CHAPTER IV

DISCUSSION

Prey Selection by Sauger as Related to Impingement and Mortality of Threadfin Shad

Threadfin shad were the most important prey species utilized by sauger and occurred as the only food positively identified from stomachs from November to January. At least four species of alternate prey were utilized after, but not before, depletion of the threadfin populations in January, indicating threadfin were the preferred prey of sauger (probably 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). Sauger did not appear to be selective for alternate prey which were utilized.

Records of fish impingement at the Kingston Steam Plant during the study period indicate striking changes in impingement of threadfin shad with time and temperature (Fig. A1, Appendix), which can be related to changes in sauger food consumption. In November and December 1976, impingement averaged several thousand per day, peaking in mid-December at over 42,000 in 24 hr. Differences existed in the size classes of threadfin impinged through time (Fig. A2, Appendix), and suggest an increased cold tolerance of the larger individuals. This differential survival affected the size range of threadfin available to and utilized by sauger throughout the winter (Fig. A3, Appendix). Impingement declined rapidly in late December and early January while water temperatures remained low, probably indicating depletion of the population in the vicinity of the canal. Continued cold weather and low water temperature in January resulted in cold-induced mortalities of threadfin at other sample sites, as evidenced by gill net catches and observations of threadfin dying in coves. With the exception of a small population in the discharge canal, probably very few threadfin survived the winter (Griffith et al. 1977).

After the decline of threadfin populations in January, sauger consumed alternate prey in approximately the same proportion as these species were impinged on intake screens (Fig. A4, Appendix). Threadfin shad utilized in February had a higher percent occurrence in sauger stomachs than on intake screens, suggesting continued selection by sauger for the remaining threadfin. It is interesting to speculate on the possibility that intake screens could provide a sensitive index of prey availability to sauger. The highest impingement counts for threadfin occurred during the months of greatest sauger predation on this species, indicating the relationship of cold stress to vulnerability to impingement, and to predation, as previously determined by laboratory experiments (Griffith and Tomljanovich 1975, Griffith 1978). Most sauger moved out of the intake canal after December, when impingement counts indicated depletion of the threadfin population at this site. Sizes of threadfin consumed by sauger increased with sizes of impinged threadfin as the smaller size classes became unavailable due to cold-induced mortality. The decline in sauger predation on threadfin and a dramatic increase in the number of empty stomachs followed approximately two weeks behind the drop in numbers of impinged threadfin, both indicating the depletion of threadfin populations due to cold-induced mortality. These relationships which existed provide evidence for the use of impingement monitoring as an index of the abundance and vulnerability of forage species, but also suggest a possible "competition" could exist between intake screens and sauger for these vulnerable prey. Food consumption by sauger was not directly limited by impingement-related mortality of threadfin shad, except perhaps in the vicinity of the intake canal, but was reduced in winter due to the combined effects of natural cold-induced mortality, predation, and impingement.

Application of Digestion Rate Studies

Use of mean-calculated regression coefficients for digestion rates allows estimates of the time required for digestion of meals by sauger during the winter months. For sauger consuming meals of 4 to 7-g threadfin shad (approx. 8-10 cm in length) at temperatures between 5 and 10 C, digestion could reach 90% completion in approximately 47 to 54 hr. At 15 C, digestion would require approximately 25 hr to reach 90% completion. Digestion of meals beyond this point, termed the residual phase (Windell 1966), consists primarily of dissolution of resistant parts and was not included in this analysis.

Other factors influencing digestion may reduce the accuracy of these estimates. In studies with walleye and sauger at 14.5 and 20 C, Swenson and Smith (1973) found food digested per hour increased with meal size and fish size. Later Swenson (1977) concluded that high stomach volumes tended to compensate for the effects of low temperature (14.5 C) on digestion. If these effects continue to operate at 5 and

10 C, digestion by sauger consuming meals of multiple shad during the winter months in Watts Bar Reservoir may proceed more rapidly than estimated by the experimental methods.

In experiments to determine the influence of a substitute food source on the digestive rate, sauger digested meals of threadfin shad slightly faster than equivalent meals of fathead minnows. This slight increase may be due to the fact that regressions on threadfin data were calculated only from observation after 12, 18, and 24 hr, as opposed to observation after 12, 18, and 24 hr for digestion of fatheads. By ignoring the lag time which exists in the early stages of digestion these regressions describing digestion of threadfin by sauger may be slightly overestimating the rate and may account for the observed increase. Swenson and Smith (1973) found slight differences in digestability of yellow perch and fathead minnows, but concluded that use of fatheads as a substitute food source did not significantly reduce accuracy of estimates of the digestion rate for walleye and sauger.

Digestion of force-fed meals by sauger was consistently less than that of voluntarily consumed meals over a wide range of meal sizes but was not significantly reduced in any case. Results from another study (Swenson and Smith 1973) indicated force-feeding of walleye significantly reduced digestion after 8 hr at 14.5 C. Data from the present study suggest that the bias introduced by force-feeding may not be as great. The slignt reduction in digestion could be due to the lack of a feeding stimulus preceding ingestion of the meal, or to the effects of the anesthetic MS-222, or to handling stress. If force-feeding exerts a continuous influence throughout the time required for complete digestion then perhaps digestion could be significantly reduced. It does not seem likely the effect would act in this manner, and force-feeding was not considered a source of significant error in these experiments. Any bias that was introduced by force-feeding would suggest that digestion of meals consumed by sauger in Watts Bar Reservoir within the temperature ranges considered could proceed faster then predicted from these experiments.

Utilization of Food Energy

The high proportion of sauger stomachs containing shad, coupled with laboratory estimates of the digestive rate, suggest that food consumption in late fall and winter was sufficient to result in quantities of excess energy available to sauger. In caloric energetic studies of walleye maintenance requirements and conversion and assimilation efficiencies, Kelso (1972) determined energy for maintenance was similar between 4 and 12 C, but increased rapidly above this point. Gross and net conversions were not affected by temperature and assimilation efficiency was high. Conversion of energy for growth was low at lower temperatures and growth did not occur at temperatures below 12 C. Walleye underwent a pronounced seasonal change in energy content and the caloric accumulation was stored in interstitial and abdominal fat deposits (Kelso 1973). The seasonal change in biocontent was judged to represent a significant contribution to the energy budget of walleye.

Similar changes in bioenergetic content of sauger would be expected to occur. Growth of sauger and walleye does not occur during the winter months in Tennessee and food consumption in winter results in accumulation of large visceral fat reserves (Dendy 1946a, Hassler 1953, Stroud 1949). Sauger examined in the present study contained fat reserves comprising approximately 1 to 9% of body weight. Larger mature sauger had proportionally more energy stored in fatty tissues; immature sauger less than 30 cm contained the least amount of fat reserves.

Energy stored in tissues and available directly from food consumed in winter was probably important to sauger for gonadal development and maintenance requirements in late winter and spring when food consumption was reduced. The principal growth phase of ovaries in Stizostedion and Perca spp. takes place during the coolest seasons when body growth ceases (Hokanson 1977). Insufficient fat reserves to meet energetic demands of oogenesis and winter maintenance requirements increased mortality of female yellow perch in two Laurentian lakes (Newsome and Leduc 1975). Deficiency in food and poor growth conditions in summer have also caused missed spawning periods and oocyte resolution in Stizostedion spp. (Forney 1965, Eschmeyer and Smith 1943). Successful spawning and good growth of sauger during the spring and summer of 1977 indicate that fat reserves probably were utilized and were important in maintaining healthy conditions of the sauger population (McGee, unpublished data).

The importance of late fall and winter feeding by sauger on threadfin shad can also be considered in terms of the seasonal abundance and distribution of threadfin. As a semi-tropical planktivorous species, threadfin shad prefer the warmest temperatures available, and are found primarily in littoral and epipelagic zones throughout the summer. Shad in Norris Reservoir, Tennessee, were most abundant in surface waters at a temperature range of 21 to 27 C through summer (Dendy 1946b). In this same study sauger were found to prefer deeper strata with a temperature range of 15.5 to 21.0 C and were concentrated just above layers of water with low oxygen content. These differences in the preferred temperatures of the sauger and threadfin shad suggest that, in summer, sauger may at times be spatially isolated from threadfin, and that this factor could reduce food consumption. Behavioral characteristics of the two species may aid in mitigating this effect on the predator-prey interaction. Diel migration in depth distribution of threadfin shad occurs (Netsch et al. 1971) and may increase spatial overlap in the distribution of the two species during the night. Crepuscular and nocturnal feeding forays of sauger into warmer waters would also increase interaction.

High water temperatures increased maintenance requirements and cyclic changes in water temperature lowered food conversion of walleye (Kelso 1972). Spatial isolation between gizzard shad and walleye due to temperature preferences decreased availability of shad and resulted in a reduced growth rate of older walleye in Hoover Reservoir, Ohio (Momot et al. 1977). Similar effects would increase the energetic costs of sauger predation on threadfin and reduce the predatory efficiency of sauger during the summer months. Sauger and walleye exhibit similar physiological optimum temperature ranges, and lower temperatures required for walleye spawning are the principal difference between the two species (Hokanson 1977).

Because of the adaptations of sauger to a cool-water, low-light environment, optimal feeding conditions should occur in late fall and winter as water temperatures cool, becoming more uniform throughout and as young-of-the-year shad become stressed. Shorter daylengths in fall and winter months increase the total hours of twilight and darkness during which sauger are more efficient predators (Ryder 1977). Data from this study suggest that for several months in late fall and winter, predation by sauger on threadfin shad was facilitated by a combination of these factors.

Destabilizing Effects of Cold-induced Threadfin Shad Mortality

Cold-induced threadfin shad mortality, as determined by this study, reduced food consumption by sauger and increased predation on at least four species of alternate prey in late winter and spring. Increased predation on alternate prey suggests that threadfin shad acted as a buffer, reducing sauger predation on other species, while threadfin remained available. Conversely it may be argued that predation on alternate prey acted as a buffer, relieving predation pressure on depleted threadfin stocks. The role of a buffer species, however, has usually been assigned to the most abundant prey species. A high density of yellow perch was suggested to act as a buffer, reducing walleye predation on other forage species in Oneida Lake, New York (Forney 1974). Alewives acted as a buffer, reducing predation on yellow perch and alternate prey in Lake Michigan (Wagner 1972). The high percentage of empty sauger stomachs in late winter, after loss of the forage base provided by threadfin, suggests that alternate prey were not utilized as heavily by sauger due to unavailability or continued selectivity for the remaining threadfin. Under these circumstances it seems reasonable to say that alternate prey relieved predation pressure on threadfin only after threadfin reached a critical minimum density, or unavailability due to larger size of surviving individuals, and these alternate prey were utilized only in approximate proportion to their vulnerability and abundance. Threadfin, however, were preferred and selected for by sauger while they remained abundant and vulnerable, and for this reason they acted as a buffer for the alternate prey which were presumably available to sauger throughout the study.

Ability of threadfin shad to compensate for the severe reduction in numbers incurred during winter 1977 may be most important in determining possible long-range impacts on sauger growth rate and fecundity. A winter mortality of gizzard shad appeared to be responsible for a decline in the growth rate of sauger in Lewis and Clark Lake, South Dakota (Nelson 1969). Lack of forage fish in some years was considered a factor limiting the growth rate of sauger from Lake Winnebago, Wisconsin (Priegel 1969).

Data collected during late summer and fall 1977 indicate that compensation by surviving threadfin shad was sufficient to successfully reestablish this species in Watts Bar Reservoir (Griffith et al., unpublished data). In view of the severity of the winter 1977, these data suggest that established populations of threadfin shad are capable of surviving winters in Tennessee despite extensive cold-induced mortality. Scale reading of sauger collected in late fall 1977 and winter 1978 indicated growth rate of sauger in 1977 in Watts Bar Reservoir was proportional to that in previous years and that the magnitude of threadfin shad mortality in winter had an unpronounced effect on sauger growth (McGee and McLean, unpublished data).

Important aspects of the predator-prey relationship of sauger and threadfin shad which can be suggested for further study include seasonal changes in energy content of sauger as influenced by food consumption, spatial and temporal restrictions on sauger-threadfin interactions in summer, and relationships between fish impingement and predation on these species by sauger.

CHAPTER V

SUMMARY

1. Threadfin shad were the only positively identified species utilized as food by sauger from November 1976 to January 1977.
2. Sauger utilized threadfin because they were the most abundant and vulnerable prey species of the preferred size available.
3. Cold-induced behavioral changes in threadfin below approximately 10 C reduced swimming abilities and increased vulnerability to predation and impingement.
4. The maximum lengths of shad consumed by sauger approximated a 3 to 1 predator-to-prey ratio and influenced the availability of threadfin to sauger.
5. Predation on threadfin by sauger less than 30 cm in length was limited by the availability of threadfin less than 8 to 10 cm.
6. Sauger over 42 cm in length could utilize yearling and older threadfin 12 to 15 cm in length. Mature female sauger were more abundant than males in the size classes of sauger able to utilize the larger threadfin shad.
7. Extensive cold-induced mortality of threadfin in December and January reduced sauger food consumption and increased predation on freshwater drum, logperch, bluegills, mayfly nymphs, and other unidentified prey species.
8. Gizzard shad were never positively identified from sauger stomachs and gizzard shad of a size available to sauger were not abundant during the study period.

9. Sauger appeared to store excess energy available at low temperatures as visceral fat reserves comprising approximately 1 to 9% body weight. Fat content was greatest in larger mature sauger. Sauger under 30 cm contained the least amounts of visceral fat.

10. Laboratory digestion rate experiments determined digestion of a 4 to 7-g meal by sauger required approximately 54 hr at 5 C, 47 hr at 10 C, and 25 hr at 15 C to reach 90% completion.

11. Comparison of digestion of force-fed and voluntarily consumed meals by sauger indicated no significant difference in digestion (T-test $P < 0.05$) using the force-feeding method.

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APPENDIX

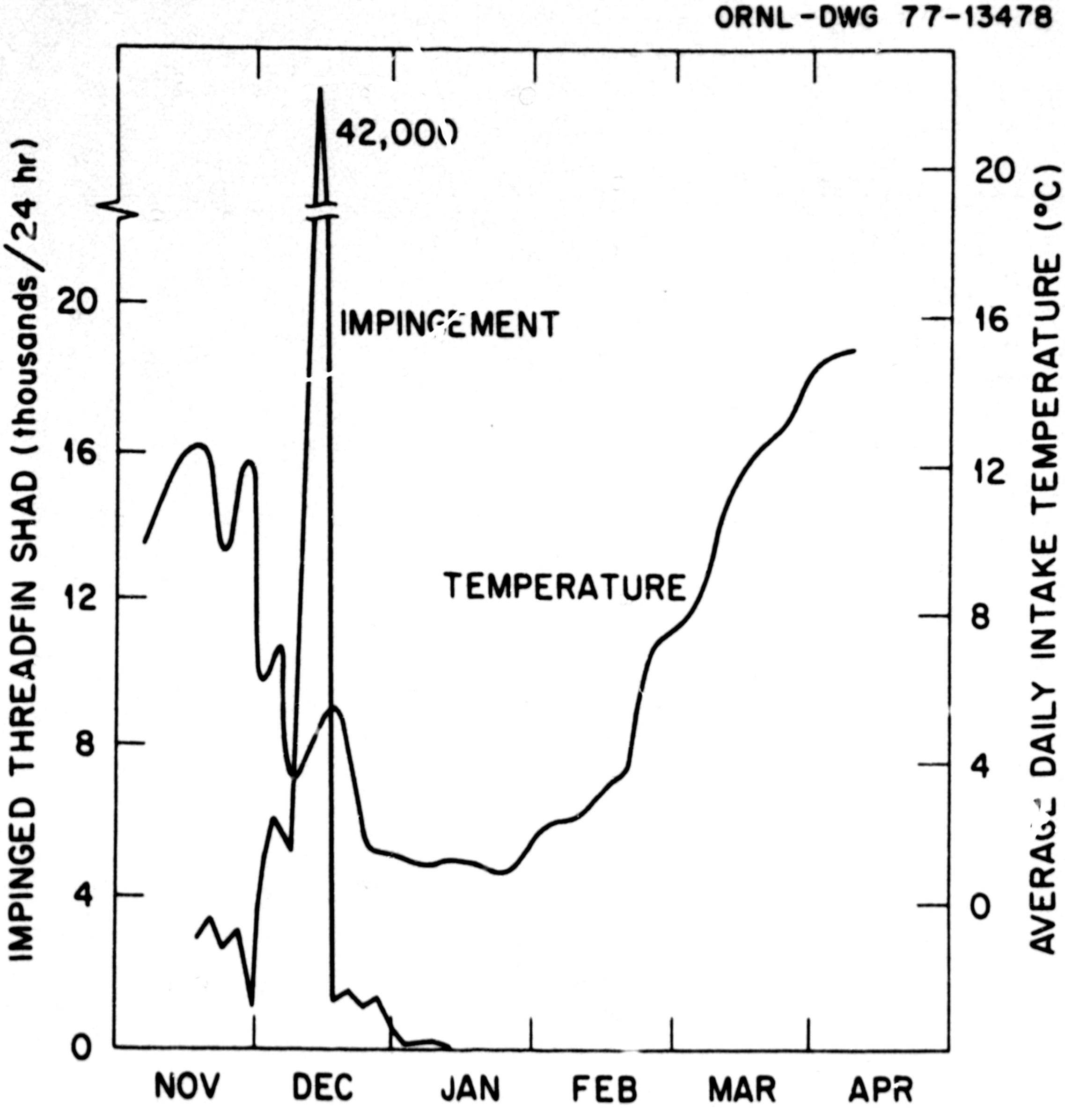
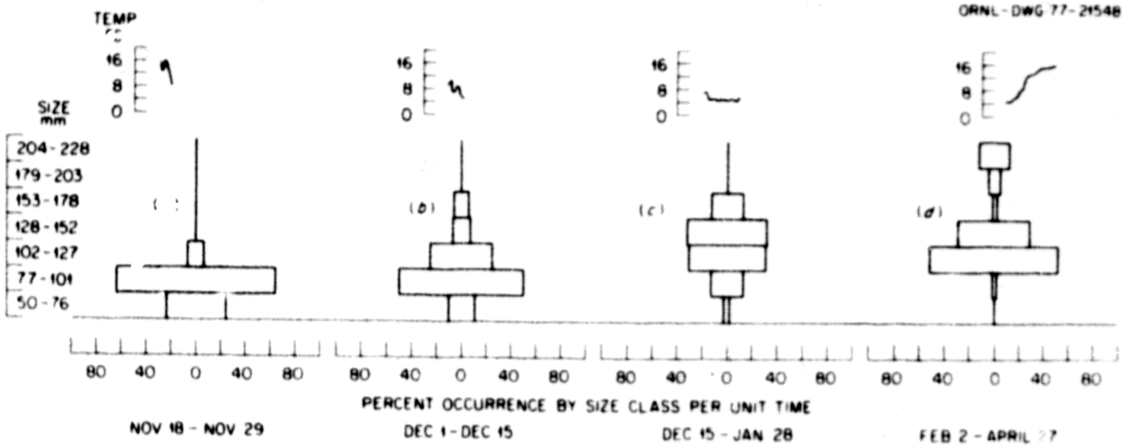


Figure A1. Impingement of threadfin shad at the Kingston Steam Plant and water temperature in the intake canal from November 1976 through April 1977 (Source; McGee et al., in press).



Figu A2. Percent occurrence by size class per unit time of threadfin shad, Dorosoma petenense, impinged at Kirgston Steam Plant, Watts Bar Reservoir, Tennessee, November 1976 through April 27, 1977. (Source, McLean et al. 1978).

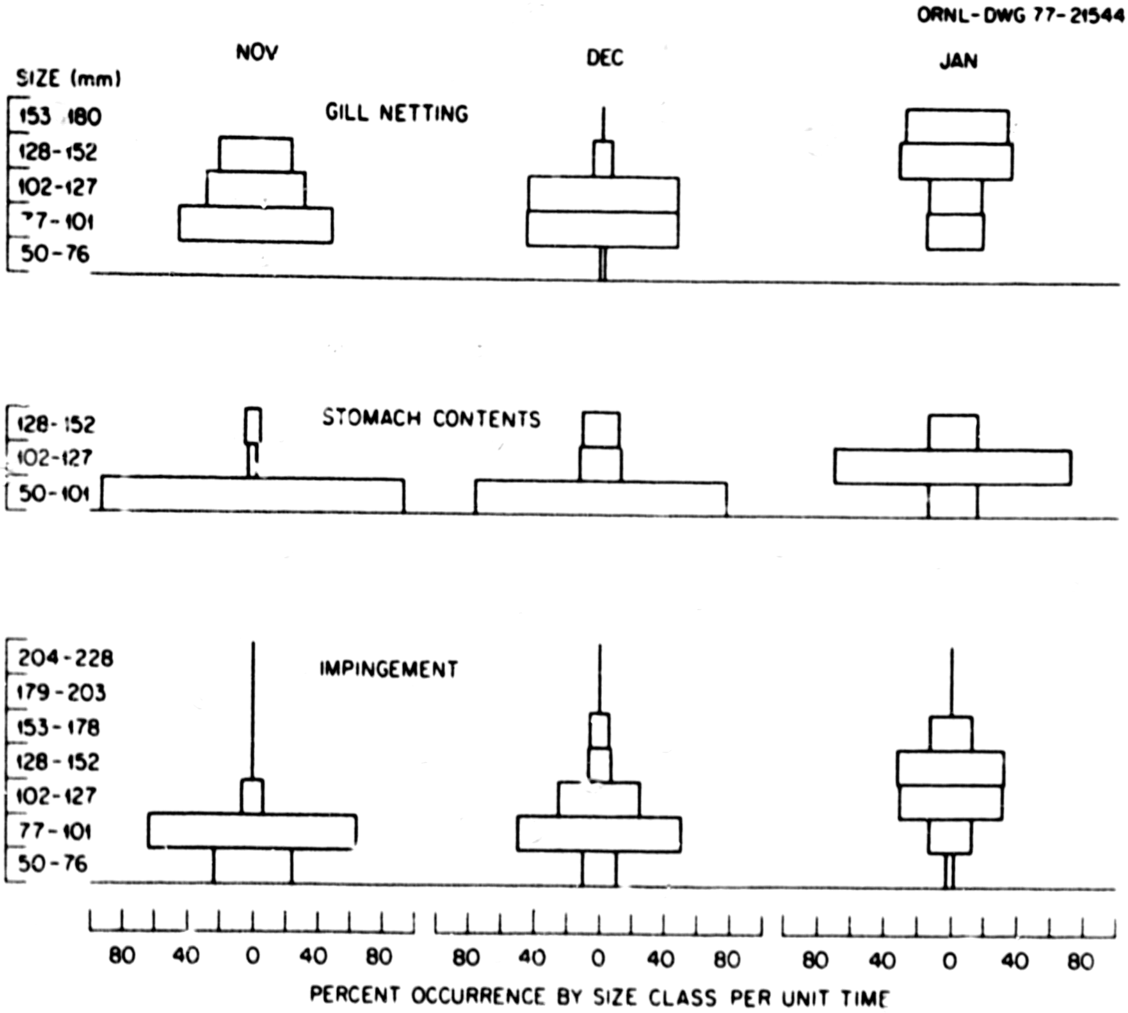


Figure A3. Comparison of size class distribution of threadfin shad collected on the intake screens, from sauger stomachs and in gill nets. (Source McLean et al. 1978).

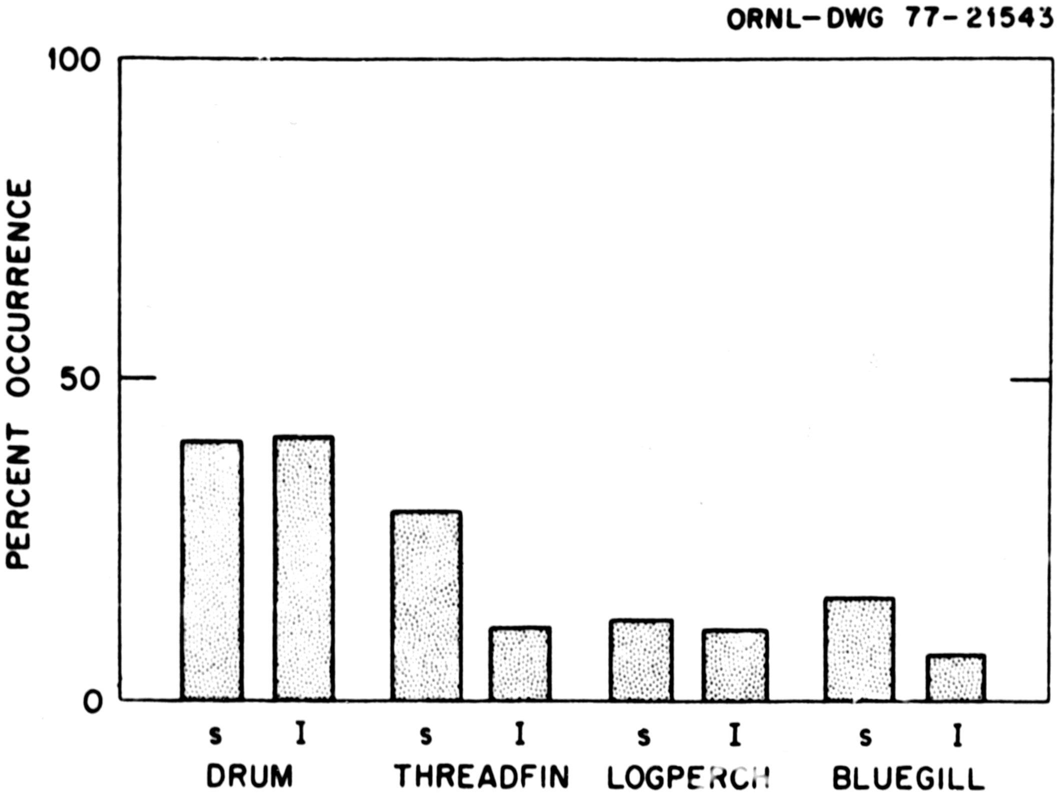


Figure A4. Comparison of sauger predation on fish species (s) and impingement of these species (I), between 2 February and 26 April 1977. (Source, McLean et al. 1978).

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