PREY SELECTION BY SAUGER IN WATTS BAR RESERVOIR, TENNESSEE, AS AFFECTED BY COLD-INDUCED MORTALITY OF THREADFIN SHAD[a,b]

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Abstract: Prey selection by sauger (*Stizostedion canadense*) was monitored from November 1976 through April 1977 in the portion of Watts Bar Reservoir, Tennessee, near the Kingston Steam Plant. Threadfin shad (*Dorsoma petenense*) provided the entire forage base for sauger until the population of threadfin was almost completely eliminated by low temperatures in December and January. Some sauger switched to alternate prey, but food consumption was greatly reduced in February-March as $> 75\%$ of stomachs were empty. Food consumption of sauger smaller than 30 cm was restricted earlier in the year by the lack of threadfin less than 8.0 cm. Digestive rate studies in the laboratory indicated digestion continued at a reduced, but effective, rate at temperatures < 10 C.

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The sauger is a coolwater species which exists in Tennessee near the southeastern margin of its range. Adult sauger are piscivorous and, unlike other resident game fishes, continue to feed actively in winter. Early studies (Dendy 1946, Hassler 1953) indicated that gizzard shad (*D. cepedianum*) was the primary forage species utilized by sauger in Norris Reservoir, Tennessee, especially in winter. However, as a result of stocking and proliferation of the threadfin shad (*D. petenense*) in the last 2 decades, this shad species might now be expected to provide the forage base for sauger during the fall and winter as it does for the walleye (*S. vitreum*) in Center Hill Reservoir, Tennessee (Scott 1976).

Threadfin shad are subject to cold-induced changes in behavior making them more susceptible to predation when water temperatures drop below approximately 12 C (Griffith and Tomljanovich 1976). In addition to enhancing their availability to predators, low temperatures are accompanied by increased impingement of threadfin on intake screens of electrical generating facilities drawing cooling water from reservoirs such as Watts Bar. If a winter is severe, natural mass mortalities may also result.

Annually recurring winter impingement and mortality of threadfin shad possibly reduces forage available to predatory fish species such as the sauger whose survival in winter is seldom directly affected by power plant operation or low temperatures *per se*. The principal objectives of this study were to assess the importance of the threadfin shad in the diet of sauger and to evaluate the effects of cold-stress of threadfin shad on sauger food consumption and prey selection. The severity of the winter of 1976-77 gave the opportunity to study the situation under a "worst-case" condition.

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MATERIALS AND METHODS

Field Collection of Fish

Watts Bar Dam, at Tennessee River Mile 529.9, impounds 13,300 ha at minimum navigation pool (224 m above mean sea level). The upper portion of the reservoir is characterized by riverine reaches of the Emory, Clinch, and upper Tennessee tributaries

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(Fig. 1). The Tennessee Valley Authority's Kingston Steam Plant, located at Clinch River Mile 2.7, has a generating capacity of 1,700 MWe and withdraws 65 m^3/sec for cooling. In winter, cooling water may be withdrawn from either Clinch or Emory sources, depending on reservoir level and temperature and flow of each source. Discharge temperature is elevated 7.8 C at maximum power generation.

Sampling was conducted from November 1976 through April 1977. Sauger were collected with bottom set gill nets (mesh size 13 to 51 mm in 13 mm increments). Thirteen netting sites were selected in upper Watts Bar Reservoir (Fig. 1) within 14.5 river km of the steam plant and included its intake and discharge canals. Nets were set for 24 hr each week at stations 1-4 and for 24 hr bi-weekly at stations 5-13. Temperature profilies were taken at the time of each set. Fish were processed (or frozen for later examination) within 3 hr after nets were pulled.

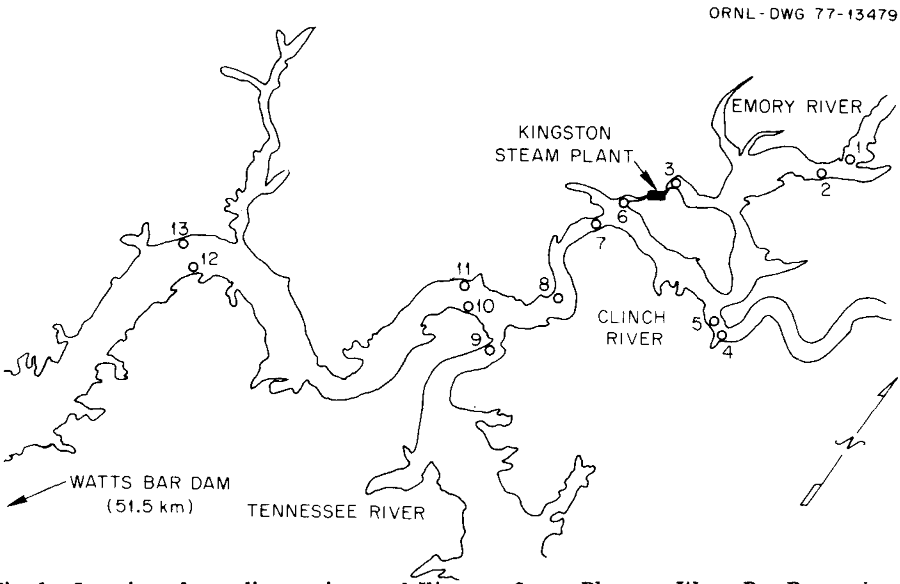

Fig. 1. Location of sampling stations and Kingston Steam Plant on Watts Bar Reservoir.

Sex was determined for each fish and total length and weight were recorded. Stomach contents were enumerated and identified to the lowest possible taxa. Particular care was taken to identify specimens which had regurgitated, evidenced by distended, but empty stomachs and often accompanied by the presence of egested material in the fish's throat and mouth.

Laboratory Studies of Digestion

Laboratory experiments were conducted with sauger captured from Watts Bar to assess effects of low temperatures on the digestive rate. We selected sauger ranging from 277 to 1,029 g, representative of fish collected from gill net catches. The fish were held in 770 l circular fiberglass tanks at 5, 10, and 15 C and force fed meals of 4-7 g. Two g ($\pm$ 0.1) fathead minnows (*Pimephales promelas*) were used as food. Meal sizes were expressed as milligrams of food per gram of sauger. Sauger were anesthetized with MS-222 during feeding and again when stomachs were pumped to recover partially digested meals. Food material from stomachs was blotted dry and weighed to the nearest 0.1 g. Rate of digestion was expressed as the percentage digestion which occurred in the time interval allotted.

RESULTS

Prey Selection

Prey species were recognizable even in advanced states of digestion because of distinct morphological and anatomical characters such as body shape, bone structures, spiny rays, otoliths, and gizzards. Seven percent of the 537 sauger examined had regurgitated stomachs, with no apparent correlation with collection date or location. Such stomachs were not included in prey selection analysis.

Examination of stomach contents of 499 sauger revealed that food consumption and prey selection differed substantially during distinct time periods (November-January and February-April). These periods corresponded with changes in threadfin shad abundance as affected by predation and cold-induced impingement and mass mortality.

From November through January, threadfin shad occurred as the only positively identified food in the 243 sauger stomachs examined (Fig. 2). Fifty-two percent of sauger

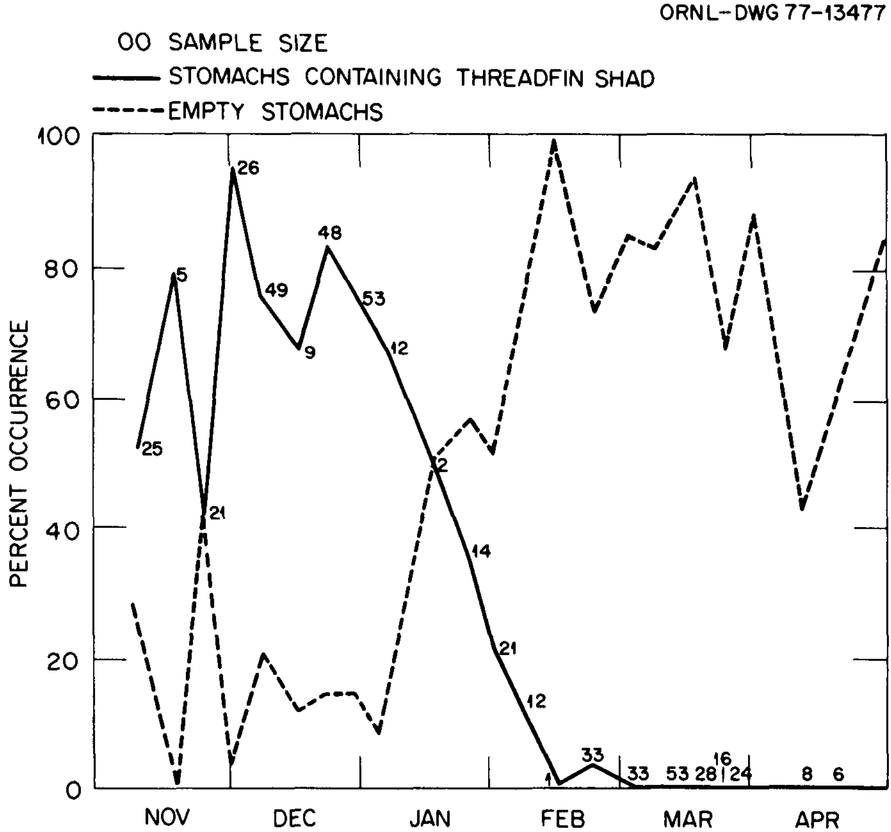

Fig. 2. Percent occurrence of threadfin shad in sauger stomachs versus empty stomachs from November 1976-April 1977. Numbers in circles represent sample size.

that preyed on threadfin contained more than 1 in the stomach, with a maximum of 7. Sauger that consumed multiple threadfin usually contained 2 or 3. Such prey were usually in different states of digestion but in some cases up to 5 were judged to be taken at the same feeding. Unidentified remains occurred in 10 percent of the stomachs and 17 percent were empty during this period.

Throughout February the occurrence of threadfin shad in sauger stomachs progressively decreased. The frequency of empty stomachs and utilization of alternate prey showed a concomitant increase (Table 1). During February, freshwater drum (*Aplodinotous grunniens*) accounted for 44 percent of identified prey and threadfin shad for the remaining 56 percent. Two-thirds of the 67 stomachs checked were empty.

Table 1. Stomach contents of 235 sauger collected in Watts Bar Reservoir, February-April 1976. Data from all sites combined.

Collection date	*Number of sauger*	*Number of stomachs containing*						
		thread-fin	*drum*	*log-perch*	*blue-gill*	*may-flies*	*uniden-tified*	*empty*
Feb. 2	21	7	2				1	11
9	12	2					1	9
16	1							1
23	33	1	5				3	24
Mar. 2	33		2	1			2	28
9	53		2	1	1	1	4	44
17	28		1				1	26
24	16			1	1		3	11
30	24				1		2	21
Apr. 6	0							
13	8			1	2	1	1	3
26	6							5

By March, threadfin shad were not found in any sauger stomachs. Freshwater drum, logperch (*Percina caprodes*), bluegill (*Lepomis macrochirus*) and mayfly (*Hexagenia* sp.) nymphs comprised the total of identifiable prey utilized in March and April. Combinations of more than one species of positively identified prey in a single stomach were never observed. During the 2 months, 82 percent of the 168 sauger stomachs examined were empty.

Cold-Induced Threadfin Shad Mortality

Records of fish impingement at the Kingston steam plant during the study period (Fig. 3) indicated striking changes in mortality of threadfin shad with time and temperature followed closely by changes in sauger food consumption. In November and December 1976, impingement of threadfin shad averaged several thousand per day, peaking in mid-December at more than 42,000 in 24 hrs. Impingement declined rapidly in late December and early January while water temperatures remained low, probably indicating depletion of the population in the intake vicinity. With the exception of a few fish in the steam plant discharge canal, very few threadfin shad probably survived the winter (Griffith et al. 1977).

The decline in sauger predation on threadfin shad lagged behind the drop in impingement, indicating that dying or possibly dead shad were more available to sauger than to the plant intake screens.

Effect of Water Temperature on Predation by Sauger

Some food was found in sauger stomachs throughout the winter and food consumption seemed to be influenced more by prey abundance than temperature. At all sampling stations, temperatures (as indicated by intake temperature, Fig. 3) were lowest in January and February but warmed to levels comparable to those of late November (approximately 10 C) by March. Food consumption by sauger, however, remained very low in March.

Low temperature in winter would be expected to reduce food consumption by slowing digestion rates of sauger. In the laboratory, mean percentage digestion of 10-20 mg/g meals of force fed fathead minnows by sauger at 15 C was 83 percent (range 71% to 98%) after 24 hrs. Sauger held at 10 and 5 C digested 47 percent (range 31% to 70%) and 39 percent (range 30% to 58%) of a similar force-fed meal after 24 hrs. A reduction in digestion rates with decreasing temperature is apparent.

Force feeding reduced the digestion rate of sauger at 15 C by nearly 50 percent in experiments by Swenson and Smith (1973). A similar effect at low temperatures would mean digestion of meals would occur faster then predicted from these experiments. If so, these experimental data suggest that digestion occurs at a sufficient rate to allow sauger to utilize forage available to them when water temperatures are between 5 and 10 C.

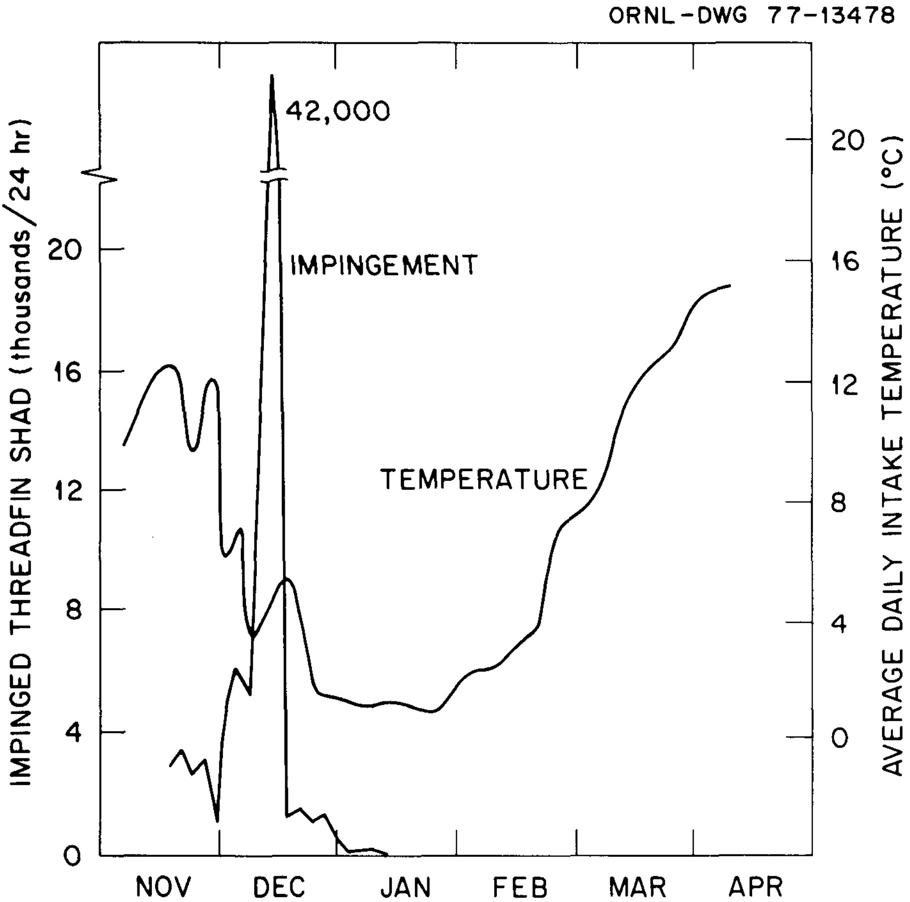

Fig. 3. Impingement of threadfin shad at Kingston Steam Plant and water temperatures at the intake canal from November 1976-April 1977.

Lengths of Threadfin and Selectivity of Sauger

Differences in size between sexes of sauger and immature fish existed and probably influenced the size of threadfin taken as forage. Mean length and weight of female sauger was 41.4 cm and 737 g, with a range in length from 30.1 cm to 52.7 cm. Mean size of males was 36.8 cm and 471 g, with length ranging from 27.7 cm to 47.5 cm. Immature sauger had a mean size of 30.5 cm and 258 g and ranged in length from 19.8 to 40.7 cm.

The majority of threadfin consumed by sauger from November through February were young of the year 8 to 10 cm in length. Sauger over 42 cm also utilized yearling and older threadfin 12 to 15 cm in length (Fig. 4). Some overlap in the length distribution of threadfin occurred but records of impinged fish and gill net catches of threadfin indicated a similar size distincton. Scale reading of threadfin shad in January confirmed the approximate break in size between young of the year and older fish was 11 cm (Griffith unpublished data).

Maximum lengths of threadfin which were consumed ranged from 29-35 percent of body length of sauger from 22-50 cm long. Sauger under 30 cm consumed very few threadfin and were probably limited by the availability of shad less than 8.0 cm.

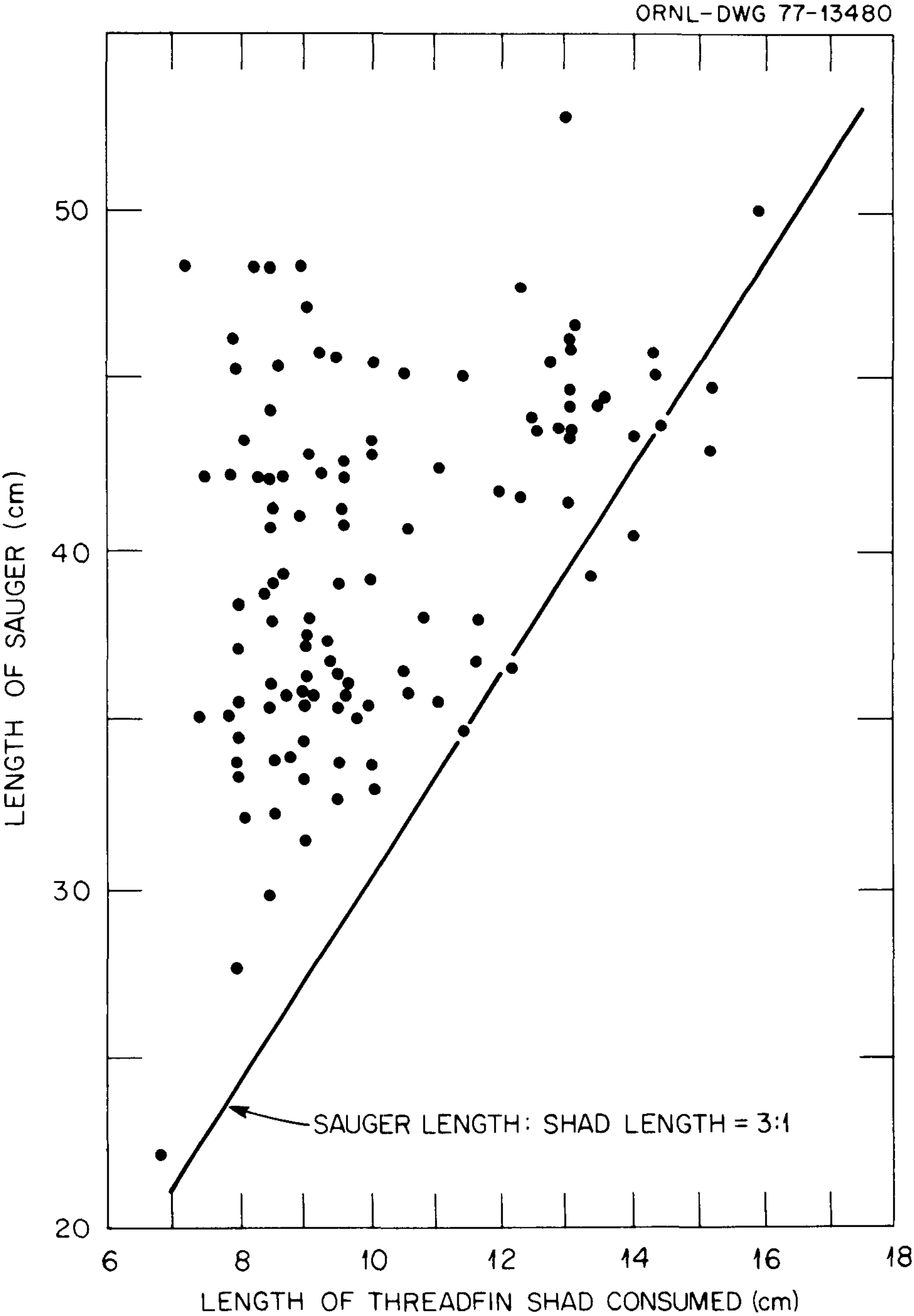

Fig. 4. Length distribution of threadfin shad consumed by sauger in Watts Bar Reservoir. Line connects maximum lengths of threadfin consumed by sauger expressed as percent body length of sauger.

DISCUSSION

Sauger predation on threadfin shad from November through January agrees with observations by others (Dendy 1946, Hassler 1953) that cold-induced changes in behavior of clupeid species increases their vulnerability to predation. Contrary to these earlier findings, however, gizzard shad were never positively identified from stomachs, which indicates that their utilization by sauger in Watts Bar was proportionally very low, if it occurred at all. Gizzard shad are more resistant to cold temperatures (Cox and Coutant 1976) and probably were less vulnerable to sauger predation than threadfin. Very few young of the year gizzard shad were captured in gill nets and these shad were probably less abundant than the threadfin. Walleyes in Center Hill Reservoir, Tennessee, also preyed most heavily on threadfin shad in fall and winter and very few gizzard shad were consumed (Scott 1976).

The presence of multiple shad in the stomachs and lack of of other identifiable prey from November-January indicates that threadfin supply the forage requirements of that portion of the sauger population over 30 cm and that food consumption is substantial at this time. Similarly, increased food consumption by sauger and walleye in northern lakes appeared to be directly related to increasing availability of yellow perch (*Perca flavescens*) (Swenson and Smith 1973).

Reduced digestion rates of sauger at low temperatures may be partially compensated for by the presence of large amounts of food in the stomach. During periods of reduced temperatures and high food availability, walleye in Lake of the Woods Minnesota and Shagawa Lake maintained high stomach volumes, digestion rates, and food consumption rates (Swenson 1977). Sockeye salmon (*Oncorhynchus nerka*) compensated for reduced efficiencies at low temperatures by increasing food consumption; the seasonal increase in food intake indicated a capacity to take on energy and retain it for gradual digestion (Brett and Higgs 1970).

A combination of cold-induced mortality and impingement of threadfin coupled with predation appeared to limit the food consumption of sauger in late winter and spring. At least 4 species of alternate prey were utilized after depletion of the threadfin population, but not before, indicating that threadfin were the preferred prey of sauger because of their relative abundance and vulnerability. Walleye in Lake Erie exhibited a similar preference for the most abundant prey of acceptable size when large numbers of forage species were available (Parsons 1971). The high proportion of empty stomachs after threadfin became scarce suggests that the alternate prey species were not as abundant or available to the sauger. In Oneida Lake, New York, Galligan (1960) suggested that the absence of food in walleye stomachs during winter reflected the unavailability of prey species at that time.

Although food consumption was reduced as indicated by the high proportion of empty stomachs, many sauger retained stores of visceral fat through winter. Such stored energy made a significant contribution to the seasonal energy budget of walleye in West Blue Lake, Manitoba (Kelso 1973. The possibility that energy stored by sauger in tissues and fat may serve as an energy sourfe for gonadal development, maintenance and growth in spring is currently under investigation.

Sauger less than 30 cm appear to be most limited in their food consumption. These smaller sauger were not found to prey on shad over 8 cm in length and may be restricted by mouth size to feeding upon shad less than 30 percent of their body length. Most threadfin shad grew beyond 8 cm by November and impingement and gill net records indicate few threadfin of this size remain after the onset of cold-induced impingement and mortality (TVA unpublished data). It can be hypothesized that an increase in the catch rate of small immature sauger that was observed in spring was because of increased searching for food to compensate for reduced consumption in the fall and winter.

The predator-prey relationship of sauger and threadfin shad is unique in that a relatively cold-tolerant species is feeding in fall and winter primarily on a cold-sensitive prey. As such, cold-induced mortalities and impingement of threadfin serve as a destabilizing force on populations of both species. The effects of forage loss on other sauger populations have been recorded. In Lewis and Clark Lake, South Dakota, a winter mortality of gizzard shad appeared to be responsible for a decline in the growth rate of sauger (Nelson 1969). Lack of forage fishes during some years was considered a factor limiting the growth rate of sauger from Lake Winnebago, Wisconsin (Priegel 1969). Extremely low growth rates of walleye and a high proportion of non-ripening females were apparently caused by a limited food supply during the growing season in Oneida Lake, New York (Forney 1965). Failure of threadfin shad to compensate for the severe reduction in numbers incurred during the winter of 1977 may result in sauger increasing predation on other species. A high density of young yellow perch was suggested to act as a buffer, reducing walleye predation on other forage species in Oneida Lake, New York (Forney 1974).

Sauger in Watts Bar Reservoir may be expected to show similar reactions if low numbers of threadfin are available during 1977. Further study is needed to determine if alternate prey can supply sauger with adequate forage, especially during the latter part of 1977, to prevent reduction in growth rates and fecundity in 1978.

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