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Montana Department of Fish, Wildlife and Parks

Preliminary Environmental Review

Walleye Introduction - Cooney Reservoir

I. Location of Project

The Cooney Dam and Reservoir are located in Carbon County, Montana, about 17 miles north of the Town of Red Lodge (Fig. 1 & 2). The earthfill dam is located in Red Lodge Creek and currently impounds approximately 28,400 acre-feet of Water (Table 1). The project was completed in 1937, and financed by the Public Works Administration and State Water Conservation Board. The dam and reservoir area are part of the Rock Creek Project and are owned by the Montana Department of Natural Resources and Conservation. All water from the project is sold to members of the Rock Creek Water Users Association, the group responsible for the operation and maintenance of the project.

In 1981, the dam was upgraded to increase storage capacity and meet safety requirements (Table 1). During construction the reservoir was drained. It was refilled in 1982.

Cooney Reservoir is one of the most heavily used fisheries in the Billings region. A 1982 fishing pressure survey estimated 16,902 man-days of use. This was during a period when the fishery consisted only of 8 to 10-inch rainbow stocked that year, and thus would be considered a low estimate compared to the existing situation today.

II. Description of Project

Cooney has a history of heavy fisherman use and poor growth rates for rainbow trout, especially when white sucker populations become high (Marcuson 1976, 1980). Stocked rainbow trout rarely achieve a length of more than 13 inches. The reservoir was chemically rehabilitated in 1958 and 1970. In both cases the sucker population showed rapid recovery. Suckers outnumbered trout by nearly 5:1 in gill net catches during 1972, within 18 months after treatment.

During the fall and winter of 1981, when Cooney was drained to allow for dam and spillway repairs, trout and rough fish populations were reduced to a small number that survived in the stream. This was probably as effective as chemical treatment had been in the past for reduction of rough fish populations.

The trout population sampled during the November 1982 gillnetting consisted almost entirely of 10-12-inch rainbow from a May-August 1982 plant of 182,450 rainbow trout in the 4-7-inch range. These fish showed better than average growth response when compared to previous plants in Cooney Reservoir (Marcuson 1976, 1980). This was expected due to a lack of competition with suckers and older trout.

White sucker populations rapidly reestablished and within 2 years reached historically high levels. Rainbow growth rates will undoubtedly drop off again in the near future.

FIGURE 1

COONEY RESERVOIR

Scale	1": 1333 Ft
Elevation	4246 Ft
Area	778 Acres
Volume	810,528,318 Cu.Ft.
Storage Capacity	18607 A.F.
Date Surveyed	8/5/70
Ht. of Dam	97 Ft
Elevation on Cable During Soundings	1038 Ft.
Contour Interval	10 Ft.

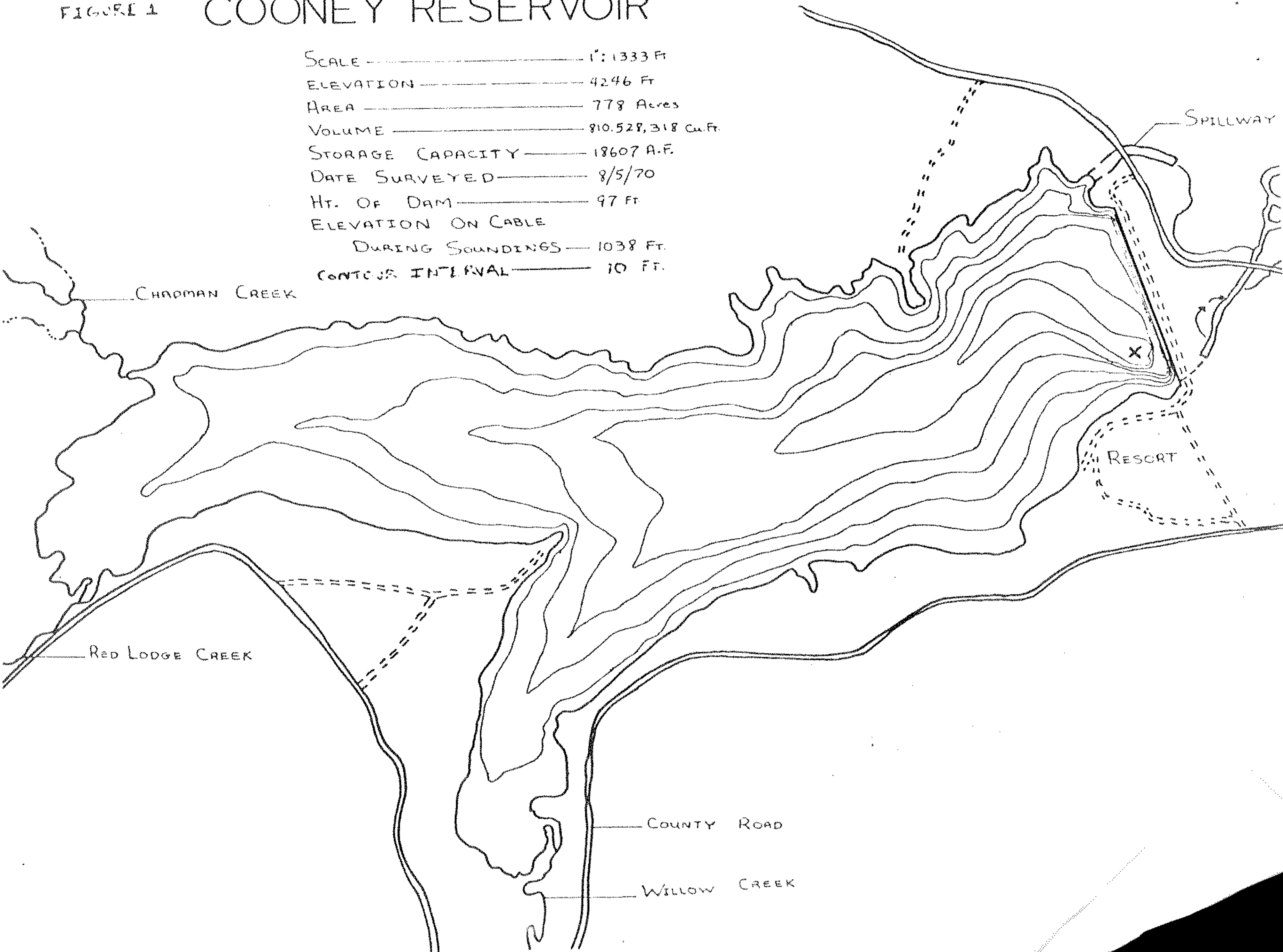


FIGURE 2. GENERAL LOCATION MAP

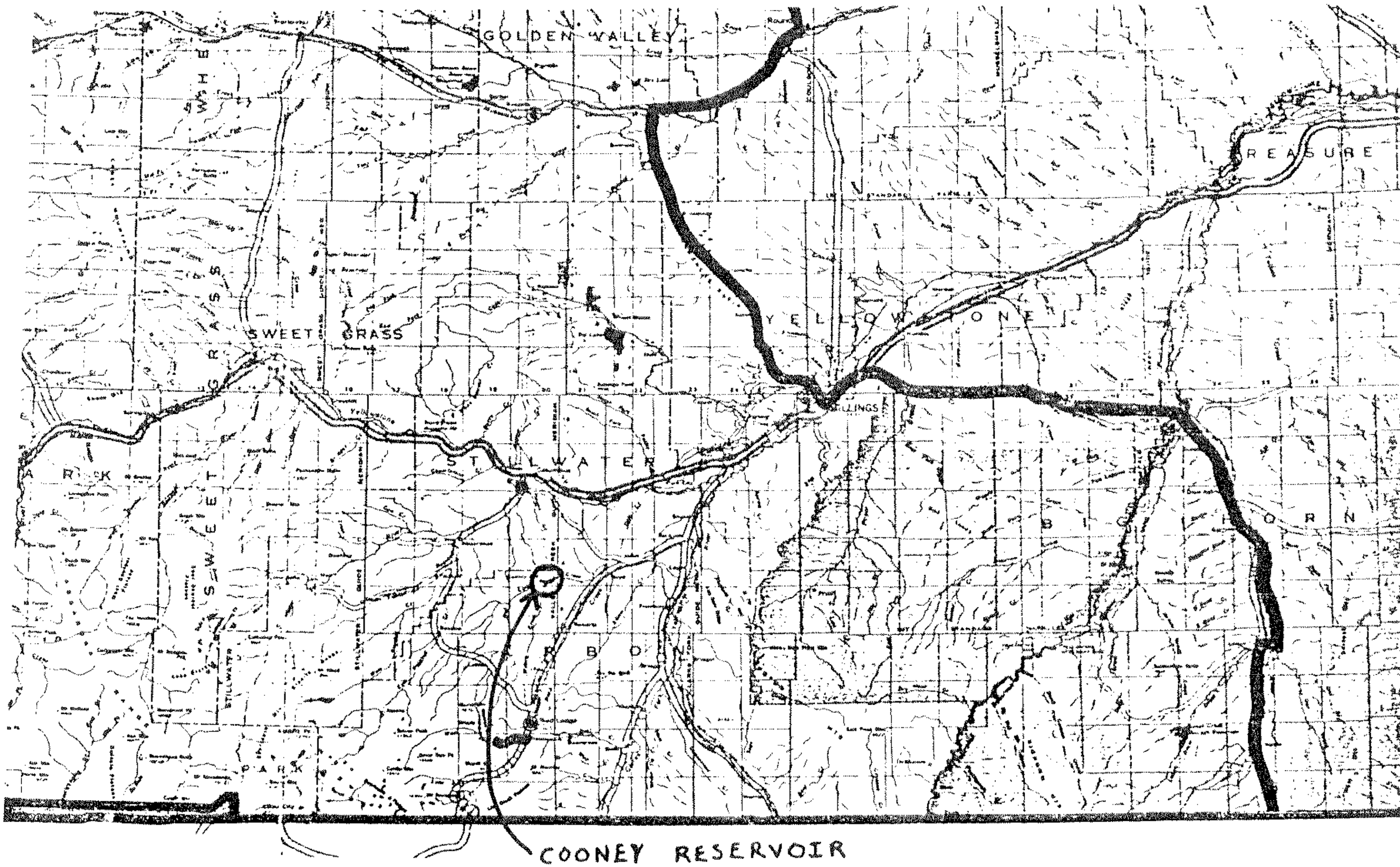


Table 1. Physical characteristics summary, Cooney Dam and Reservoir Project[1]

Parameter		
Height	102	ft.
Crest elevation	4,265.0	ft.
Normal water surface elevation	4,251.0	ft.
Active storage capacity	28,400	AF
100-year peak inflow	6,010	cfs
100-year peak outflow	3,570	cfs
Maximum 100-year W.S. elevation	4,255.4	ft.
Maximum design flood		PMF
Maximum spillway design flow	52,000	cfs
Maximum W.S. elevation	4,260.3	ft.
Freeboard at maximum W.S.	4.7	ft.

[1]Source: HKM Associates. Rehabilitation of Cooney Dam Spillway Feasibility report prepared for the Montana Department of Natural Resources and Conservation, April 1978.

A predatory species is needed in Cooney Reservoir that could partially control or at least modify the tremendous growth potential of sucker populations. Walleye will be planted in the reservoir in an attempt to create a "two-story" fishery. Since no other predatory species (with the exception of a limited brown trout population) exists in the reservoir, walleye show good survival if planted as fry. Recommended stocking rate would be about 1,000/acre or 1 million fry in total. These fish should be planted in the spring of 1984 with follow-up plants in 1985 and 1986 (possibly with fingerlings). Evaluation of netting and stomach analysis will indicate whether walleye have provided any control on sucker populations and to what degree they are coexisting with the trout.

Under ideal conditions, walleye would provide some control of rough fish and provide a fishery to supplement the trout fishery. One result should be better growth rates and larger maximum sizes of rainbow trout. The present stocking rate of rainbow trout will be cut in half to accommodate the walleye.

The public has favored the creation of a walleye fishery in the Billings area. The introduction of walleye was also recommended in a previous progress report (Marcuson 1980).

Life history, distribution, biology and other physical parameters for walleye are summarized in the attached report (Appendix I) excerpted from Freshwater Fishes of Canada (Scott and Crossman 1973).

III. Purpose of the Project

It is proposed that 1,000,000 walleye fry be introduced into Cooney Reservoir during each of the next 3 years to supplement the trout fishery and provide partial control of sucker populations. Walleye predation on the trout population is a concern, but in order for it to be a problem a substantial walleye population and fishery will have to be established. If that situation develops, the gain in the walleye fishery will offset the loss in the trout fishery.

IV. Discussion

Introduction of fish species in order to improve fishing is one of the more important tools available to fisheries managers. Such introductions are generally attempts to change the structure of aquatic communities to improve the status of species favored by man. However, these attempts have been largely "games of chance," and many of them have had unexpected negative consequences (Li and Moyle 1981). Any new introduction has the potential of creating negative impacts.

To insure that this plant would not have negative impacts, criteria for introductions presented by Li and Moyle (1981) were reviewed. These criteria are as follows:

1. No introductions should be made into the few aquatic systems left that show little evidence of human disturbance. Cooney Reservoir is a man-made structure and shows evidence of extensive human activity.

2. Introductions should be considered mainly for bodies of

water that are sufficiently isolated that uncontrolled spread of the introduced species is unlikely.

Cooney Reservoir drains approximately 28 miles downstream into Red Lodge and Rock creeks, and then into another 15 miles of the Clarks Fork River before it reaches the Yellowstone River at Laurel. Red Lodge and Rock creeks are small cold-water trout streams with habitat types that would not be conducive to walleye. The Clarks Fork is a marginal cold-water fishery and the lower end contains burbot and sauger populations. Walleye that drift downstream from Cooney would enhance this fishery. The Yellowstone River has documented walleye occurrence as far upstream as Huntley Diversion which is only 27 miles downstream from the mouth of the Clarks Fork. Walleye that drifted into this reach of the Yellowstone would also serve to enhance the fishery. It is unlikely walleye would invade the upstream cold-water reaches of the Yellowstone River. A walleye population exists in Dailey Lake south of Livingston, and these fish already have the potential to invade the upper Yellowstone if there was concern that might occur.

3. Any system being considered for an introduction should be inventoried thoroughly. Fish population work is conducted twice annually in the reservoir and will continue.

4. The species should be part of a co-adapted trophic assemblage, members of the assemblage already being present within the system. Walleye normally coexist with yellow perch or centrarchid species in their native ranges. This plant is being attempted in order to use walleye as a biological control on rough fish species (suckers) in the absence of their preferred food source (yellow perch). If the walleye plant proves successful in producing a fishery that is more desirable than the existing situation, and if walleye reproduction occurs and existing trout fishery is reduced substantially, it is probable that yellow perch introductions would be considered to supplement the forage base and establish a more natural trophic assemblage. However, such action would be undertaken only after considerable study and evaluation of all alternatives. A large population of lake chubs (Couesius plumbeus) is expected to supplement the white sucker (Catostomus commersoni) and longnose sucker (Catostomus catostomus) forage base under the existing situation.

5. The species should have low vagility, so that should it escape from the site of introduction, there will be a good chance of controlling its spread. As previously pointed out, walleye would be unlikely to establish in any upstream or downstream habitats that they might migrate to. In most cases under the existing situation, the establishment of walleye would be considered beneficial to the fishery.

6. The species should be free of contagious diseases and parasites exotic to the system. Since the fish will come from the Miles City Hatchery, they will be reared from eggs in water from a tributary of the Yellowstone River drainage. Proper precautions will be taken to ensure that the eggs are disease-free before hatching and planting occurs.

It appears that the effects of a walleye introduction in Cooney Reservoir would be mostly positive. The potential negative aspects have been addressed and are considered to be of minimal importance. If the plant is successful, recreation in the area should benefit.

Cooney Reservoir also offers potential to develop as a walleye brood source which could be tapped to augment hatchery supplies of walleye eggs in the future. Natural reproduction of walleye in Cooney Reservoir is considered unlikely. Thus, if the walleye plants are not successful or prove detrimental, a cessation of stocking should eliminate them from the system over the course of one generation.

V. The Basis of the Preliminary Environmental Review

Literature review indicates there will be no irreversible environmental or social problems associated with this introduction. Walleye introductions have been successful in enhancing the fishery in a number of different habitats all over the United States and Canada. The demand for a walleye fishery in the Billings area has been amply demonstrated, and is evidenced by the recent formation of a local Chapter of Walleyes Unlimited of Montana.

VI. Persons Compiling This Review

The PER was prepared by Wade Fredenberg, acting regional fisheries manager for the Billings regional office of the Montana Department of Fish, Wildlife and Parks. Fredenberg received a M.S. degree in Fish and Wildlife Management from Montana State University in 1980. He has been with the Department since that time.

VII. Literature Cited

Li, H. and P. Moyle. 1981. Ecological analysis of species introducinto aquatic systems. Trans. Amer. Fish Soc. 110(6): 772-782.

Marcuson, P. E. 1976. Inventory of waters of the project area, south central Montana fisheries study. Mont. Dept. Fish, Wildl. and Parks, Job Prog. Rept. F-20-R-20, Job. 1-a, mult., 24 pp.

____________. 1980 Inventory of waters of the project area, south central Montana fisheries study. Mont. Dept. Fish, Wildl. and Parks, Job Prog. Rept. F-20-R-24, Job 1-a, mult., 10 pp.

Scott, W. and E. Crossman. 1973. Freshwater Fishes of Canada. Fish Res. Bd. of Canada Publ. No. 184, Ottawa, Canada: 966 pp.

VIII. Suggested List of Mailing Distribution

Red Lodge Rod and Gun Club -

Billings Rod and Gun Club - c/o Dave Scott, President

Laurel Rod and Gun Club -

Walleyes Unlimited - c/o Gregg Pauley

Billings Gazette - c/0 Mark Henckel

Carbon County News - c/o Jim Moore

Laurel Outlook -

Montana Co-op Fisheries Research Unit - c/o Dr. Bill Gould

Department of Natural Resources and Conservation

Governor's Office -

Rock Creek Water Users Association -

Department of Fish, Wildlife and Parks, Helena -

Montana Environmental Information Center -

Beartooth Chapter Trout Unlimited -

Montana Wildlife Federation -

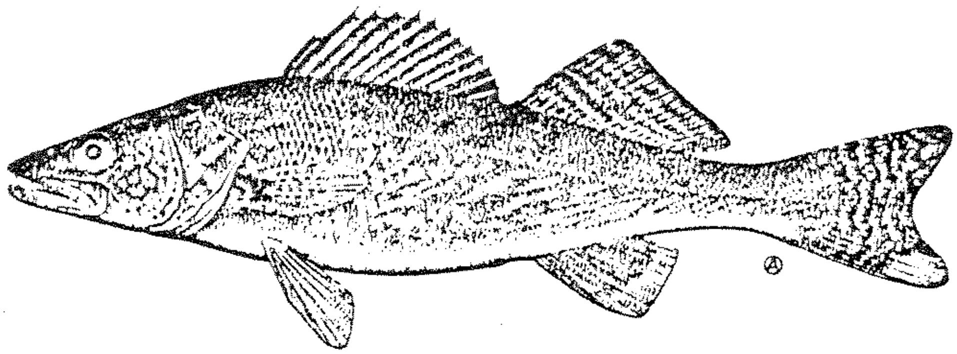
Billings Chapter, Audubon -

Department of Biology, Eastern Montana College - % Dr. Norm Schoenthal

Appendix I

WALLEYE*

Stizostedion vitreum (Mitchill)



Description Meristics and proportions for populations from Ontario to Alberta. Body elongate, subcylindrical when young, average length 13–20 inches (330–508 mm), slightly compressed, more so in large adults in some populations, greatest body depth under anterior half of first dorsal 12.5–19.3% of total length; caudal peduncle moderately long and deep, somewhat compressed. Head deeper than sauger, a blunt point at front, its length 23.8–28.4% of total length (greatest in young), moderately wide, interorbital distance 15.7–21.5% of head length (least in young), gill membranes extended forward, not broadly joined nor broadly joined to isthmus; preopercle bone strongly serrate, serrae sometimes curved forward; opercle with at least one short, sharp spine; eye large (larger in young), diameter 16.1–26.7% of head length; snout long, bluntly pointed, not extending beyond upper jaw, its length 25.3–33.5% of head length; premaxillaries protractile; mouth large, terminal, almost horizontal, jaws equal; maxillary very long, extending to posterior edge of eye; strong teeth on premaxillaries, jaws, head of vomer, and palatines numerous, large, often recurved canine teeth on head of vomer, palatines, jaws, and premaxillaries; pharyngeal teeth large, sharp, recurved. Gill rakers moderately long and tooth bearing on outer edge of gill arch, inner edge has short, rounded, tooth-bearing

*Mr R. A. Ryder, Ontario Ministry Natural Resources, prepared outlines on which much of the write-ups for this species and that for the sauger were based. He will be publishing expanded versions on these two species in Ontario.

knobs, 6–8 rakers on lower arch, 4 or 5 on upper arch. Paetz and Nelson (1970) gave gill rakers of 7–14 + 6–8 for Alberta and McPhail and Lindsey (1970) cited 12–15 + 4–5 (counting both sides of lower limb?). Branchiostegal rays 7,7 or 7,8. Fins: dorsals 2, obviously separated, first dorsal spiny, high, long, rounded, strong spines 12–16 (usually 14), second dorsal as high or higher, with 1 fine spine and 18–22 rays (usually 19–21), square to slightly emarginate; caudal long, not overly broad, well forked, tips rounded points; anal with 2 spines and 11–14 (usually 12 or 13) soft rays, height little greater than base, not as long as second dorsal, square; pelvics thoracic, widely spaced, base of 1 fin 58.2–74.6% of space between fins, length about equal to pectoral fins, tip rounded, 1 spine and 5 rays; pectorals only moderately broad, tips rounded, 13–16 (usually 14) rays. Scales strongly ctenoid (*see* Priegel 1964, for development of scales), cheeks scaleless or slightly scaled, opercles mostly naked, breast and belly normally scaled; lateral line complete, high, little curved, lateral line scales rather small, 83–104 (usually 86–92) including 3 or 4 pitted scales of the lateral line which extend on to the base of the caudal fin. McPhail and Lindsey (1970) extend the number to 108. Peritoneum white, short intestine well differentiated, pyloric caeca usually 3, each about same length as stomach; ovaries of post-spawning females reddish-purple. Vertebrae 44–48.

No nuptial tubercles. Differentiation of sexes difficult.

Colour Highly variable with habitat and to lesser extent with size. In turbid water paler and less marked with obvious black pattern, in clear water more vividly marked. Background usually olive-brown, to golden brown, to yellow, dorsal surface of head and back darker, sides paler, often with golden flecks on scales, ventral surface milk-white or yellow-white. In smaller fishes, 4–14 inches (102–356 mm), vague to obvious, dark, vertical bands across back and down sides, usually absent in adults; dorsal fin dusky, clear or vaguely speckled, no definite rows of spots, noticeable black blotch at base of last few membranes (except in very small); second dorsal and caudal fins with speckles or tiny spots in rather regular rows, lower lobe of caudal and tip of anal fins milk-white; pelvic fins yellow or orange-yellow; pectoral fins dark or pale olive, with dark blotch at base; eyes silvery from light reflected by light sensitive layer (*Tapetum lucidum*).

Grey-coloured walleyes (called "hards" in Lake Erie), which are the result of a bluish colour of the mucus, occur with varying frequency in most populations. Individuals of a slightly bluer colour occur in Lake Nipissing (*see* section on blue walleye in *Systematic notes*). Infrequently orange coloured mutants are taken in Ontario.

The blue walleye of lakes Erie and Ontario was distinguishable from the yellow walleye, and from these grey-blue forms, in that it was more slate-blue or steel-blue on the dorsal surface, ice-blue to silvery on the sides, and silvery to white on the ventral surface. The pelvic fins were white.

Systematic notes Variability of characters within populations is possibly as great as between populations, and characters may be rather stable over the total range of the material examined (*see* following table). Genotypic variability is apparently greater with at least three major genetic types existing in Canadian waters (*see* Uthe and Ryder 1970, for details).

This species consists, or did until recently, of two subspecies, the yellow walleye, *Stizostedion v. vitreum* and the blue walleye, *Stizostedion v. glaucum*. The blue walleye (or blue pike of the Lake Erie fishermen and the trade) was originally described by Hubbs (1926) as a separate species *Stizostedion glaucum*, but the number of fish considered to be intergrades between the two walleyes led to the change to subspecific status. The blue walleye was placed on the "Rare and Endangered" list (McAllister 1970) as "rare or perhaps even extinct." In spite of periodic reports of supposed blue walleyes it has now apparently totally disappeared from lakes

	Spines									
	1st dorsal					2nd dorsal				
	12	13	14	15	16	18	19	20	21	22
Peterborough, Ont.	–	–	4	5	–	–	2	4	3	–
L. Erie	1	7	2	–	–	1	2	5	2	–
L. Nipissing	–	5	5	–	–	–	8	2	–	–
L. Superior	–	2	7	1	–	–	–	1	6	3
Savanne L. (Hudson Bay system)	–	–	6	3	1	–	2	2	5	1
Sask.	–	3	5	2	–	–	6	4	–	–
Alta.	–	–	4	–	–	4	–	–	–	–

	Rays							
	Anal				Pectoral			
	11	12	13	14	13	14	15	16
Peterborough, Ont.	1	–	7	1	4	5	–	–
L. Erie	1	7	2	–	–	–	–	–
L. Nipissing	–	7	3	–	–	–	–	–
L. Superior	–	4	6	–	6	4	–	–
Savanne L. (Hudson Bay system)	1	3	5	–	–	–	8	1
Sask.	–	5	5	–	–	–	–	–
Alta.	–	3	1	–	–	4	–	–

	Lateral line scales												
	83	84	85	86	87	88	89	90	91	92	93	94	104
Peterborough, Ont.	–	–	1	2	1	2	–	2	1	–	–	–	–
L. Erie	3	–	1	3	2	–	–	1	–	–	–	–	–
L. Nipissing	–	–	–	2	1	–	1	2	–	–	–	–	–
L. Superior	–	–	1	1	1	–	–	–	4	2	–	–	1
Savanne L. (Hudson Bay system)	–	–	–	–	1	2	–	1	2	2	1	1	–
Sask.	1	–	1	–	2	3	2	1	–	–	–	–	–
Alta.	–	–	–	–	1	–	1	1	–	1	–	–	–

Erie and Ontario. Consequently, it will not be treated here as a distinct entity but various comments will be made throughout the discussion of the yellow walleye, the only remaining walleye.

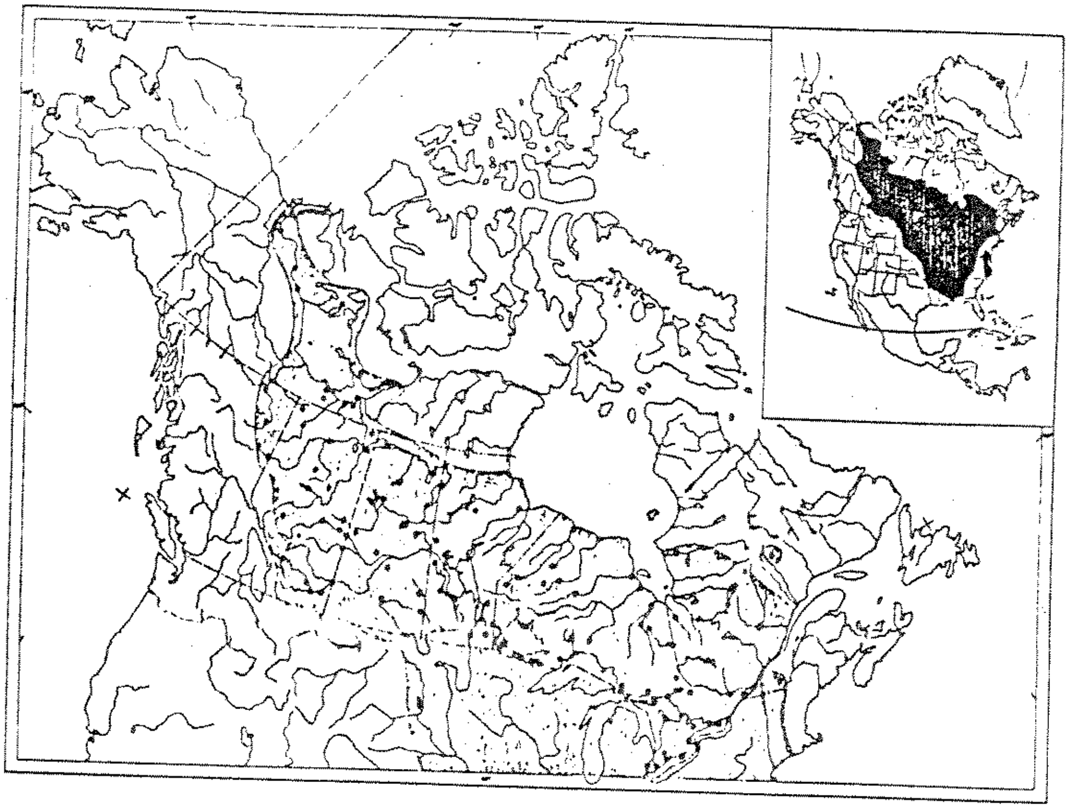
In most aspects other than colour and certain biological features, the two subspecies were difficult to separate. The eyes of the blue walleye were slightly larger, higher on the head, and consequently closer together (interorbital width less). Trautman (1957) showed a greater distance between angle of preopercle bone and branchiostegal rays, otherwise proportions and counts were very similar. The blue walleye had a different spawning time and place, a slower growth rate and smaller ultimate size, and different depth distribution.

The situation of establishing the distinction of the blue walleye was made doubly difficult by the high frequency of the supposed intergrades with the yellow walleye, the presence of grey-coloured mutants of the yellow walleye, and of supposed hybrids of both subspecies with the sauger. Stone (1948), who studied the taxonomy of these forms in lakes Erie and Ontario, concluded that the yellow and blue walleyes were separate species each with separate subspecies in each of the two lakes. This is interesting when we consider the 1970 evidence mentioned above of different genotypes.

The grey-blue walleyes seen regularly in Lake Nipissing, Ont., (and more rarely elsewhere) have long been considered by some to be blue walleyes. On the basis of characteristics available to us, this cannot be denied nor proven. They are largely undistinguishable from the blue-grey mutants of the yellow walleye seen elsewhere. One interesting fact is that they are seen there more often when there is a very successful year-class of yellow walleye dominating the fishery.

The common name of this species in Canada has long been a problem. Both the names pickerel and pike-perch allude to a supposed similarity between the head and teeth of this species and those of the northern pike. Since the name pickerel (a diminutive of *pick* or *pike*) was first applied to the smaller, new-world pikes *(Esox)*, the name walleye is more suitable and less confusing. It alludes to the smoky, silvery eye which is said to be similar to that of blinded or "walleyed" domestic animals. *See* Weed (1927) for an extensive list of common names of this species.

Distribution The walleye is limited to the fresh water (and rarely brackish water) of North America. It occurs from Quebec south to New Hampshire, southwest to Pennsylvania, southward west of the Appalachian Mountains to the Gulf coast in Alabama, northwest to eastern Oklahoma, northwest through the eastern half of the states from Nebraska to North Dakota, north to near the Arctic coast in the Mackenzie River, southeast across James Bay to Quebec. There is a residual, apparently native, stock along the central Atlantic seaboard (Pennsylvania to



North Carolina). It has been widely introduced elsewhere on the eastern seaboard and in virtually all the states to the west of its natural range.

In Canada it occurs generally in Quebec in tributaries of the St. Lawrence downstream at least to the Manicouagan River, north to rivers tributary to the east coast of upper James Bay, northwest from the Hudson Bay coast in Ontario to Athabasca, Great Slave and Great Bear lakes, north in the Mackenzie River to the delta, south through the Peace River drainage of northeastern British Columbia and south, east of the foothills, to southern Alberta (apparently much more sporadic and less abundant in northwest Alberta). It forms a dominant part of the fish fauna particularly in the boreal forest zone. Canadian stocks originate from a Mississippi and an Atlantic glacial refugium. It probably spread into northern Ontario, and Quebec via glacial lake Barlow–Ojibway and its outlets. It has been introduced in various places in Canada within its native range where barriers precluded its natural occurrence.

Contrary to a number of published range statements, it does not occur in Labrador.

The blue walleye occurred in Lake Erie, the lower Niagara River, and western Lake Ontario. It was reported as far east in Lake Ontario as the Bay of Quinte. Records of it in Long Lake, tributary to the Napanee River, and in other small inland lakes may have been based on the grey mutant of the yellow walleye. Its presence in Lake Nipissing is debatable (*see Systematic notes*).

Biology The biology of this species in Canada has been extensively studied. Information on Canadian populations was derived from Hart (1928), Kennedy (1949a), Rawson (1957), Payne (1964), Ellis and Giles (1965), Ryder (1968), and Regier et al.

102 mm) longer at any age. Growth rates for other Canadian populations were given by Adamstone (1922, Lake Erie) and Hart (1928, lakes Nipigon and Abitibi). Adamstone also contrasted with that of yellow walleye the age and growth of the blue walleye. The blue walleye at its maximum age (11) did not exceed 14.7 inches (375 mm) in length. Average weight at age 7 was 17 ounces.

Walleyes seen by anglers are usually 1–3 pounds in weight and 3 years of age. In Ontario, walleyes of 12–19 pounds win annual anglers contests but the largest Ontario walleye was 42 inches (106.7 cm) in fork length, 27 inches (686 mm) in girth, weighed 23 pounds 9 ounces, and was taken in spawning operations in Moon River, Georgian Bay. A 28-inch (711-mm) walleye is the largest known from Alberta. Trautman (1957) said that the largest Lake Erie specimen was 31 inches (787 mm) long, and weighed 11 pounds 14 ounces. The present angling record is a walleye taken in Old Hickory Lake, Tenn., in 1960, which was 41 inches (104.1 cm) long, 29 inches (737 mm) in girth, and weighed 25 pounds. The previous long standing record was a walleye of 22 pounds 4 ounces caught at Fort Erie, Ont., in 1943. The blue walleye rarely exceeded 12–14 inches (305–356mm) and ¾–1 pound.

Male yellow walleyes generally mature at 2–4 years of age, over 11 inches (279 mm) in length, and females at 14–17 inches (356–432 mm) or 3–6 years of age. Maximum age varies from 10–12 years in the south to a possible 20 years in the north. Gillnets in common use by commercial fishermen (4½ inch or 114 mm mesh) often take females before they have contributed to the population. Walleyes taken in the Georgian Bay commercial fishery are usually about 19 inches (483 mm) total length.

Walleyes are tolerant of a great range of environmental situations, but appear to reach greatest abundance in large, shallow, turbid lakes. Optimum transparency in a shallow lake, which will allow walleye to feed intermittently throughout the day, is in the order of 1–2 m Secchi disc. They also thrive in clear lakes but the special layer of the eye (*Tapetum lucidum, see* Ali and Anctil 1968) is extremely sensitive to bright daylight intensities, so feeding is restricted to twilight or dark periods. Large streams or rivers, providing they are deep or turbid enough to provide shelter in daylight, are suitable habitat. This species often uses sunken trees, boulder shoals, weed beds, or thicker layers of ice and snow as a shield from the sun. They may even remain in a depth, the temperature of which is above their usual selection, if there is better protection there. In clear lakes they often lie in contact with the bottom apparently "sleeping." In these lakes, they often feed from top to bottom at night. In more turbid water they are more active during the day, swimming slowly in schools close to the bottom. Walleyes are often associated with other species such as yellow perch, northern pike or muskellunge, and smallmouth bass. White suckers often orient themselves in walleye schools and behave as a part of it. The habitat does not change in winter except for an avoidance of strong currents. They are active all winter and are taken by ice fishermen. Usually fish of moderately shallow water (to 49 feet or 15 m) they were taken as deep as 69 feet (21.04 m) in August in Lac la Ronge whereas the blue walleye was usually found below 40 feet (12.2 m).

Movements involve a spring spawning run to shallow shoals or to tributary rivers, daily movements up and down in response to light intensity, and daily or seasonal movements in response to temperature or food availability. In Lac la Ronge, greatest net catches took place at depths where temperature ranged from 55.4°–64.4° F (13°–18° C) and in Wisconsin at 69.08° F (20.6° C). Their summer wanderings are usually limited to 3–5 miles, but tagged fish have been known to travel over 100 miles. *See* Magnin and Beaulieu (1968) for movements in the St. Lawrence River. There is evidence of homing to spawning grounds year after year in Michigan (Crowe 1962). Walleyes seem to remain in loose but discrete schools with separate spawning grounds and summer territories.

The food of the walleye shifts very quickly, with increase in size, from invertebrates to fishes. This is in part a reflection of their

(1969); and from publications on populations in the northern United States by Wolfert (1969) and Priegel (1970).

Spawning occurs in the spring or early summer (early April in southwestern Ontario, to end of June or later in far north) depending on latitude and water temperature. Northern populations do not spawn in some years when temperature is not favourable. Normally, spawning begins shortly after ice breaks up in a lake, at water temperatures of 44°–48° F (6.7°–8.9° C) but has been known to take place over a range of 42°–52° F (5.6°–11.1° C). Prespawning behaviour (courtship) may commence much earlier, when water temperature is 34° F (1.1° C). Males move to the spawning grounds first. Spawning grounds are the rocky areas in white water below impassable falls and dams in rivers, or boulder, to coarse-gravel shoals of lakes. Fish often move into tributary rivers immediately the rivers are ice free and while the lake is still ice covered. Spawning takes place at night, in groups of one larger female and one or two smaller males or two females and up to six males. Males are not territorial, and no nest is built. Prior to spawning there is much pursuit, pushing, circular swimming, and fin erection. Finally, the spawning group rushes upward into shallow water, stops, the females roll on their sides and eggs and sperm are released. Apparently most individual females deposit most of their eggs in one night of spawning. Egg diameter is 1.5–2.0 mm and eggs are sticky at first but apparently not so after water hardening. The eggs are broadcast and fall into crevices in the substrate (on mats of vegetation in flood-bench marshes in some areas of Wisconsin). Egg number has been given as high as 612,000 in females 31.5 inches (801 mm) in length, and it increases yearly at least to age 11. Eggs hatch in 12–18 days in temperatures prevalent on the spawning grounds. The yolk sac is absorbed rapidly (feeding takes place prior to disappearance of yolk) and by 10–15 days after hatching the young have dispersed into the upper levels of open water. Fish (1932), Norden (1961b), and Nelson (1968b) gave details of early development of young. Nelson also gave means of distinguishing between the young of walleye and sauger. Newly hatched fry are 6.0–8.6 mm in length and have 22–29 postanal myomeres. By the latter part of the summer, young-of-the-year move toward the bottom and are found in 20–30 feet (3.05–9.15 m) of water.

Growth is fairly rapid in the south but slower in the northern part of the range. In Lake Erie they may reach 3.5–8.0 inches (89–203 mm) by the end of the first growing season, but only 3–4 inches (76–102 mm) in the north. The following table gives the age–length and age–weight relations for various populations.

Payne (1964) gave the length–weight relation in Bay of Quinte, Lake Ontario, as Log W (pounds) = −3.690 × 3.271 Log L (fork length in inches). As can be seen, growth differential between Lake Ontario and Lac la Ronge can be as much as 4 inches (102 mm) at any age. There is a difference in the rate of growth of females over males. This occurs from age 7 onward in Saskatchewan and is approximately 6%. In the Moon River, Ont., females can be 2–4 inches (51–

		Age														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Bay of Quinte, L. Ontario (Payne 1964)	FL *inches*	8.4	12.7	15.8	18.3	20.4	21.9	23.0	24.2	25.0	25.6	26.3	26.2	26.5	27.0	27.8
	mm	213	323	401	465	518	556	584	615	635	650	668	665	673	686	706
	Wt (*lb*)	0.22	.83	1.70	2.75	3.92	4.95	5.81	6.86	7.63	8.25	9.01	9.00	9.24	9.82	10.80
L. Manitoba (Kennedy 1949a)	Avg FL *inches*	–	–	10.9	12.3	14.2	15.5	16.3	17.0	18.7	19.1	19.8	–	21.0	–	–
	mm	–	–	277	312	361	394	414	432	475	486	503	–	533	–	–
	Avg wt (*oz*)	–	–	9.8	14.0	20.7	25.1	30.7	34.4	47.4	52.6	57.5	–	71.6	–	–
Lac la Ronge, Sask. (Rawson 1957)	Avg FL *inches*	3.9	8.8	10.6	12.3	14.2	15.9	17.5	19.0	20.5	21.8	23.0	24.2	25.3	–	–
	mm	99	224	269	312	361	404	445	483	521	554	584	615	643	–	–
	Wt (*oz*)	–	2.9	4.5	9.0	16.3	–	26.3	36.0	–	48.0	–	61	79	–	–

change in habitat from surface to bottom. During the first 6 weeks of life food consists mostly of copepods, Cladocera, and fish (*see* Priegel 1963b, for details). They are highly cannibalistic if small yellow perch or another forage fish are not more readily available. Some populations, even as adults, feed almost exclusively on emerging larval or adult mayflies or chironomids for part of the year.

The relative amounts of various species of fish taken apparently depend on availability. However, when present, yellow perch and freshwater drum seem very important. Species listed have been rainbow smelt, alewife, ciscoes, ninespine stickleback, white sucker, longnose sucker, yellow perch, lake whitefish, walleye, sauger, spottail shiner, darters, white perch, freshwater drum, trout-perch, emerald shiner, common shiner, silver chub, gizzard shad, rock bass, pumpkinseed, black crappie, smallmouth bass, brown bullhead, goldeye, mooneye, cottids, burbot, and various other unidentified minnows, as well as those regularly used as bait. It would seem safe to say they utilize any species of fish readily available to them. Other items such as crayfish, snails, frogs, mudpuppies, and small mammals are taken but only rarely, and usually when fishes and insects are scarce. Food in winter is not particularly different other than possibly in species composition.

Northern pike are probably the most important predators of the walleye over much of its range. The muskellunge also preys on walleye in more restricted areas. Northern pike may also be an important competitor as it is the only other major, shallow-water predator in the north. Adult perch, walleye, and sauger prey on the young as probably do a wide variety of predatory fishes. Many fish-eating birds and mammals, as well as lampreys, prey on walleyes regularly but are probably not important predators. Yellow perch, sauger, smallmouth bass, and lake whitefish compete with walleye for food. More important in controlling populations are water temperature, stream flow and wind at spawning time, and other species which spawn over the walleye eggs or roil up the silt. A major controlling factor is fry mortality (death + predation including cannibalism) which is up to 99% to the postlarval stage in some of the Finger Lakes in New York.

The walleye is host to a wide variety of parasites. Hoffman (1967) listed the following for the yellow walleye from the whole of its range: protozoans (3), trematodes (22), cestodes (10), nematodes (10), acanthocephalans (4), leeches (2), molluscs, crustaceans (7). Parasites from Canadian habitats were given in detail by Bangham and Hunter (1939) (both yellow and blue walleyes from Lake Erie), and Bangham (1955).

In certain areas of Saskatchewan and Alberta walleye are infected with the broad tapeworm *Diphyllobothrium latum*. This parasite regularly infects sleigh dogs fed raw fish, and human infection is known to have occurred. If fish are properly cooked this parasite will not infect man.

Lymphocystis, a virus disease, is very common on spawning walleye and appears as a white, tumorlike protuberance on the body. It apparently does not cause mortality in natural populations (Ryder 1961) and usually disappears when the water reaches summer temperatures. This species is also subject to black-spot and yellow grub and while these two parasites render the whole fish unsightly they can usually be removed by filleting and skinning, are harmless to man, and are killed when the fish are cooked.

The yellow walleye hybridizes in nature with the sauger (*see* Stroud 1948; and Nelson 1968b for details). In the past, intergrades between the yellow and blue walleye were common in Lake Erie.

Relation to man The walleye is probably the most economically valuable species in Canada's inland waters. It is a major commercial and sport fish in Ontario and the Prairie Provinces, and a sport fish in Quebec. An angler survey in Ontario showed that the walleye was the game species most often fished for and was the second most abundant in anglers' catches. It is an important species in both the summer sport fishery and for ice fishermen in the winter. The walleye is usually angled by still fishing with live minnows as bait or with artificial lures such as spinners, spoons, plugs, and jigs. Drifting and trolling seek out the schools of moving walleye. The two twilight periods of sunset and sunrise are the most productive. The walleye is not a spectacular fighter but a steady battler always boring for the bottom. The average walleye caught by angling is about 1½ pounds in weight.

Canadian commercial fisheries harvest several million pounds of walleye annually. Over the years 1919–1968 there was considerable fluctuation in catch but a peak of almost 21 million pounds in 1956 had a landed value of over 3.1 million dollars. The catch record also emphasizes the rapid decline since 1956. Lake Erie formerly produced about one-half of this catch but in recent years the fishery there has declined drastically due to overexploitation and deterioration of the environment (for details *see* Regier et al. 1969). In 1956, the Canadian and American walleye production from Lake Erie was 24 million pounds (Baldwin and Saalfeld 1962). As a result, the contribution of the Prairie Provinces to the total Canadian catch of 8.5 million pounds in 1968 was much higher than in previous years. The commercial fishery commonly employs gillnets and poundnets to harvest this species. Current fisheries are usually restricted by quota, minimum size, and minimum mesh-size regulations. The walleye has a firm, white to pinkish flesh, which is easily filleted and prepared. It is a prime species on the market, presently commanding as much as $1.25/pound depending on size, and type of processing and packaging. It is also highly regarded by anglers as a food fish.

Apparently competition between commercial and sport fisheries for this species has often led to heated controversy and to the necessity of a study of the walleye stocks in those areas. For extensive treatment of exploitation of such stocks, *see* Olson (1958), Ryder (1968), Regier et al. (1969), and numerous unpublished reports of various provincial governments. An extensive treatment of blue walleye fishery of Lake Erie was given by Parsons (1967).

Nomenclature

Perca vitrea	— Mitchill 1818a: 247 (type locality Cayuga Lake, N.Y.)
Perca Fluviatilis	— Pennant 1792: 298
Perca fluviatilis, var. ? L.	— Richardson 1823: 725
Lucio-perca Americana (Cuvier)	— Richardson 1836: 10
Lucioperca Canadensis	— Forelle 1857: 280
Lucioperca grisea	— Forelle 1857: 280
Lucioperca Americana	— Forelle 1857: 280
Stizostedion vitreum (Mitchill)	— Jordan and Evermann 1896–1900: 1021
Stizostedion glaucum	— Hubbs 1926: 58 (type locality Lake Erie, off Ashtabula, Ohio)
Stizostedion vitreum vitreum (Mitchill)	— Hubbs and Lagler 1941: 73
Stizostedion vitreum glaucum (Hubbs)	— Hubbs and Lagler 1941: 73

Etymology *Stizostedion* — pungent throat; *vitreum* — glassy, alluding to the nature of the large, silvery eyes.

Common names Walleye, yellow walleye, wall-eye, pickerel, yellow pickerel, yellow pike, pike-perch, yellow pike perch, walleye pike, wall-eyed pike, wall-eyed pike-perch, wall-eyed pike perch, wall-eyed pickerel. French common name: *doré*.