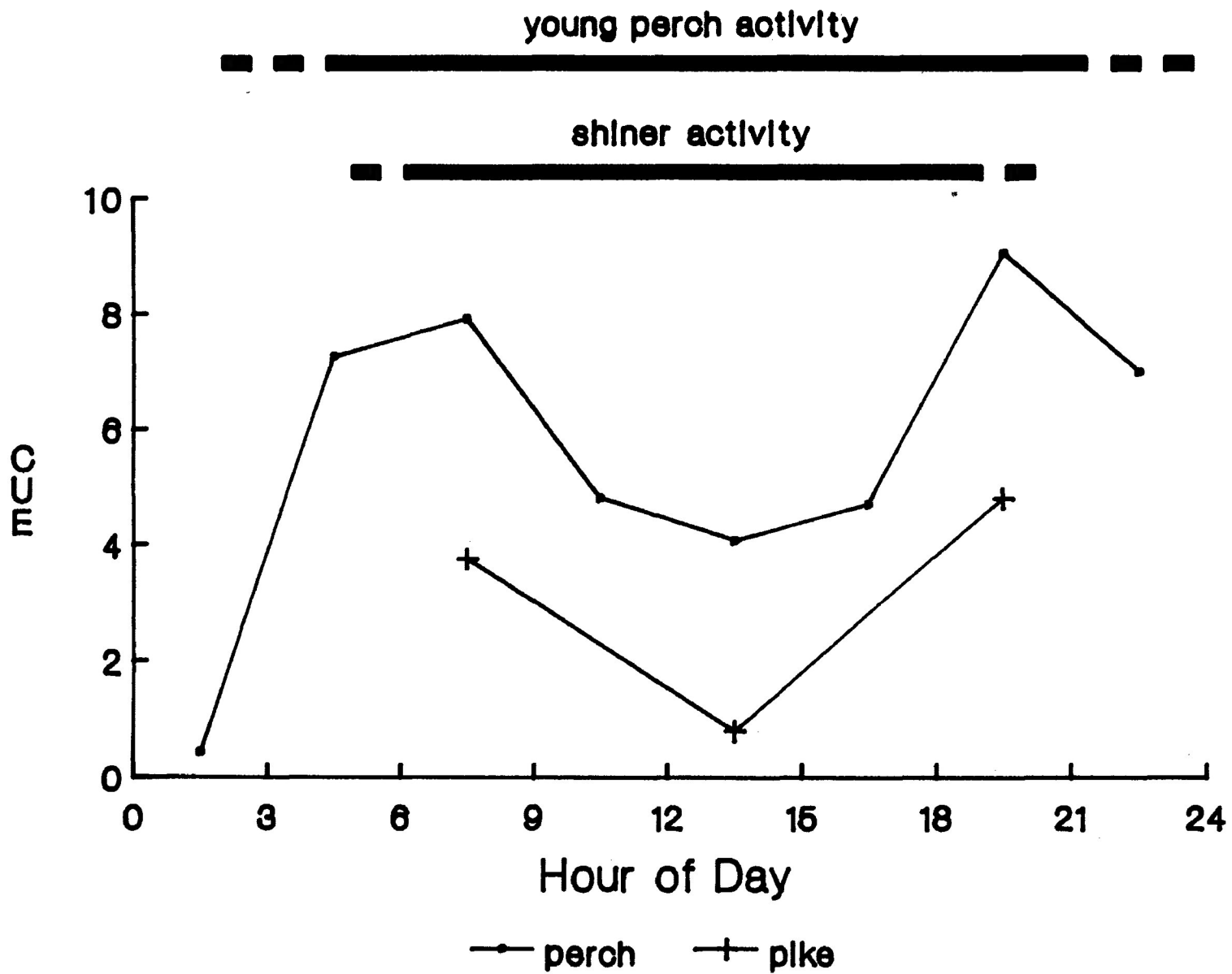
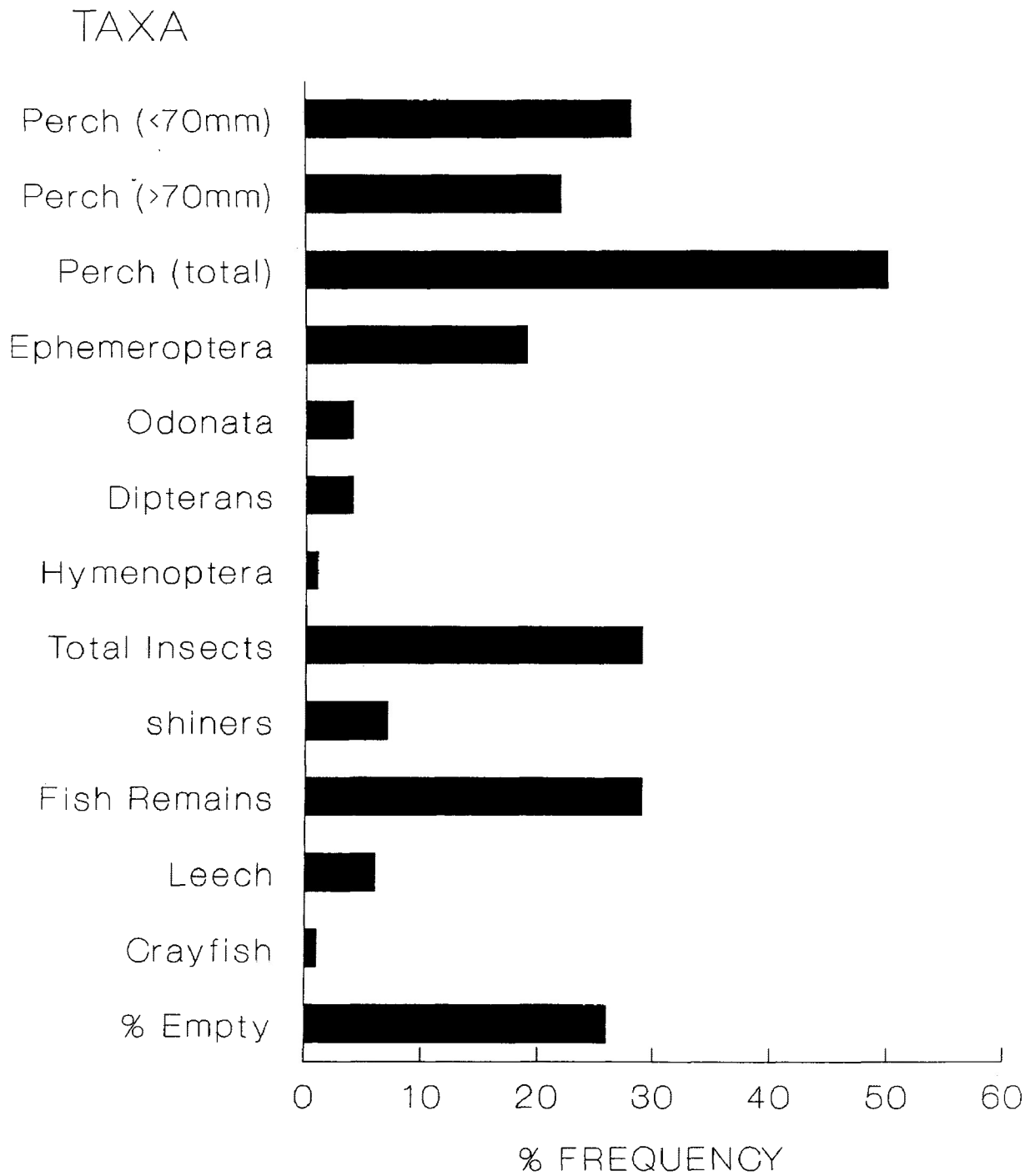


Figure 2.5. Percent frequency of occurrence of food taxa in the stomachs of gillnetted northern pike, 1985.



The proportion of pike body weight comprised of food items could not be used as an index of peak feeding periodicity. Mean percentages were usually less than 1% with high standard deviations regardless of size class distinction or diurnal periods used for 92 pike samples. Food items were often in a state of advanced digestion, only one stomach appeared full, 72% of stomachs containing food were less than half full, and there were no trends in the data.

DISCUSSION

The more we know about the ecology of north temperate fish species the more they appear segregated from one another, even if only as a result of past competition or niche overlap (Moyle 1973; Hickey 1975; MacLean and Magnuson 1977; Persson 1987b). My feeding ecology studies of young yellow perch and shiners support this premise. Nursall and Pinsent (1969) and Keast (1985) agreed that young perch may share some secondary or alternate prey types with minnows while remaining largely segregated. A number of studies suggest that species of Notropis, including blacknose and mimic shiners, are specialist feeders and young yellow perch are opportunistic or generalist feeders (Keast 1985; Craig 1974; Tarby 1974; Weber and Les 1982; Black 1945).

Although my analyses tend to conform with the literature, feeding ecology is subject to a variety of community interactions. Variability among populations, prey assemblages, years and seasons must all be considered when interpreting data and drawing comparison with other studies (Black 1945; Moyle 1973; Eddy and Underhill 1974; Weber and Les 1982; Rask 1986).

Moreover, methodology in segregation and feeding studies are subject to misinterpretation. For instance, the food habits of two species may diverge under resource limitation (Gillen and Hart 1980). Observations such as this lead Persson (1987b) to suggest that a lack of overlap may actually be the result of prey shifts in the presence of competition. At first glance the minnows and young perch of Henderson Lake did not appear to be competing from my observations. However, what I observed may actually have been a response, by one or both populations, to past competition. Existing literature suggests shiners consume the same types of forage preferred by similar sized yellow perch (Moyle 1973; Eddy and Underhill 1974; Rask 1986; Persson 1987b). Therefore, this particular study may not reflect the competitive forces operating in the Henderson Lake forage fish assemblage.

The diet of yellow perch has received the most extensive study of any of the north temperate forage species. Perch populations are represented by a wide range of diets (Rask 1986). While some authors feel that perch feeding habits reflect prey availability (Tarby 1974; Clady and Hutchinson 1976; Craig 1974) others suggest that they reflect predator size (Mills et al. 1986; Weber and Les 1982). The large yellow perch population in Henderson Lake is not characterized by size dependent diet shifts such as those exhibited in nearby Savanne Lake (Ritchie 1984). Therefore intraspecific competition for limited resources probably contributes to current population and community structure in Henderson Lake.

The existence of both competition and resource limitation is manifested in stunted growth of Henderson Lake perch. Most researchers overwhelmingly attribute stunting to a lack of appropriate forage (Mills and Forney 1981; Keast 1977; Deedler 1951; Rask 1986; Heath and Roff 1987; Post and Cucin 1984). In addition, experimental introductions of minnows have caused declines in yellow perch growth (Schneider 1972; Persson 1987b). Alternatively increases in forage availability or decreases in perch density have caused growth to increase (Alm 1946; Schneider 1972). Clearly, both intra- and interspecific interactions in the community are important in yellow perch population dynamics.

Yellow perch population size and age structure are also regulated from higher trophic levels. By removing predatory walleye, forage fish densities were allowed to increase. The yellow perch population response was a retardation of individual growth rates. According to Botsford (1981) responses such as these may bring new equilibria between prey and predators.

Reasons for the avoidance of minnows by northern pike remain unclear. Although the exact periodicity of pike feeding was not determined there was a definite pattern in catch-per-unit-effort of pike. Since most of the fish had not recently eaten, their movement into the study area during twilight periods may reflect a foraging behaviour. Preliminary seining suggests shiners are not as available as young yellow perch during the period of peak northern pike activity. The precise timing of shiner vulnerability during twilight is variable in different communities (Helfman 1981; Pitcher and Turner 1986; Emery 1973).

Helfman (1981) has suggested that the threat of predation alone may be sufficient to effect changes in diurnal vulnerability of prey. Vulnerability and defense mechanisms of each prey should be considered in relation to the vulnerability and defenses of other potential prey (Mauk and Coble 1971; Moody et al. 1983). In Henderson Lake for instance, yellow perch are: abundant in size ranges acceptable to pike; available at appropriate times; lack schooling defenses; and may be selected by learned preference.

Awareness of the variety of possible species interactions at the community level may soon become important in determining the yield potential of a fishery (Trimble and Colby in prep.). Hess and Heartwell (1978) citing Latta (1971) pointed out that reduced perch numbers, caused by heavy pike predation, could cause growth responses which, in turn, could allow the yellow perch population to supplant a depressed walleye population as a top predator. Alternatively, large hatches of stunted forage fishes may contribute to survival and recruitment of top predators (Shephard and Cushing 1979; Forney 1974), thus enhancing recovery of overexploited stocks. Although these possibilities impede our predictive capabilities, they show that examination of variable community responses to perturbation are important in the management of target species populations.

GENERAL SUMMARY

In a period during which competition and predation on yellow perch were reduced in Henderson Lake, the perch population produced a very large year class. This strong cohort survived well and recruited to dominate the population for several years. Adult density increased while growth, mortality, size at maturity and fecundity significantly decreased. Since perch growth was stunted to begin with, the walleye fishery probably exacerbated intense intraspecific competition by reducing predation and competition.

Climatic factors were not a likely cause of these responses, or were overshadowed by the effects of walleye exploitation and the disappearance of sticklebacks. Production of yellow perch year classes in a nearby lake with similar weather patterns did not follow the same trends as those of Henderson Lake perch. However, abiotic variables were not extensively analysed for the present study and they require further research.

Adult shiners did not appear to compete directly with young perch during mid summer. Therefore, stunted growth of perch was probably not attributable to interspecific competition with shiners for food.

Northern pike did not utilize shiners as prey even though shiners were much more abundant than perch. Preliminary studies of temporal behavior indicated that yellow perch were more available than shiners during periods of increasing northern pike activity.

The role of shiners in Henderson Lake community dynamics remains uncertain and should be addressed in future study. It is possible that they are segregated from young yellow perch as a result of past competition, that they interact with perch and pike during other seasons, or represent an energy sink by not contributing to top predator food chains. However, their role may change as the walleye recovery proceeds. Wisenden (1988) documented minnows in the stomachs of young walleye in 1986. Shiners were not a forage fish of adult perch before the decline of the stickleback population, but a perch diet study may now be in order. In addition, studies of the benthic and planktonic components of the community may prove valuable during this recovery period. As a community changes, all of its components should be monitored to further describe their relationship to walleye.

Forage base responses to the pulse fishery for walleye appear conducive to walleye recovery. Large numbers of small forage fish are available and perch did not supplant walleye as a top predator.

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Appendix 1. Beach seine catches and number per hectare seined for forage species on each sampling date.

Date	Area Seined (ha.)	Yellow Perch		YOY perch		Mimic Shiner		Blacknose Shiner		White Sucker		YOY sucker	
		no.	no./ha	no.	no./ha	no.	no./ha	no.	no./ha	no.	no./ha	no.	no./ha
29/06/84	0.423	271	640.6	1984	4690.3	3958	9356.9	5650	13356.9	1	2.4	0	0.0
02/07/84	0.423	625	1477.5	685	1619.4	2462	5820.3	6574	15541.4	5	11.8	0	0.0
13/07/84	0.376	342	909.6	1201	3194.1	3090	8218.1	1978	5620.6	16	42.5	232	617.0
26/07/84	0.423	131	309.7	843	1992.9	640	1513.0	2020	4775.4	8	18.9	112	264.8
28/07/84	0.376	327	869.7	1368	3638.3	79	210.1	1971	5242.0	16	42.5	98	260.6
23/08/84	0.423	1471	3477.5	345	815.6	1761	4163.1	857	2026.0	2	4.7	31	73.3
MEAN			1280.8		2658.4		4880.2		7700.4		20.5		303.9
30/06/85	0.282	1332	4726.9	3922	13907.8	17437	61833.3	7357	26088.6	0	0.0	0	0.0
06/07/85	0.235	279	1187.2	33	140.4	3643	15502.2	615	2617.0	5	21.3	1	4.3
29/07/85	0.282	169	599.3	806	2858.1	944	3347.5	1699	6024.8	239	847.5	7	24.8
31/07/85	0.235	64	272.3	803	3417.0	417	1774.5	146	621.3	72	306.4	5	21.3
MEAN			1696.4		5080.8		20614.4		8837.9		391.7		16.8

Appendix 2. Catch per unit effort of yellow perch from Henderson Lake gillnets, 1984.

Date	Catch no.	Site	Hrs	Number caught	Number/hour
03/06/84	001		0.0		
	002	2a	4.0	80	20.0
	003	3b	4.0	41	10.3
04/06/84	004	1b	4.0	157	39.3
	005	2b	4.0	123	30.7
	006		0.0		
15/06/84	007	2b	3.0	77	25.7
	008	1a	3.0	214	71.3
	009	3b	3.0	62	20.7
16/06/84	010	3b	3.0	56	18.7
	011	2d	3.0	186	62.0
	012	1d	3.0	205	68.3
17/06/84	013	1c	3.0	209	69.7
	014	2a	3.0	49	16.3
	015	3b	3.0	43	14.3
19/06/84	016	1b	3.0	124	41.3
	017	2a	3.0	81	27.0
	018	3c	3.0	160	53.3
01/07/84	019	1a	3.0	239	79.7
	020	3b	3.0	25	8.2
	021	2c	3.0	276	92.0
02/07/84	022	2b	3.0	142	47.3
	023	3d	2.6	82	31.8
	024	1a	2.9	314	107.5
10/07/84	025	3c	2.0	89	44.5
	026	1a	2.0	130	65.0
	027	2a	2.4	162	66.9
12/07/84	028	2c	2.0	123	61.5
	029	3b	2.3	39	16.7
	030	1d	2.5	27	10.8
24/07/84	031	1b	1.8	44	24.0
	032	3d	1.9	74	38.5
	033	2c	2.0	151	75.5
27/07/84	034	1c	1.6	121	76.6
	035	2d	1.7	241	144.3
	036	3c	1.9	68	35.4
08/08/84	037	2b	1.3	180	144.0
	038	1c	1.4	485	341.5
	039	3c	2.7	12	4.5
20/08/84	040	3a	0.7	13	17.3
	041	2a	0.7	302	402.7
	042	1a	0.9	12	13.0
22/08/84	043	2b	0.5	46	92.0
	044	3b	0.6	12	20.7
	045	1c	0.7	102	152.2

Appendix 2. continued. 1985

17/05/85	001	1b	0.5	27	54.0
	002	2b	0.7	12	16.0
24/05/85	003	1a	0.3	35	140.0
	004	3d	0.3	15	45.5
12/06/85	005	3a	0.3	02	6.1
	006		0.3	03	9.1
	007		0.5	14	28.0
13/06/85	008	3a	0.6	28	48.0
	009	1a	0.6	25	42.9
	010	2b	0.7	28	41.8
15/06/85	011	1c	0.5	12	24.0
	012	3b	0.7	09	13.4
	013	2a	0.9	18	19.6
29/06/85	014	2d	1.0	31	31.0
	015	3d	1.2	63	53.8
	016	1c	1.3	66	49.6
01/07/85	017	1a	0.7	34	45.3
	018	3a	0.9	06	6.5
	019	2a	1.0	43	43.0
02/07/85	020	1b	0.5	22	44.0
	021	3d	0.6	41	70.7
	022	2d	0.8	14	18.7
04/07/85	023	1c	0.9	51	55.4
	024	2a	1.2	109	93.2
	025	3a	1.5	75	50.0
05/07/85	026	2c	0.4	67	159.5
	027	1d	0.5	86	172.0
	028	3c	0.6	61	103.4

Appendix 3. Analysis of covariance (ANCOVA) statistics comparing length at age between years.

Years compared	F-slope (df)	F-int (df)	F-var (df)
1981/82	0.1577 (1,209)	3.8253 (1,1)	1.1448 (101,108)
1982/83	1.1995 (1,169)	20.222*** (1,170)	1.0105 (108,61)
1983/84F ^a	0.6084 (1,139)	4.5737* (1,140)	1.4657* (61,78)
1983/84M	4.4619* (1,120)	12.1621*** (1,121)	1.7573** (61,59)
1984/85F	3.5609 (1,207)	0.0011 (1,208)	1.2979 (129,78)
1984/85M	2.6738 (1,145)	0.0011 (1,146)	1.0889 (59,86)
1981/85M	30.1393*** (1,187)	97.2100*** (1,188)	2.2100*** (101,86)
1981/85F	4.2100* (1,230)	27.3300*** (1,231)	0.7700 (129,101)

^a All years for combined sexes except where indicated by 'F' (females) or 'M' (males)

* Significant at .05

** Significant at .025

*** Significant at .001

Appendix 4. Comparison of age estimates from yellow perch otoliths and opercles by 4 technicians.

1985 otolith comparison with S. McClelland (SM)

fish number	109	232	234	238	242	246	247	255	267	273	276	281	282	285	287	313	088	262	178	155	074	066	031	053	042
SM AGE	5	4	4	4	6	4	4	3	2	5	5	6	5	4	6	6	6	6	6	6	3	2	3	4	6
KT AGE	5	4	5	4	6	4	4	2	2	5	5	6	5	4	5	6	5	6	6	7	4	3	3	4	5
DIFFERENCE	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	1	1	1	0	0	1

1985 opercle comparison with S. McClelland (SM)

fish number	153	159	175	181	184	194	197	205	206	209	212	220	221	250	234	313	199
SM AGE	6	5	5	2	2	10	7	5	6	3	4	5	7	1	4	6	6
KT AGE	6	5	5	3	3	6	5	5	6	4	4	6	5	2	5	6	4
DIFFERENCE	0	0	0	1	1	4	2	0	0	1	0	1	2	1	1	0	2

1981 opercle comparison with J. Babuluk (JB)

fish number	012	073	176	177	089	259	105	162	109	112	082	139	138	273	197	134	123	128	100	257	297	319	060	255	122	036	293
JB AGE	2	6	4	4	5	4	3	3	2	2	2	2	3	2	1	1	1	1	4	3	1	2	2	4	1	2	1
KT AGE	2	5	4	4	5	4	4	3	3	2	3	—	3	2	1	1	1	1	4	3	2	3	2	5	—	—	2
DIFFERENCE	0	1	0	0	0	0	1	0	1	0	1	—	0	0	0	0	0	0	0	0	1	1	0	1	—	—	1

1985 otolith comparison with J. Tost (JT)

fish number	053	262	109	108	054	042	041	037	038
JT AGE	4	6	5	5	2	5	4	6	6
KT AGE	3	6	5	5	2	5	5	6	6
DIFFERENCE	1	0	0	0	0	0	1	0	0

Appendix 5. Age composition and catch per unit effort (CUE) of yellow perch age groups from gillnets, 1981-1985.

Year		Age Group			
		III	IV	V	VI
1981	Number	649	268	70	12
	Percent	53.2	22.0	5.7	1.0
	CPUE	4.33	1.79	0.47	0.08
1982	Number	1371	498	44	16
	Percent	45.4	16.5	1.5	0.5
	CPUE	5.60	2.03	0.18	0.07
1984	Number	3910	694	110	19
	Percent	70.6	12.5	2.0	0.3
	CPUE	37.89	6.73	1.07	0.18
1985	Number	640	508	66	29
	Percent	47.8	38.0	4.9	2.2
	CPUE	35.19	27.93	3.63	1.59

Appendix 6. Absolute fecundity of gillnetted yellow perch by 1 cm length groups, Fall 1985.

length (cm)	Absolute fecundity						N	Mean
10-10.9	1534	2141	1406	0856			4	1484
11-11.9	2640	1848	1290				3	1926
12-12.9	2903	3158	2629	2987	3113	2518	6	2885
13-13.9	4019	2897	2936				3	3284
14-14.9	6117	4362	4743	4533	4881		5	4927
15-15.9	5218	5286	5510	5697	5399		5	5422
16-16.9	7441						1	7441
17-17.9								
18-18.9								
19-19.9	10484						1	10484