WARMWATER FISHERIES INVESTIGATIONS

Federal Aid Project F-34-R

Job 1. Walleye Studies
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The results of the research investigations contained in this report represent work of the author and may or may not have been implemented as Division of Wildlife policy by the Director or Wildlife Commission.

ABSTRACT

A preliminary study was conducted in 1978 on 24 reservoirs in Colorado known or suspected to contain populations of walleye. From these, certain reservoirs were chosen for further study and to test fry planting procedures and schedules developed during a 10-yr study of the Boyd Lake walleye fisheries.

In 1979 Bonny Reservoir (Yuma County), North Sterling Reservoir (Logan County), and Summit Reservoir (Montezuma County) were sampled extensively with trawls, seines and gillnets to determine survival and growth of young-of-the-year walleye. Bonny Reservoir served as a control throughout the course of study with no manipulation of planting schemes. North Sterling and Summit reservoirs were designated as primary target waters where planting would be manipulated according to the Boyd Lake criteria. At the end of the 1979 studies, Narraguinnep Reservoir was added to the study in place of Summit Reservoir, which was found to contain a large, self-sustaining population of northern pike with resultant poor survival of walleye. During 1980 and 1981, plants of walleye fry were withheld from both primary reservoirs. Narraguinnep was found to contain abundant populations of forage fish (yellow perch [>2,000/ac]) and a largely self-sustaining population of walleye (an average of 40 fingerlings/ac). Growth and survival of fingerling walleye was, however, poor as was the growth rate of adult walleyes sampled by gillnet. North Sterling Reservoir in comparison, produced little evidence of natural recruitment, poor growth and survival of fingerling and adult walleye (<10 fingerlings/ac in 1979) and extremely poor production of forage fish (<400/ac). Attempts were being made to reintroduce gizzard shad and yellow perch, but with little evidence of positive results.

At the close of the 1981 field season, a decision was made to cancel the walleye research operations on all the reservoirs. Newly appointed management biologists assumed the responsibility of monitoring yearly changes in forage production and adjusting walleye fry plants accordingly.

INTRODUCTION

In 1978 a new study was initiated with Segment 11 of F-34-R, Warmwater Fisheries Investigations. Entitled "Walleye Studies" and designated as Job 1, the PNO objective was:

> To develop optimum fry planting rates and schedules for improvement of certain potential walleye lakes and reservoirs in Colorado, utilizing recommended procecures resulting from the Boyd Lake research studies.

Segment objectives were:

1. Manipulate planting rates of walleye fry as part of an overall program to create an optimum walleye fry fishery.
2. Develop indices comparing growth and survival of walleye to the abundance of available forage.
3. Describe certain basic limnological factors common to each project reservoir.

Data resulting from studies at Boyd Lake (Reservoir) from 1968 through 1977 (Weber and Gregory 1968; Gregory, Weber and Powell 1970; Puttmann and Weber 1980) indicated that optimum walleye populations might be achieved with a 4-yr fry planting scheme. In order to establish a viable walleye population in a given reservoir containing sufficient forage, plants of walleye fry numbering 2,000 per acre and 3,000 per acre are made during the first 2 yrs, respectively, followed by no planting during the remaining 2 yrs. Theoretically, this would produce a harvestable population of 2-yr-old and older fish, while naturally occurring forage species would have the opportunity, following years of suspended fry planting, to again increase in numbers.

In Job 1, two or more reservoirs were to be selected for testing of the stocking scheme. Preliminary work in 1978 involved the survey of 24 warmwater reservoirs in Colorado known or suspected to contain walleye populations (Puttmann and Finnell 1979). From this list of reservoirs, three were chosen for further study, beginning in 1979. Bonny Reservoir, located in Yuma County, was chosen as its walleye fishery was found to be one of the best and most stable in the State. It served, during the course of the study, as the "control" reservoir. Little or no manipulation of current stocking rates (2,000 per acre annually) would be proposed. The other two initially chosen were North Sterling (Logan County) and Summit (Montezuma County), which were designated as "primary" reservoirs. At North Sterling (2,789 surface acres) where the stocking rate for walleye fry was currently 2,000 per acre annually, populations of such forage fish as gizzard shad, yellow perch, drum, etc. were found to be extremely low in numbers. Calculated growth rates of walleye taken during the survey were well below the State average and reflected the shortage of forage species. In order to directly compare growth and survival of walleye in North Sterling with Bonny and establish other baseline information, no changes were made in the planting rates during 1979. In 1980 and 1981, plants of walleye fry were withheld at North Sterling to test the theory that repressed forage fish would begin to increase in abundance. This also allowed documentation of the success of walleye natural recruitment.

In contrast, Summit Reservoir, a much smaller body of water at 334 surface acres, was currently receiving yearly plants of 900 fry per acre. Sampling in 1978 had indicated an abundance of young-of-the-year forage fish (yellow perch and black crappie) and sufficient samples of walleye were taken to estimate that growth, at least of age groups I-III, was well above the State average. Therefore it was planned to begin the study in 1979 with a walleye fry plant of 2,000 per acre, the same as the other two project reservoirs. However, due to severe weather conditions during the preceding winter, the reservoir remained ice covered well into spring. Fry had ceased to be available from the hatchery by the time the reservoir began producing zooplankton food organisms. For this reason, it was decided to cancel the 1979 plant, but continue studying the reservoir to document the extent of natural reproduction of walleye. In 1979 Summit Reservoir was found to have a self-sustaining and abundant population of northern pike but poor natural recruitment and survival of walleye. Thus, prior to the 1980 field season, this reservoir was dropped from the study and 571-acre Narraguinnep Reservoir (Montezuma County) was added. From the standpoint of deep-water habitat, the latter appeared to be better suited to the establishment of a viable walleye population.

When the study was originally formulated in early 1978, no other research project or management-oriented work was currently being done on walleye in Colorado. The study was designed to continue through 1984 with possible extensions beyond that time. However, the Division of Wildlife was then in the process of hiring additional personnel for duty as warmwater management biologists in three of the four State regions and the Denver Metro area. It has become their duty to yearly survey reservoirs in their respective regions, including the three project reservoirs mentioned above, determine natural reproductive success of forage and game species and manipulate stocking to compensate for any changes in the fish populations. It became increasingly apparent that a specific research study of walleye was no longer needed. Therefore the decision was made to cancel the study at the end of the 1981 field season, even though insufficient data had been collected to evaluate the Boyd Lake planting scheme.

The following report will consist of a discussion of the methods and results of the preliminary survey and the three completed field seasons on the control and primary study reservoirs. Although the results are incomplete, some conclusions and recommendations can be made.

METHODS

Preliminary Lake Survey

In the survey of potential walleye lakes conducted in 1978, one of the factors first considered was lake bottom topography. Depth contours, location of shoals and possible spawning areas were recorded on field maps. Thus, regardless of which lakes were to be chosen for further study, this information was available for use in establishing permanent stations for periodic collection of fish samples, temperature data, etc. Sonar mapping usually consisted of a timed course between identifiable points plotted on field survey maps constructed from USGS quadrangle maps. Larger bays were traversed separately. After determining the approximate water level from corresponding maximum elevations shown on the USGS maps, depth contours were plotted. Planimetering of the completed map provided an estimate of total acreage and approximate shoal area or that portion of the lake basin under 10 ft (3 m) in depth. Also mapped was any shoreline development, soil and vegetative types, etc.

Trawling Operations

Collection of sub-adult and adult game and forage fish was accomplished at randomly selected sampling stations at each reservoir with overnight sets of standard-mesh gillnets (1-3 nets of 3/4-in. mesh and 3-5 nets of 2-in. mesh). The number of nets set in each reservoir varied according to its size, accessibility, etc. In addition, 2-3 framenets were set for the same time period. Young-of-the-year forage and game fish were sampled at various locations with a 100-ft beach seine. A further description of sampling gear and the laboratory procedures employed in analyzing the collected data appears in the first preliminary report (Puttmann and Finnell 1979).

With the selection of the primary and control reservoirs, methods of sampling changed considerably. Emphasis was placed on the determination of growth and survival of fry, fingerling and sub-adults of both planted and self-recruiting game and forage fish. A search of the literature indicated that one of the best methods of sampling walleye fingerling populations and associated forage fish was with a semi-balloon bottom trawl (Congdon 1968; McWilliams, Mitzner and Mayhew 1974). A net similar to that described by Talsma (1976) was subsequently obtained for the study (Puttmann and Finnell 1979). In order to estimate the catch-per-unit-of-effort (CPUE) of fingerling walleye, as well as available forage fish, it was necessary to establish a consistent method of trawling. Distance trawled at each sampling station was determined by timing trawls made along a 200-ft course at an indicated trawling speed of approximately 1,000 rpm. As the duration of each sample trawl was chosen to be 10-min in length, it was computed that approximately 1,700 linear ft of lake bottom would be covered at each sampling station. In some cases shorter or longer hauls were necessary due to overall size of the area sampled, net becoming clogged with vegetation, etc. Trawling was quite efficient at each of the study reservoirs with the exception of Narraguinnep where filamentous algae was found to cover most of the lake bottom. This resulted in completely clogging the net after only 2-3 min of trawling. During the first segment of study all trawling and seining operations were made during daylight hours. Catch was usually of sufficient magnitude during this time period to make night trawling unnecessary even though Talsma (1976) found that night trawling greatly increased the CPUE. Many of the problems associated with night trawling (difficulty with locating and maintaining a known position, fish samples overlooked in the net, etc.) were thus avoided.

The number of sampling sites for trawling varied, depending on the size of the reservoir, availability of acceptable sites (snag- and vegetation-free) and amount of drawdown. A total of 15 sites were located and maintained yearly at Bonny Reservoir, 15 on North Sterling Reservoir and 5-8 on Summit Reservoir depending on environmental conditions. As previously mentioned, algae at Narraguinnep Reservoir precluded use of the trawl. Sample trawls at each reservoir were usually made for a duration of 10-min at 1,000 rpm. With a trawl path of approximately 9 ft, about 15,560 ft^2 of lake bottom was covered in each operation. All samples, including walleye YOY and forage species, were enumerated and all or a representative number saved for more detailed analysis in the laboratory.

Walleye Fry Sampling

At the beginning of the study, it was hoped that walleye fry might be sampled shortly after hatching and/or planting. A method described by Miller (1961), Houde (1968) and Noble (1970) involved the use of a high-speed (Miller) plankton trap. Use of this type of equipment proved to be unsuccessful at the project reservoirs. Successful use of the plankton trap appears to be dependent, not only on abundance, but upon size of the fry (under 35 mm in length) and their pelagic distribution. Concentrations of larval walleye probably never approached numbers noted by the above authors in Eastern lakes. Also, the walleye fry were found to remain under 35 mm in length and pelagically dispersed in the project reservoirs for an extremely short period of time. However use of the bottom trawl and beach seining appears to have provided an adequate means of sampling walleye fingerling and subadults.

Seining Operations

Selection of sites for shore or beach seining was very difficult on all of the project reservoirs. Rocks, vegetation and soft substrate were the primary limiting factors, particularly during periods of high water level. Prior to initial operations, six or more areas were established at each reservoir. The number of stations was occasionally reduced as changes in lake level, vegetation, etc. occurred. In operation, the seine was laid out parallel to shore. Distance offshore was 100 ft as determined by the length of the lines attached to each end of the seine. It was estimated that the seine's length was reduced by 33% due to bagging as caused by water resistance. This resulted in approximately 6,700 ft^2 of area being covered per haul.

Gillnetting and Electrofishing

Adult and subadult game and forage fish were sampled by means of gillnets and occasionally boat-operated electrofishing equipment. During each of the regular sampling periods, a minimum of two fine-mesh (3/4-in.-square mesh) nets were set in each reservoir at specifically chosen sites. In addition, 3-5 experimental (graduated mesh) nets were fished at Narraguinnep Reservoir and Summit Reservoir to supply sufficient examples of adult walleye and other game and forage fish for age and growth determinations. Electrofishing equipment was used when available to provide additional samples of adult fish.

Limnological Sampling

A station was established in the deepest portion of each reservoir at which the following information was obtained monthly:

1. Changes in the temperature profile were recorded with an electronic thermistor unit.
2. Fluctuations in the abundance of zooplankton was checked by three vertical hauls with a Wisconsin-type plankton net.
3. The water level was measured at or near the outlet structure.
4. Changes in turbidity were measured with a secchi disk.

RESULTS

1978 Preliminary Surveys

Of the 24 lakes and reservoirs surveyed in 1978, 19 were found to contain at least remnant populations of walleye (*Stizostedion vitreum vitreum* Mitchell). Physical descriptions of all the surveyed waters, together with chemical analysis of water samples, invertebrate sampling results, occurrence of rough, forage and game fish species, and age/growth analysis of all walleye samples taken appear in an earlier report (Puttmann and Finnell 1979).

Table 1 shows the overall catch-per-unit-of-effort (CPUE) of rough, forage and game fish in each of the surveyed reservoirs, expressed as the number taken per net hour. Bonny Reservoir, the control used in the later segments of the walleye studies, is not included in the table. Sufficient data on the walleye populations at Bonny were available from previous sampling, spawntaking operations, etc. to preclude setting additional study nets during the survey. Included in the listing are the three primary reservoirs, all of which exhibited relatively low CPUE values.

Table 1. Overall catch per unit of effort (CPUE) of rough, forage and game fish for various reservoirs surveyed in Colorado in 1978. (CPUE expressed as numbers per net hour).[a]

Reservoir	No. & Kind of nets		Rough fish		Forage fish					Game fish								Total fish	CPUE	Total fish/ net hr	Total hours
	Gill	Trap	WWS	CA	GS	BH	DR	YP	RG	WE	NP	CR	CC	WB	TR	K	L & SMB				
Black Hollow																		GF- 79	0.44		
	7	2	179	82		103		4		11	5	53	10					FF-107	0.59	2.48	180.0
																		RF-261	1.45		
Boedecker																		GF- 38	0.27		
	7	2		96		1		11		29		9						FF- 12	0.09	1.05	140.0
																		RF- 96	0.69		
Cheesman																		GF- 40	0.22		
	7	2	100					368			1				9	30		FF-368	1.99	2.75	185.25
																		RF-100	0.54		
Empire																		GF- 4	0.05		
	3	2	2	45	1			5				4						FF- 6	0.08	0.72	80.0
																		RF- 47	0.59		
Horsetooth																		GF- 20	0.18		
	4	3	58					1		18							2	FF- 1	0.01	0.70	113.75
																		RF- 58	0.51		
Jackson																		GF- 14	0.12		
	6	2		150	405	3		2		11		2	1					FF-410	3.48	4.83	118.75
																		RF-150	1.26		
Lon Hagler																		GF-158	0.70		
	7	2	66					1197		66		14	77		1			FF-1197	5.33	6.32	224.5
																		RF- 66	0.29		
Loveland																		GF- 13	0.19		
	4	2		32	1			1		11		2						FF- 2	0.03	0.69	68.5
																		RF- 32	0.47		
Prewitt																		GF- 35	0.29		
	6	2		450	77					11		2	22					FF- 77	0.64	4.68	120.0
																		RF-450	3.75		

Table 1. Overall catch per unit of effort (CPUE) of rough, forage and game fish for various reservoirs surveyed in Colorado 1978. (CPUE expressed as numbers per net hour). (Continued)

Reservoir No. & Kind of nets Gill	 Trap	Rough fish WWS	 CA	Forage fish GS	 BH	 DR	 YP	 BG	Game fish WE	 NP	 CR	 CC	 WB	 TR	 K	 L & SMB	Total fish	CPUE	Total fish/ net hr	Total hours
Riverside 3	2		213		3		2				6						GF- 6 FF- 5 RF-213	0.06 0.05 2.15	2.26	99.25
Rocky Ridge 7	2	29	22				4		2		18	10					GF- 30 FF- 4 RF-.51	0.20 0.03 0.34	0.57	149.0
N. Sterling 4	3		103	3					4		19					2	GF- 25 FF- 3 RF-103	0.22 0.03 0.92	1.17	111.75
Adobe Creek 6	2		62	383	1				5			86					GF- 91 FF-384 RF- 62	0.83 3.50 0.56	4.89	109.75
Elevenmile 7	2	173	12							19				14	3		GF- 36 FF- 0 RF-185	0.32 0.00 1.66	1.98	111.25
Nee Noshe 7	2		420		7				3		4	38					GF- 45 FF- 7 RF-420	0.37 0.06 3.44	3.87	122.25
Two Buttes 4	2	18	12	445	9	12			24			30				1	GF- 55 FF-466 RF- 30	0.47 4.02 0.26	4.75	116.0
Upper Queen 4	0		70			36					2	4	1				GF- 7 FF- 36 RF 70	0.13 0.69 1.35	2.17	52.0
Narraguinnep 7	2	3					8		4	3	1	111					GF-119 FF- 8 RF- 3	1.00 0.07 0.03	1.10	118.75

Table 1. Overall catch per unit of effort (CPUE) of rough, forage and game fish for various reservoirs surveyed in Colorado in 1978. (CPUE expressed as numbers per net hour). (Concluded).

Reservoir No. & Kind of nets		Rough fish		Forage fish					Game fish											
Gill	Trap	WWS	CA	GS	BH	DR	YP	BG	WE	NP	CR	CC	WB	TR	K	L & SMB	Total fish	CPUE	Total fish/ net hr	Total hours
Totten																	GF- 54	0.49		
7	1						45	8	13	6	3	32					FF- 53	0.48	0.97	109.6
																	RF- 0	0.00		
Summit																	GF- 52	0.46		
5	2						3		7	21	14	8				2	FF- 3	0.03	0.49	112.5
																	RF- 0	0.00		
Puett																	GF- 29	0.21		
7	2						13		16	8		5					FF- 13	0.09	0.30	139.5
																	RF- 0	0.00		
Sanchez																	GF- 31	0.19		
7	2	120	1				3		1	27		3					FF- 33	0.02	0.93	167.5
																	RF-121	0.72		
Seeley																	GF- 26	0.20		
4	3	5	2	1				3	14	1	2	2		4			FF- 4	0.03	0.28	130.5
																	RF- 7	0.05		

[a] Code for species:

GF - Game Fish
FF - Forage Fish
RF - Rough Fish

WWS - Western White Sucker
CA - Carp
GS - Gizzard Shad
BH - Bullhead
DR - Drum

YP - Yellow Perch
BG - Bluegill
WE - Walleye
NP - Northern Pike
CR - Crappie

CC - Channel Catfish
WB - White Bass
TR - Trout
K - Kokanee
L & SMB - Large- & Smallmouth Bass

Trawling Operations

Sampling of juvenile walleye and forage fish at the study reservoirs began in June 1979. Direct comparisons of growth and survival of walleye young-of-the-year (YOY) obtained by this method with Bonny, the control reservoir, was possible only during the first year of study and only at North Sterling Reservoir. Only one fingerling walleye was taken at Summit Reservoir in 1979 where fry plants had been withheld. As shown by Figure 1, seasonal survival of fingerling walleye from the 1979 fry plant at North Sterling Reservoir was quite similar to that at Bonny Reservoir. In subsequent years of the study (1980 and 1981), fry plants at North Sterling Reservoir were withheld to determine the extent of natural reproduction and aid in forage production. With sampling effort equal to that in 1979, only four YOY walleye were recovered by trawling in 1980 and one in 1981, indicating that natural reproduction of this species in the reservoir is probably negligible. Species of forage fish indigenous to the study reservoirs varied considerably. At Bonny Reservoir, gizzard shad (*Dorosoma cepedianum* Lesueur) were found to be the most abundant, followed by freshwater drum (*Aplodinotus grunniens* Rafinesque), white bass (*Morone chrysops* Rafinesque) and crappie (*Pomoxis* sp.). Occasionally yellow perch (*Perca flavescens* Mitchell), bluegill (*Lepomis macrochirus* Rafinesque) and sand shiners (*Notropis* sp.) entered the trawl catch. At North Sterling Reservoir, where all forage fish were in short supply, drum and crappie appeared to be dominant, followed by yellow perch, gizzard shad, fathead minnows (*Pimephales promelas* Rafinesque) and sand shiners. Although large populations of adult carp (*Cyprinus carpio* Linnaeus) and river carpsucker (*Carpiodes carpio* Rafinesque) were present, only an occasional YOY specimen was taken in sampling. At both Summit and Narraguinnep Reservoirs forage species consisted

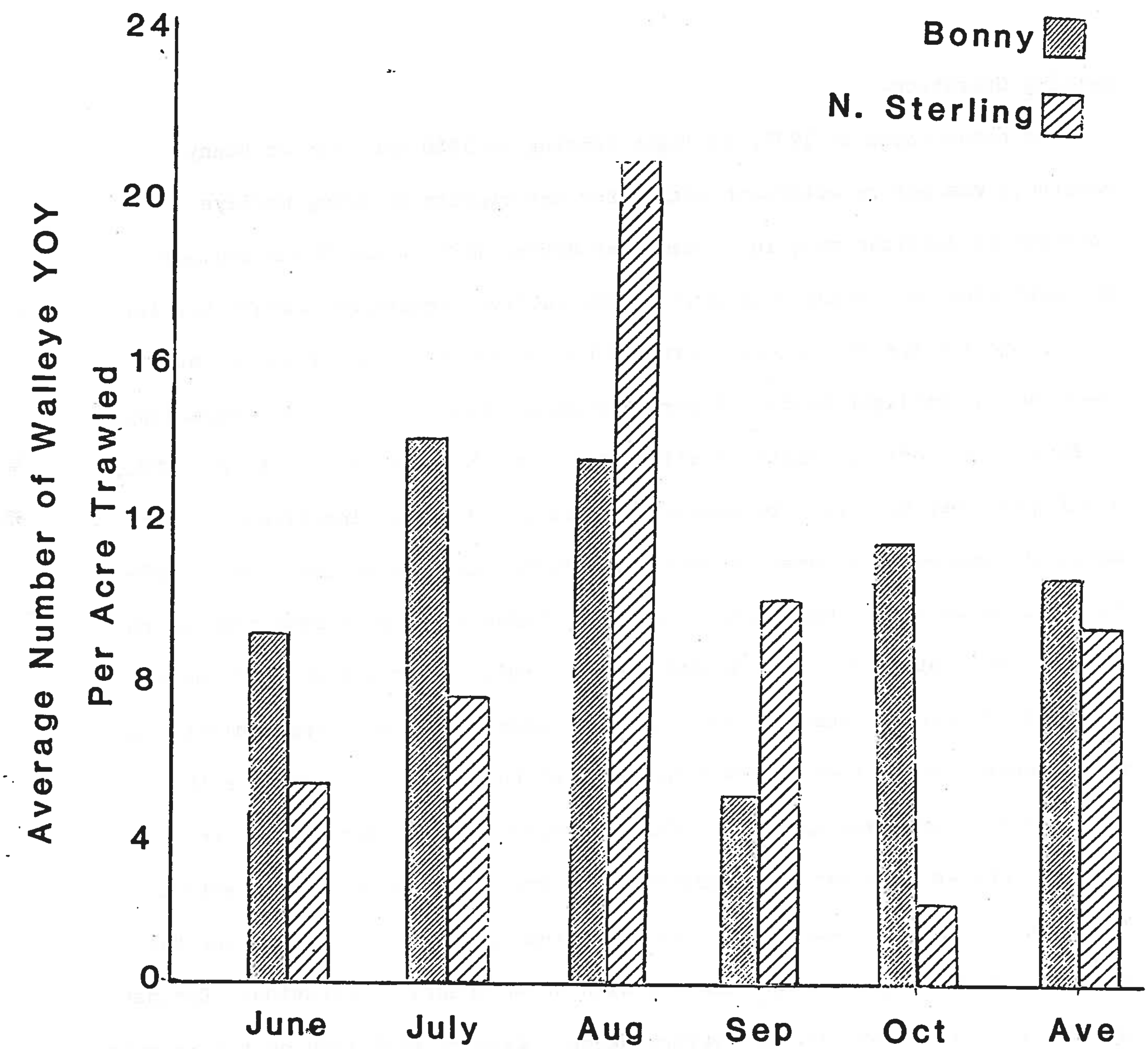

Figure 1. Average number of walleye young-of-the-year per acre taken during trawling operations in 1979 at Bonny and North Sterling reservoirs.

almost entirely of yellow perch and crappie. Also present, but only in trace amounts, were western white suckers (*Catostomus commersoni* Lacepède). Figure 2 summarizes the catch of forage species by trawling in each of the reservoirs for the duration of the study. Summit Reservoir was sampled only in 1979. Use of the trawl was abandoned at Narraguinnep Reservoir due to dense vegetation.

Seining Operations

As experienced in 1979, daylight seining in 1980 and 1981 at Bonny Reservoir was not an efficient method for the capture of young walleye compared to daylight trawling. Sampling during July of all 3 yrs produced the best results. After July most of the walleye fingerlings apparently left the littoral zones of the reservoir and became concentrated offshore, at least during daylight hours. Figure 3 compares the July catch of fingerlings at Bonny with those at North Sterling (1979) and Narraguinnep (1980 and 1981). The figure does not truly represent the overall catch of fingerlings at North Sterling Reservoir, as peak success for seining occurred during June of 1979, rather than July. A comparison of the July seine catch of forage fish at the project reservoirs (Fig. 4) yielded results similar to trawling, but usually with greater overall numbers being taken. Again, North Sterling exhibited a much reduced forage fish population. Most of the available forage in the littoral zone was made up of sand shiners, which had not appeared in the trawled open-water areas. Narraguinnep Reservoir, and to a lesser extent, Summit Reservoir, revealed very abundant forage populations inhabiting the littoral zone, usually in association with dense aquatic vegetation. Dominant species at both reservoirs was yellow perch. Gizzard shad made up the majority of the seine catch at Bonny and varied little from year to year.

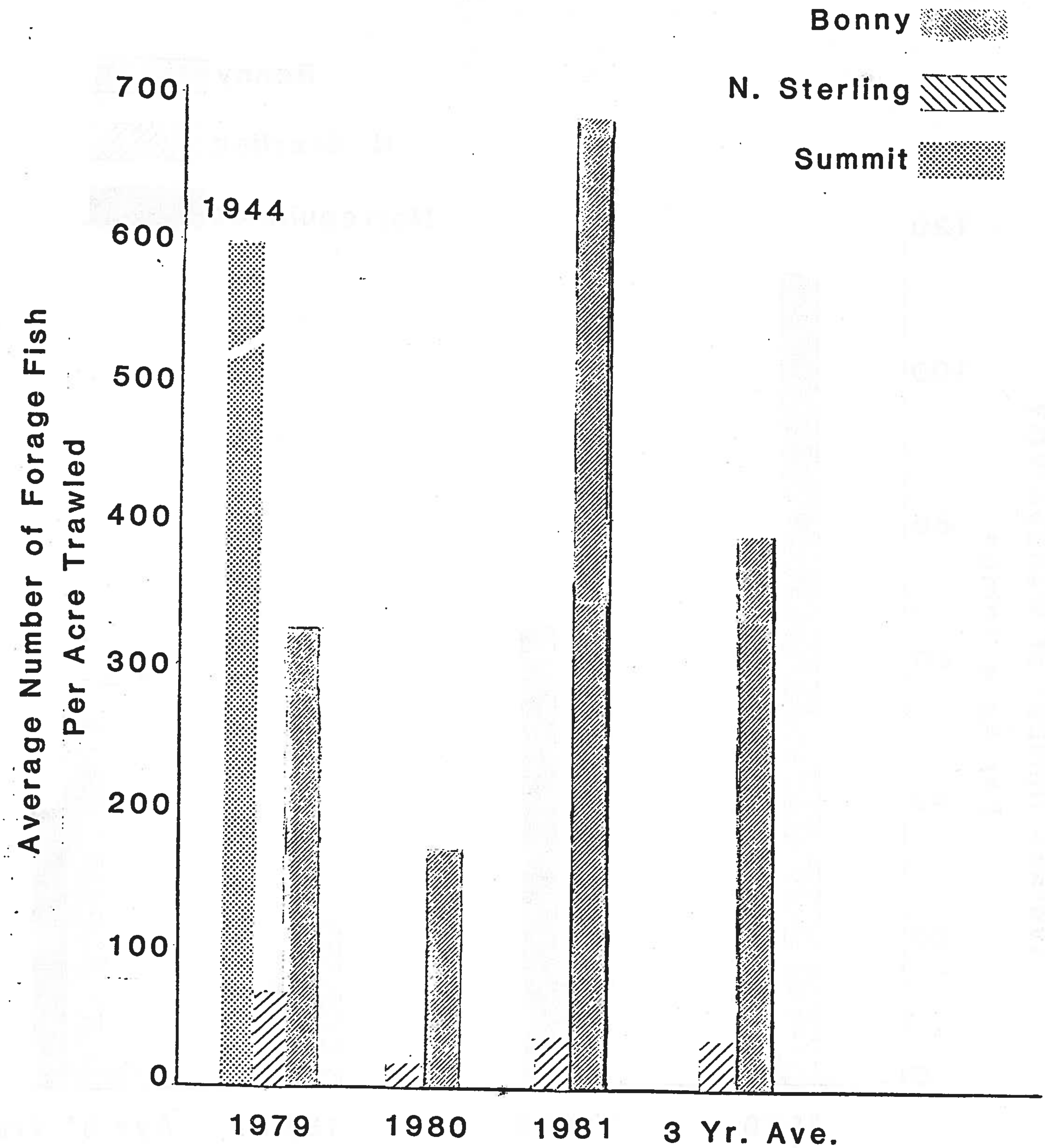

Figure 2. Average number of forage fish YOY (all species) per acre taken during trawling operations in 1979, 1980, and 1981 at Bonny, North Sterling and Summit Reservoir (Summit Reservoir sampled only in 1979).

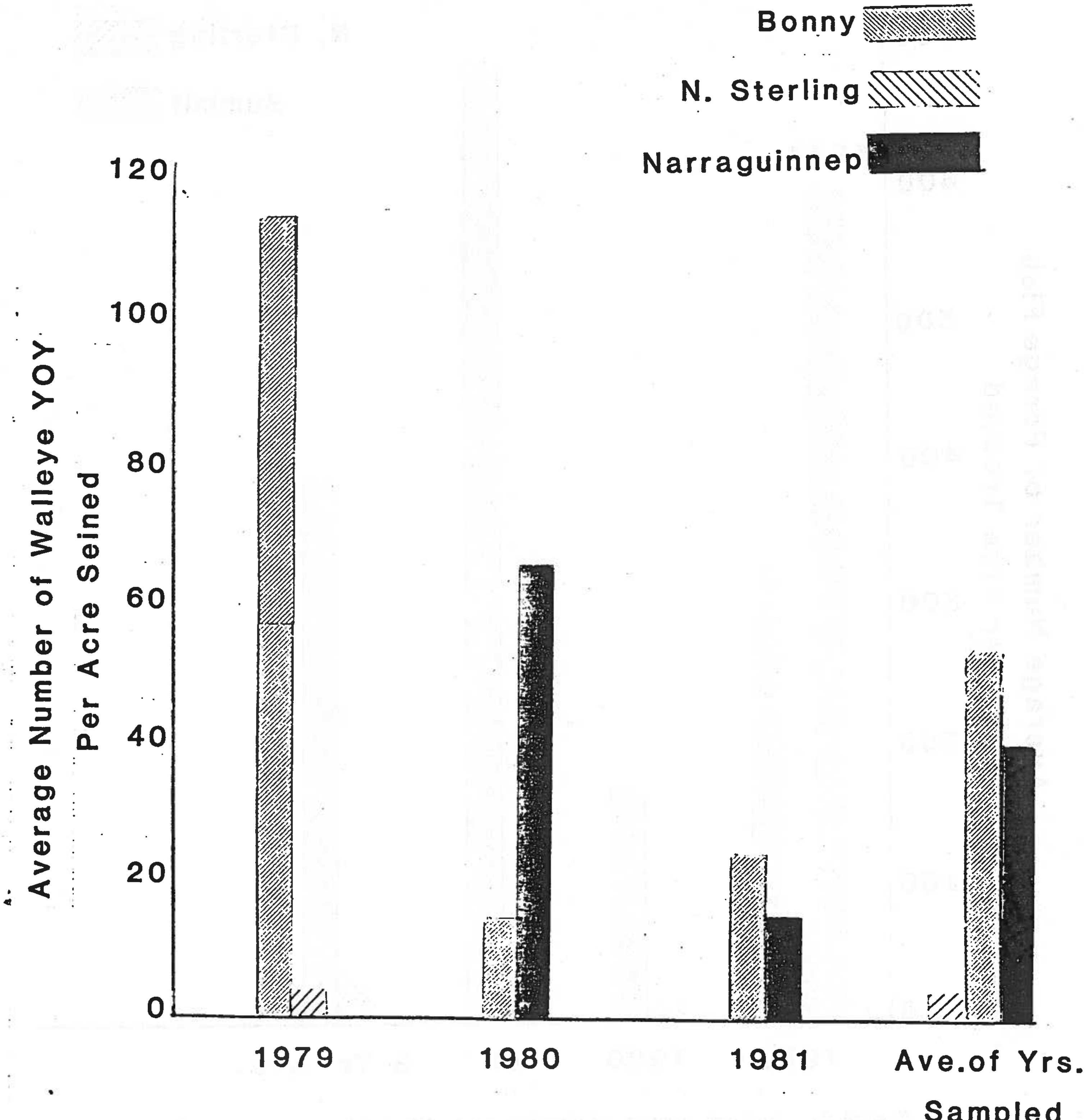

Figure 3. Average number of walleye YOY per acre taken during July seining operations at Bonny (1979-1981), North Sterling (1979), and Narraguinnep (1980-1981) reservoirs.

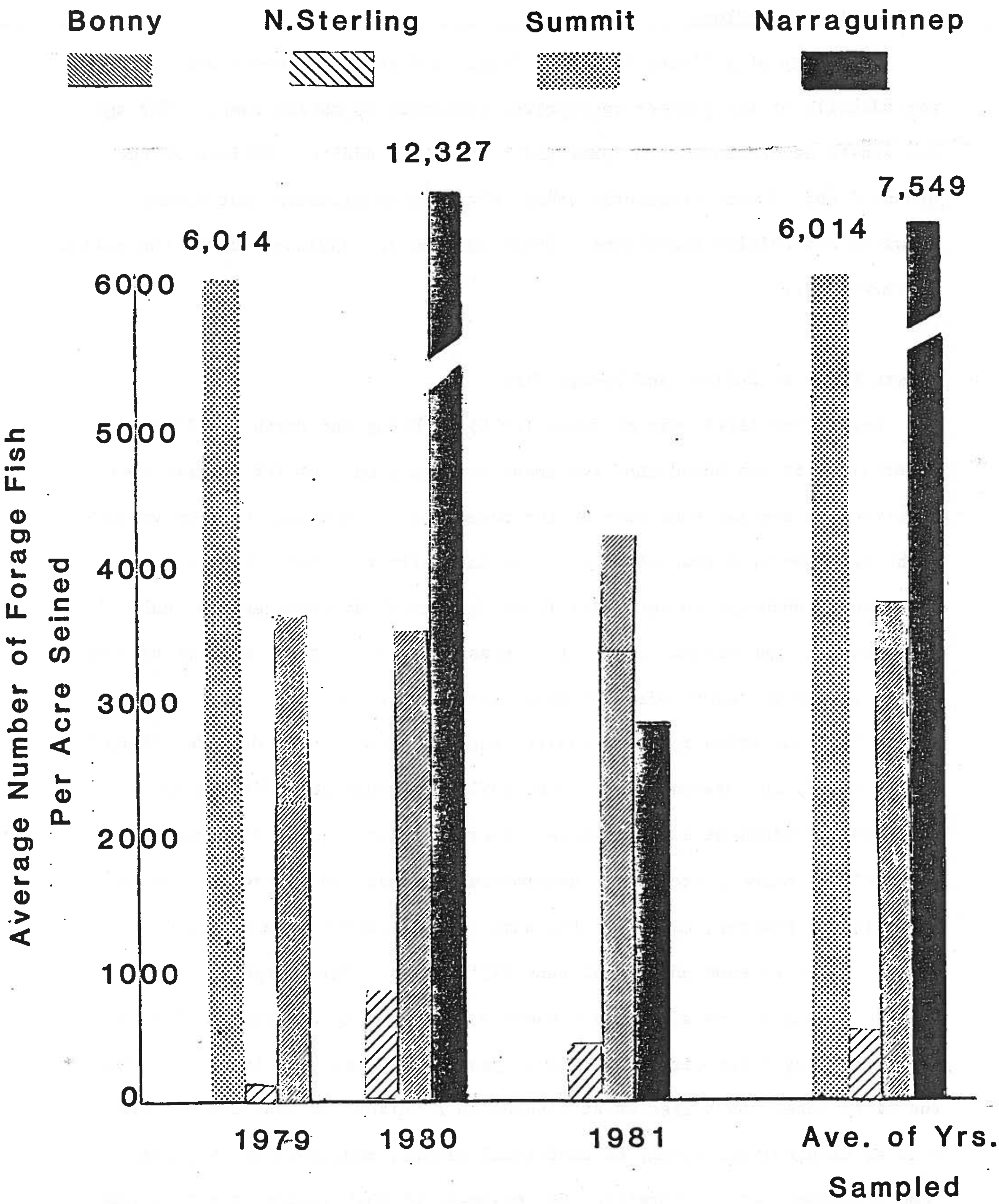

Figure 4. Average number of forage fish (all species) per acre taken during July seining operations at Bonny (1979-1981), North Sterling (1979-1981), Summit (1979) and Narraguinnep (1980-1981) reservoirs.

Gillnetting Operations

A variety of gillnets (3/4-in., 2-in., and graduated mesh) were set periodically at the project reservoirs, primarily to obtain samples for age and growth determinations of game and forage fish adults. Walleye of age groups I and II were frequently taken, not only by gillnets, but during trawling and seining operations. These samples are included in the tabulation of food habits.

Growth Rates of Walleye and Forage Fish

During the first year of study (1979) at Bonny and North Sterling reservoirs, it was noted that two apparent size groups of YOY walleye were occurring in samples from each of the reservoirs. Thinking the size variation might have resulted from planted versus naturally reproduced walleye fry, tests were conducted to determine if morphological differences also had occurred. It was assumed that differences in growth between walleye hatched and reared in the reservoirs and those incubated at the Wray Hatchery might result from variation in water quality and/or temperature. Garside (1966), Haaker (1977) and Dawson (1964, 1966, 1971) all found that differences in vertebral development can be induced experimentally in some fish species by a variety of stimuli including temperature, salinity and dissolved oxygen variations. However, counts of the number of vertebrae from each of the groups failed to show any significant differences. This, together with failure to sample any significant numbers of naturally produced walleye at North Sterling Reservoir in succeeding years would lead one to suspect that the differences might also be attributed to a variety of additional factors such as cannibalism, timing of individual plants, availability of plankton food organisms, etc. Therefore, for purposes of this report, the size groups are combined to show overall monthly growth increments. Table 2 summarizes the mean monthly total lengths of YOY walleye at each of the four project reservoirs. It will be noted that growth of walleye fingerlings at North Sterling Reservoir exceeds that of fingerlings at Bonny Reservoir during the months of June and July. A similar pattern also exists at Narraguinnep Reservoir, but is delayed by approximately one month. Spawning activity by adult walleye in Narraguinnep Reservoir appears to be a month to 6 wks later than at the eastern plains reservoirs. From August through October, growth at Bonny Reservoir begins to exceed that at North Sterling and Narraguinnep reservoirs.

Table 2. Mean monthly lengths (mm) of walleye YOY by various methods at North Sterling, Bonny, Summit, and Narraguinnep reservoirs, 1979-1981

Reservoir	Month				
	June	July	Aug.	Sept.	Oct.
			1979		
N. Sterling	51	92	125	150	163
Bonny	40	84	135	184	205
Summit				138	155
			1980		
N. Sterling	67	128			
Bonny	46	103	153	194	212
Narraguinnep		61	93	121	
			1981[a]		
N. Sterling		70			
Bonny		110		165	
Narraguinnep		57			

[a]Sampling reduced due to project funding restrictions.

As seen by Table 3, growth pattern of the principal forage species at each of the project reservoirs exhibits considerable variation. Growth of all represented species appears to be much faster at North Sterling than at any of the other reservoirs.

Table 3. Mean monthly lengths (mm) of various forage species YOY taken by all sampling methods at North Sterling, Bonny, Summit, and Narraguinnep reservoirs, 1979-1981.

Species	Reservoir	Month				
		June	July	Aug.	Sept.	Oct.
Yellow perch	N. Sterling	34	59	79	93	101
	Bonny		53	74	65	91
	Summit		26		45	46
	Narraguinnep		45	64		
Crappie	N. Sterling	40	43	64	79	86
	Bonny		44	59	69	73
	Summit		27		48	50
	Narraguinnep		23	49		
Drum	N. Sterling		29	59	78	118
	Bonny		26	47	69	83
	Summit	--------Not present---------				
	Narraguinnep	--------Not present---------				
Gizzard shad	N. Sterling			83	128	135
	Bonny		61	64	75	87
	Summit	--------Not present---------				
	Narraguinnep	--------Not present---------				
White bass	N. Sterling			48		131
	Bonny		40	66	77	83
	Summit	--------Not present---------				
	Narraguinnep	--------Not present---------				

Food Habits of Walleye YOY and Subadults

All walleye YOY taken during seining and/or trawling operations at each of the project reservoirs were examined in the laboratory to determine changes in food habits from June through October. Table 4 compares the results obtained at Bonny and North Sterling reservoirs in 1979, the only year in which sufficient samples were obtained. Occurrence of invertebrates, primarily zooplankton and diptera larvae, occurred much more frequently in the diet of North Sterling walleye than those at Bonny. Fish became the sole item utilized at Bonny after July, but occurred in less than 30% of all samples from North Sterling. With the switch to a fish diet, growth of Bonny walleye began to increase markedly over those at North Sterling.

Table 5 compares walleye food habits between Bonny and Narraguinnep reservoirs for 1980 and 1981. Walleye at Narraguinnep, apparently hatching at a much later date than at the plains reservoirs, were still relying heavily on invertebrates. By August 1981 the transition to fish had begun. Insufficient samples were obtained in 1981 to determine if this also occurred, although from the availability of forage fish present, such a transition is likely.

As previously mentioned, numerous I+ walleye (1979 plants) were taken in sampling operations at both Bonny and North Sterling reservoirs in 1980. Table 6 summarizes the results of the stomach analysis of these specimens. Although those at Bonny Reservoir relied significantly on invertebrates in May and June before YOY forage fish became readily available, those at North Sterling continued to feed almost entirely on invertebrates throughout the summer and into the fall.

Table 4. Frequency of occurrence of general food items of YOY walleye taken June-October, 1979 in Bonny and North Sterling reservoirs by various methods.

Month	Reservoir	Number stomachs examined	Number containing food	Walleye Mean lgth (mm)	Frequency of occurrence: Fish Number	Fish Percent	Invertebrates Number	Invertebrates Percent
June	Bonny	57	41	43	11	26.8	28	68.3
	North Sterling	33	33	47	5	15.2	30	90.9
July	Bonny	78	68	84	65	95.6	12	17.6
	North Sterling	34	30	91	9	30.0	24	80.0
Aug.	Bonny	72	65	136	65	100.0		
	North Sterling	61	54	126	21	38.9	35	64.8
Sept.	Bonny	18	15	189	15	100.0		
	North Sterling	32	27	144	6	22.2	22	81.5
Oct.	Bonny	31	26	194	26	100.0		
	North Sterling	7	7	152	1	14.3	6	85.7
Total	Bonny	256	215		182	84.7	40	18.6
	North Sterling	167	151		42	27.8	117	77.5

Table 5. Frequency of occurrence of general food items of YOY walleye taken June-September, 1980 and 1981 in Bonny and Narraguinnep reservoirs by various methods.

Month	Reservoir	Number stomachs examined	Number containing food	Walleye mean lgth (mm)	Frequency of occurrence: Fish Number	Fish Percent	Invertebrates Number	Invertebrates Percent
1980								
June	Bonny	15	13	46	0		13	100.00
	Narraguinnep	None taken in sampling						
July	Bonny	22	20	103	19	95.0	1	5.0
	Narraguinnep	57	54	61	6	11.1	52	96.3
Aug.	Bonny	38	36	161	36	100.0		
	Narraguinnep	16	15	93	12	80.0	3	20.0
Sept.	Bonny	14	13	212	12	92.3	1	7.7
	Narraguinnep	Not sampled						
1981								
June	Bonny	Not sampled						
	Narraguinnep	Not sampled						
July	Bonny	55	48	114	44	91.7	4	8.3
	Narraguinnep	19	17	57	7	41.2	11	64.7
Aug.	Bonny	Not sampled						
	Narraguinnep	Not sampled						
Sept.	Bonny	9	7	165	7	100.0		
	Narraguinnep	Not sampled						
TOTAL	Bonny	153	137		118	86.1	19	13.9
	Narraguinnep	92	86		25	29.1	66	76.7

Table 6. Frequency of occurrence of general food items of age group I+ walleye taken May-October, 1980, in Bonny and North Sterling reservoirs by various methods.

Month	Reservoir	Number stomachs examined	Number containing food	Walleye mean lgth (mm)	Frequency of occurrence: Fish Number	Fish Percent	Invertebrates Number	Invertebrates Percent
May	Bonny	17	14	205	0		14	100.0
	North Sterling	48	44	170	2	4.5	42	95.5
June	Bonny	46	34	215	9	26.5	29	85.3
	North Sterling	24	15	182	0		15	100.0
July	Bonny	8	7	226	7	100.0		
	North Sterling	26	21	199	1	4.8	20	95.2
Aug.	Bonny	None sampled						
	North Sterling	21	15	207	5	9.3	11	73.3
Sept.	Bonny	None sampled						
	North Sterling	None sampled						
Oct.	Bonny	None sampled						
	North Sterling	3	3	220	1	33.3	2	66.7
TOTAL	Bonny	71	55		16	29.1	43	78.2
	North Sterling	122	98		9	9.2	90	91.8

Age and Growth Determinations

Scales from walleye of age group I and older were analyzed from each of the project reservoirs. After the age was determined by location of annuli from the projected scale images, the relationship of scale length to body length was determined by linear regression (Puttmann and Finnell 1979). Results from the analysis and back-calculation of growth of over 500 walleye scales appears in Table 7. As expected, Bonny Reservoir continues to show the best yearly growth rate for walleye, followed by Summit Reservoir. North Sterling and Narraguinnep reservoirs show equal growth, although well below that of Bonny Reservoir.

Limnological Studies

During 1979 and 1980 seasonal changes in various limnological factors (temperature, zooplankton abundance, changes in turbidity, etc.) were recorded monthly from June to October at each of the project reservoirs. A report of these findings appear in an earlier publication (Finnell and Krieger 1981). As the 1981 field season was reduced in scope, insufficient additional data was accumulated to make meaningful comparisons with the previous data.

Table 7. Average length (mm) of net-caught walleye at all project reservoirs, 1978-1981. (Numbers in parentheses indicate actual numbers of a particular age group).

Year sampled	Number samples	Back-calculated length at time of annulus I	II	III	IV	V	VI
Bonny Reservoir							
1978	80[a]	196(80)	302(57)	396(54)	468(38)	533(19)	599(7)
1979	81[a]	208(81)	316(46)	372(12)	424(5)	504(3)	533(2)
1980	29	196(29)	331(15)	418(12)	462(6)	525(5)	574(5)
1981	25	222(25)	330(24)	412(20)	493(5)	534(5)	558(1)
Average size		204	314	399	466	529	579
Average annual growth increment		114	80	62	62	42	
Summit Reservoir							
1978	33	227(33)	314(8)	385(8)	431(7)	452(4)	483(1)
1979	31	176(31)	276(13)	364(12)	401(6)	432(4)	
1980	---Not sampled---						
1981	---Not sampled---						
Average size		202	290	372	417	442	483
Average annual growth increment		93	80	41	26	41	
North Sterling Reservoir							
1978	85[a]	182(85)	264(84)	349(61)	406(52)	456(12)	523(3)
1979	30	201(30)	250(29)	296(26)	337(9)	373(1)	
1980	46	165(46)	238(38)	314(34)	362(19)	403(7)	431(2)
1981	7	172(7)	242(6)	310(6)	358(1)		
Average size		180	254	327	387	433	486
Average annual growth increment		69	68	49	45	66	
Narraguinnep Reservoir							
1978	---No samples taken---						
1979	---Not sampled---						
1980	80	157(80)	239(79)	307(70)	388(26)		
1981	26	188(26)	274(26)	342(25)	389(24)	427(11)	
Average size		165	248	316	388	427	
Average annual growth increment		84	68	64	38		

[a]Includes samples taken during spawning run

SUMMARY AND CONCLUSIONS

Following a general survey of 24 known or suspected walleye reservoir fisheries in Colorado in 1978, a study of three of these reservoirs was initiated to test a 4-yr fry planting scheme originally developed at Boyd Lake (Reservoir). During the first year of study (1979), North Sterling Reservoir (Logan County), designated one of the project's "primary" target reservoirs, continued to receive plants of walleye fry numbering 2,000 per surface acre. The second primary reservoir--Summit (Montezuma County)--received no fry plants in 1979 to test natural recruitment of walleye. Bonny Reservoir (Yuma County) was chosen as the control. Fry plants remained at 2,000 per surface acre. At the conclusion of the first year of study, Narraguinnep Reservoir (Montezuma County) was added to the study in place of Summit as a more likely location for establishment of a viable walleye fishery. For the remaining years of the study (1980 and 1981) until cancellation at the close of the 1981 field season, both primary target reservoirs received no fry plants. Bonny Reservoir continued to be managed with fry plants ranging from 1,000-2,000 per surface acre. Cancellation of the project before actual testing of the Boyd Lake principles could be accomplished was deemed advisable as a result of staff changes at the regional fish management level. Personnel hired as warmwater biologists were given the responsibility of monitoring yearly all warmwater fisheries in the State, including the reservoirs chosen for the current walleye study. Management directives specified that the Boyd Lake planting scheme, with modifications where necessary, would be incorporated in the development of the State's walleye fisheries. Therefore, continuation of research activities on these waters amounted to a duplication of effort.

In concluding this report, each of the project reservoirs will be briefly discussed and recommendation for their continued management made based on data accumulated to date.

Bonny Reservoir

Throughout the course of the study this reservoir continued to exhibit perhaps the most stable and viable warmwater fishery in the State. Aside from some loss of water due to evaporation, yearly water level fluctuation is held to a minimum. Adequate growth of aquatic vegetation results in excellent habitat for both forage and game fish as well as a variety of invertebrate food organisms. Abundant yearly recruitment of nearly all forage fish species makes it possible to maintain a relatively high predator fish population (walleye) without sacrificing growth. Continued monitoring of yearly forage production with possible modification of walleye fry plants to suit the situation appears to be all that is necessary to insure the reservoir's sport fishery remaining at optimum levels.

Summit Reservoir

Although based solely on data obtained from only one season of research effort on this reservoir, it is the opinion of this author that development and maintenance of a viable walleye fishery is impractical under current conditions. Natural recruitment and survival of fry plants of walleye appear to be minimal, possibly due to extreme water level fluctuations, loss by escapement through the outlet, lack of sufficient spawning substrate, and/or predation by other species. Although forage fish production (yellow perch and crappie) appears to be more than adequate, existence of a large, self-sustaining northern pike population makes development of a good walleye population unlikely. However, continued plants of walleye fry, if available, might produce sufficient survivors to make a worthwhile contribution to the sport fisherman's catch.

Narraguinnep Reservoir

This body of water was chosen for study as a replacement for Summit based on its larger size and greater average depth. In both 1980 and 1981 walleye fry plants were withheld to determine success of natural reproduction. As a result of the 2 yrs of study, it is apparent that natural recruitment of forage fish, namely yellow perch, can be very abundant if adequate spawning habitat is available. In order for this situation to occur, the reservoir elevation must be maintained at a relatively high level during the spawning season (May and June). Past operation records for the reservoir indicate this may not occur with any degree of predictability. Placement of artificial brush shelters at various depths in the reservoir in recent years by the Division of Wildlife may aid considerably in development of a good forage base from year to year. During both years of the study, walleye natural reproduction was also found to be more than adequate to maintain the fishery without any additional fry plants. However, growth and apparent survival of the fingerling walleye to adults has been very disappointing. Lack of age group I+ walleye in gillnet sampling each year indicates either poor overwintering survival or at least insufficient size to be taken in 3/4-in. mesh nets. Existence of strong age groups of II+ and III+ adults may account for some mortality due to predation, but it doubtful that this alone could account for the poor survival, particularly with the abundant forage fish populations acting as a buffer for the fingerling walleye. Also unexplained is the relatively poor growth of adult walleyes in Narraguinnep Reservoir. Even with an abundant forage base, growth of walleye is no better than at North Sterling where there is a decided lack of forage (Table 7). With forthcoming construction of Dolores Reservoir by the U.S. Bureau of Reclamation, indications are that water levels at Narraguinnep will become more stable, with little or no yearly fluctuation (M. Japhet, 1981 per. comm.). This alone may greatly enhance survival and growth of both game and forage fish populations of the reservoir. In the interim, it is recommended that continued monitoring of the reservoir's fishery be conducted by management personnel yearly and that unless walleye natural recruitment ceases to occur at the current level, no further introductions of this species be made.

North Sterling Reservoir

Records indicate that North Sterling Reservoir, prior to the early 1970's provided an excellent fishery for a wide variety of warmwater species (Puttmann and Finnell 1979). Since that time both size and numbers of game fish such as walleye, crappie, and black bass have steadily declined. White bass, fairly abundant in the 1960's, no longer exist in adequately harvestable numbers. Forage species such as gizzard shad, yellow perch and drum began to decline shortly before the game fish populations and as of this writing have shown little indication of making a strong comeback. Efforts by management personnel to re-establish a forage base by the introduction of adult gizzard shad and yellow perch have shown little promise of success. However, in recent years initial success may have been enhanced by attempting introductions of gizzard shad by means of placement in North Sterling of mats containing fertilized shad eggs obtained at a neighboring reservoir (J. Stafford, 1980 per. comm.). Sufficient data is not yet available to determine the ultimate success of this method.

A summary of the results of 3 yrs of study at North Sterling Reservoir indicates that natural recruitment of walleye is insignificant. Harvestable populations of this species can only be maintained by fry plants. However, with the current lack of abundant forage, growth and survival will probably remain poor. Food habit studies of walleye fingerlings in 1979 and resulting survivors in 1980 generally indicate a failure to shift from invertebrates to fish. Growth of advanced fingerlings and subadults, although excellent in the early stages of development, is most certainly affected adversely by the reliance upon invertebrates. Effects of this diet on survival could not be ascertained by the study.

Yearly drawdown of North Sterling Reservoir is often extreme. Loss of fish by way of the outlet may be significant, but is probably not the only factor contributing to a decline of the fishery. Water quality, which was not addressed by the current study, may also be a prime contributing factor. Yearly production of zooplankton organisms (Finnell and Krieger 1981, Table 2) is extremely good, but so, also, is abundant growth of phytoplankton, including blue-green algae, often considered an indicator of organic pollution. Increased concentrations of agricultural and petroleum chemicals and wastes through the inlet may be occurring. This, in turn, may be the underlying factor in a failure of forage fish populations to expand. It is recommended that a study of this situation be strongly considered as part of future overall management plans.

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