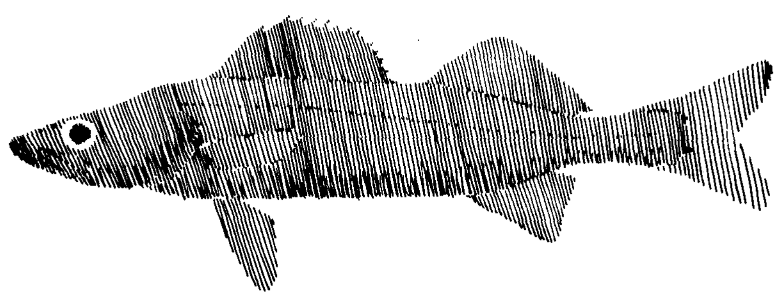
Research Technical Completion Report
Project A-060-IDA

PROBABLE WALLEYE (*Stizostedion vitreum*) HABITATION IN THE SNAKE RIVER AND TRIBUTARIES OF IDAHO

By David H. Bennett
Fishery Resources



Idaho Water Resources Research Institute
University of Idaho
Moscow, Idaho 83843

April, 1979

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David H. Bennett

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INTRODUCTION

The walleye (*Stizostedion vitreum*) is an important sport and commercial fish species in eastern and central North American (Scott and Crossman 1973). This species is well known throughout its native and introduced range as a voracious predator inhabiting lentic and lotic ecosystems. Walleye has been widely introduced as an exotic outside its native range because of its esteemed value as a sport fish and highly desirable flesh. Many of these introductions have been made after careful consideration of the indigenous aquatic community while other introductions have been made illegally by sportsmen.

Some fish and game agencies have resisted introductions of walleye into their waters because walleye, as an efficient fish predator, can potentially have serious deleterious affects on indigenous fish species. Competition for food, direct predation on important species, and alteration in the food base are significant adverse affects that must be carefully examined before walleye introductions are made into a new system.

The Pacific Northwest is one area where walleye have been introduced. The presense of walleye in the northwest affords additional opportunities for widespread illegal introductions into a vast area of large and diverse waters. Also, extensive drainage systems in the Pacific Northwest create an opportunity for wide distribution within a watershed when introductions are made. One area where walleye have been introduced is in the Columbia River system. The extensive nature of this river drainage provides potential for walleye migration into Washington, Oregon and Idaho.

The first known walleye introduction in the Pacific Northwest was illegally made by sportsmen. Available literature suggests that walleye were probably planted in Roosevelt Lake, above Grand Coulee Dam, sometime during the 1940's and 1950's (Nielsen 1975). Early in the 1960's walleye catches were first confirmed from Banks Lake, an irrigation supply reservoir, which receives pumped water from Roosevelt Lake. Since then, a significant fishery has developed in the Spokane Arm of Roosevelt Lake and walleye have migrated below Grand Coulee Dam in the Columbia River. Because the Snake River is a major tributary of the Columbia River, the potential for walleye immigration into Idaho is excellent.

Report of walleye in the lower Snake River has aroused concern over the possible expansion of populations into the upper Snake, Clearwater and Salmon river systems. These river systems have historically produced large runs of anadromous fishes, especially steelhead trout (Salmo gairdneri) and chinook salmon (Oncorhynchus tshawytscha), and resident salmonid fishes; i.e., rainbow and cutthroat (S. clarki) trouts. In the last few years, these fish stocks have been depressed by resource development activities. For example, poorly executed logging operations have caused significant reduction in the quality of spawning and rearing habitat by contributing large amounts of sediment to streams (Platts and Megahan 1975). In addition, dam construction has accounted for high juvenile anadromous fish mortality during the downstream migration to the Pacific Ocean. Gas supersaturation of water and predation by northern squawfish (Ptychocheilus oregonensis) have been identified as two factors responsible for the mortality. At the present time, the squawfish is the major predator below dams and in the reservoirs. Walleye, however, are more voracious and efficient piscivorous feeders than squawfish and consequently, could intensify predation on emigrating juvenile salmonids which could contribute further to the decline of anadromous fishes in Idaho. For this reason, this study was initiated with the following objectives:

1. To review the historic impact of walleye on salmonid fishes;
2. To document the occurrence of walleye in the lower Snake River; and,
3. To complete a literature review of the ecological requirements of walleye.

The Walleye

Description:

Body elongate, slightly compressed; caudal peduncle long and deep. Opercle with at least one short, sharp spine. Eye large, 16-27% of head length; snout long and blunt. Premaxillaries protractile, mouth large, terminal and nearly horizontal; jaws equal, maxillary long, extending to posterior edge of eye (Scott and Crossman 1973). Spinous dorsal fin with a large dusky blotch between the last three dorsal spines; blotch absent in smallest young. Cheeks with few to no scales. Rays of soft dorsal 19-23 (Trautman 1957). Lateral line complete, high, slightly curved, scales small, 83-104. Peritoneum white, intestine short and well differentiated. Sex differentiation difficult.

Systematics:

Two subspecies of walleye have been recognized, the yellow walleye, *Stizostedion vitreum vitreum*, and the blue walleye, *Stizostedion vitreum glaucum*. The blue walleye was originally described as a separate species, *S. glaucum* (Hubbs 1926), but was changed to subspecific status because of the abundance of integrades with the yellow walleye. Blue walleye, once common in lakes Erie and Ontario, have completely disappeared after being listed as a Rare and Endangered species. The yellow walleye, consequently, is the one remaining subspecies.

Names:

Common names of fishes are often very confusing and consequently, rarely used by biologists. Walleye is the accepted common name (Bailey et al. 1970) while yellow walleye, pickerel, yellow pickerel, yellow pike, pike-perch, walleye pike, wall-eyed pike, wall-eyed pickerel, and wall-eyed pike-perch are only a few of the more frequently used common names for this species. The preferred common name, walleye, emanates from the smoky, glossed, silvery eye, a term used to describe blinded or "walleyed" domestic animals (Scott and Crossman 1973).

Distribution:

The distribution of walleye is restricted to the freshwaters of North America. In Canada, walleye are found east to Quebec, northwest from the Hudson Bay coast in Ontario to British Columbia and south to southern Alberta (Scott and Crossman 1973). Walleye have been also widely introduced into Canadian waters. Original walleye distribution was located east of the Mississippi River but has been expanded to 42 states in the U.S. (Fig. 1).

Taxonomy:

Walleye are members of the family Percidae. Family characters are presented by Collette and Banarescu (1977). Nine genera comprise the Percid family. Walleye and sauger (*S. canadense*) are the only two North American representatives of the genus *Stizostedion*. Three additional species of *Stizostedion* are found in Europe; all species are large benthic predators (Collette and Banarescu 1977). Walleye and sauger are very similar in external appearance differing in that walleye have a dusky blotch at base of last three dorsal spines and have a higher number of soft dorsal rays (Trautman 1957). Sauger do not grow as large as walleye although highly esteemed, also as a sport fish. Because of their smaller size, sauger have not been widely introduced like walleye.

Sauger and walleye will hybridize and the resulting embryo resembles the female parent (Nelson 1968). Juveniles must be greater than 100 mm before identification from coloration patterns is possible.

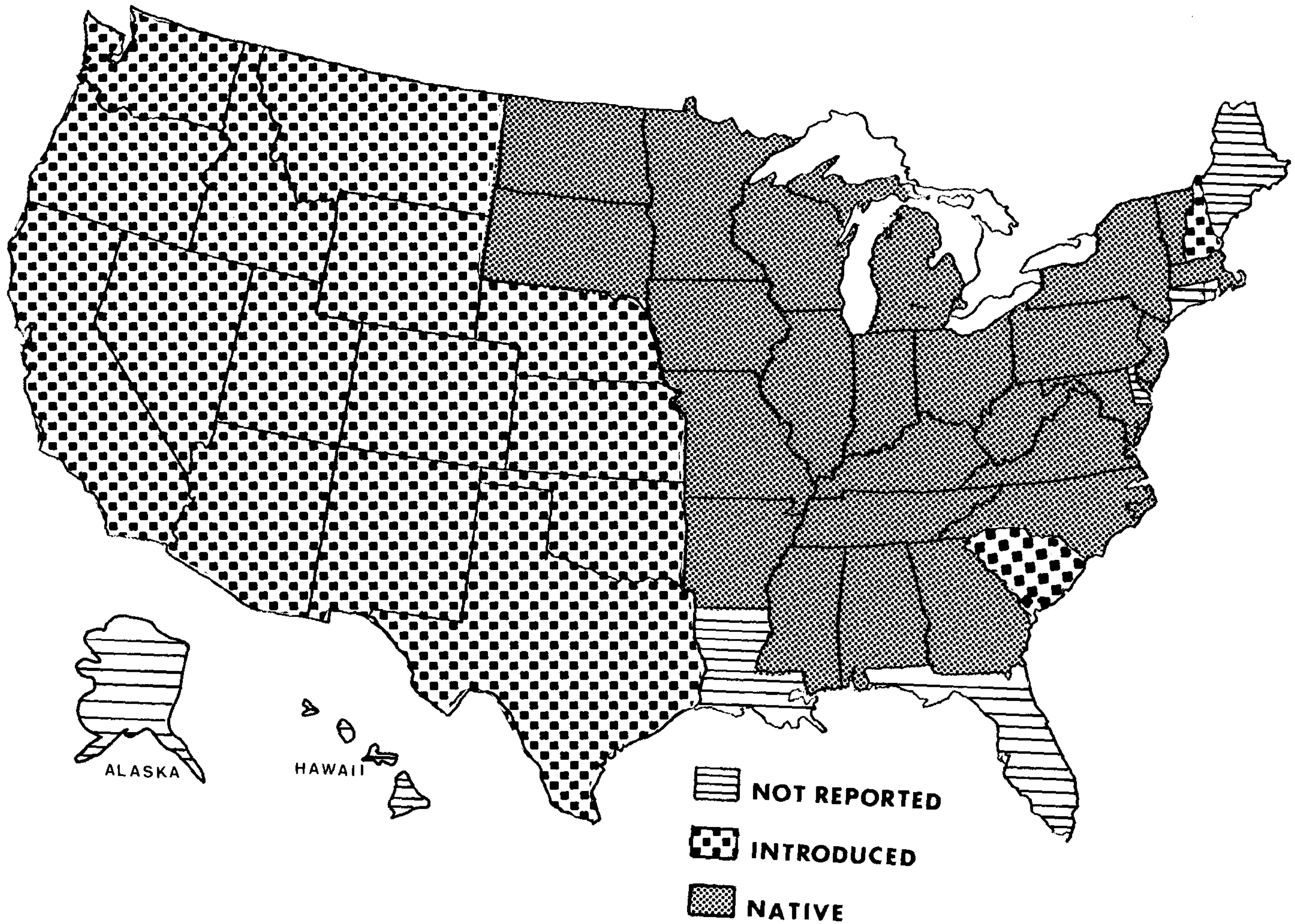

Figure 1. Reported distribution of walleye in the United States (updated from Prentice et al. 1977).

Life History

Much literature has been amassed on the life history and ecological requirements of walleye, primarily as related to stock abundance and sport fishing catch. Trautman (1957), Calhoun (1966) and Scott and Crossman (1973) have summarized the life history of walleye. Recently, an indepth survey of North American percids has been published (Stevenson 1977).

Spawning:

Spawning requirements of walleye have been researched by many investigators with the general concensus being that these vary among years and throughout the range of this species. Walleyes have been known to spawn in lakes and streams depending on the prevailing conditions. Spawning migrations are common and fish will travel nearly 100 Km (60 mi) to spawning grounds (Priegel 1970). Males arrive earlier than females and the first arrival usually follows "iceout".

Walleye spawn over a wide range of water temperatures. Priegel (1970) observed walleye spawning in Wisconsin from 1.8 C (36 F) to 12.4 C (60 F). Peak spawning was observed from 4.6 C (42 F) to 7.8 C (46 F) which coincides with the optimum temperatures for egg fertilization (6-12 C) reported by Kienst and Smith (1976). One unconfirmed report suggested that walleye will spawn under the ice.

Spawning rapidly follows a brief courtship behavior. Individuals approach each other making bodily contact followed by an upward rush (Ellis and Giles 1965) of grouped spawners exposing dorsal fins and backs and breaking the water surface (Priegel 1970). One female usually spawns with two or more males; spawning consists of a series of violent synchronized acts by groups of fishes to broadcast the eggs and milt over a preselected substrate.

Two fish may also spawn together in less violent action (Eschmeyer 1950).

Most of the spawning activity occurs at night although there are reports of daylight spawning. During the daytime, males maintain their position on the spawning area (Ellis and Giles 1965; Priegel 1970) or migrate to deeper waters (Eschmeyer 1950). The level of spawning activity increases as evening ensues. Although the males stay on or near the spawning area during the entire spawning period, females leave shortly after spawning. The length of the spawning period varies with temperature; 11-12 day spawning period was observed in Wisconsin when cold weather was prevailing while a 5-8 day spawning period occurred with warm weather (Priegel 1970).

A variety of locations and substrates have been used for walleye spawning. Some of these are as follows: at mouths of rivers and creeks (Smith 1892); on sandy bars in shallow water (Bean 1903); along the entire shoreline near shore, on gravel bottom (Evermann and Latimer 1910); on shallow bars or "flats" at the edge of deep water (Miles 1915); on sticks and stones in running water at the foot of waterfalls (Bensely 1915); on sand and gravel in shallow water (Henshall 1919); in lakes over broken rocks at points where waves break, if walleye don't enter streams (Cobb 1923); in streams or sandy bays (Dymond 1926); near mouth of streams or in lakes (Adams and Hankinson 1928; Stoudt 1939); in small creeks and rivers or in shallow bays near shore (Bajkov 1930); in streams on sandy bars (Fish 1932); on hard bottoms usually in moving water (Hinks 1943); tributary streams in riffles or on gravel reefs in shallow waters of lakes (Eddy and Surber 1947); on gravel shoals and bars in a lake or gravel bottom in a stream with a good flow of water (Kingsbury 1948); along the lee shore of the lake over a bottom consisting of a mixture of gravel, rubble and boulders or a substratum of sand and fine gravel (Eschmeyer 1950); tributary streams (Rawson 1957); flowing water in streams or along lake shores where wave action keeps the water in motion and substrate ranges from broken rocks to sand (Niemuth et al. 1959); gravel bottoms when available and mats of vegetation, detritus, and root masses (Priegel 1970). This summary of spawning locations suggest the plasticity of spawning requirements of walleye.

Water depth over the spawning grounds is usually less than 3.0 m. Johnson (1961) reported that most spawning occurred in 30 to 75 cm of water; spawning success does not usually occur at depths greater than 1.5 m (White 1977).

The fertilized eggs initially adhere to the spawning substrate. As the external membrane of the embryo water hardens, the adhesive qualities are lost (Priegel 1970). For this reason, walleye select spawning sites with some water movement which provides aeration to the embryos and elimination of waste products.

No parental care is afforded to the embryos and hatching fry. After spawning, the adults return to the feeding grounds while the embryos incubate. Optimal temperatures for incubation are from 9-15 C; rapid temperature changes have minimal effects on juvenile survival (Kienst and Smith 1976). At hatching, the fry range in size from 6 to 9 mm. Fry must have food within 3 to 5 days after hatching to survive; consequently, if hatching occurs in rivers, water movement is needed to transport the juveniles to a food source. Available food supply is not usually limiting for a lake spawning stock of walleye.

<u>Fry Behavior</u>:

Variation in fry behavior has been observed on different stocks of walleye. Raney and Lackner (1942) found that walleye initially inhabited water a few centimeters deep until they gradually migrated in July to weed beds having about 1.2 m of water in August. In September and October, walleye were found in about 3 m of water. Forney (1966), however, found that walleye fry in Oneida Lake, New York, are pelagic until 25-30 mm long when they migrate to the bays. In the fall, these fish gradually migrate offshore to depths of 6 to 12 m. Priegel (1970) found that most walleye emigrated from the spawning marshes to Lake Winnebago, Wisconsin before the yolk sac was fully absorbed. Distribution in the lake was not reported.

Food and Feeding:

Walleye fry initiate their feeding activity prior to complete absorption of the yolk sac (Priegel 1970). Food of walleye from 10 to 50 mm is initially zooplankton, Copepods (*Diaptomus*, *Cyclops*) and Cladocerans (*Leptodora*, *Daphnia*) are important food items. Also important are chironomid larvae and fish fry (white sucker, *Catostomus commersoni*; trout perch, *Percopsis omiscomaycus*; and yellow perch, *Perca flavescens*).

Large walleye feed primarily on fish when suitable sized forage fish are available. Forney (1974) found that walleye selected yellow perch although larger walleye fed on white perch (*Morone americana*) as well as other smaller walleye when yellow perch were not available. Seaburg and Moyle (1964) found that yellow perch was the most important forage item for walleye although minnows (Cyprinidae) and centrarchid panfish were available. Trout perch, freshwater drum (*Aplodinotus grunniens*), yellow perch and white bass were the major food items of walleye in Wisconsin (Priegel 1970). The importance of fish in the diet of walleye has been shown by Eschmeyer (1950). He reported that 80% of the adults over a 3 year period contained fish and an even higher proportion of fingerlings and yearlings consumed fish. Other dietary components (insects, leeches, crayfish) are of importance when an adequate forage base is not available (Walker and Applegate 1976). Cannibalism can affect walleye year class strength when forage is lacking (Chevalier 1973).

Walleye feeding patterns are affected by light conditions in the water. Feeding occurs throughout the day in turbid waters (Scott and Crossman 1973) but is generally limited to dusk or dawn in clearer waters (Marshall 1977). Also, night feeding has been shown to occur on juvenile yellow perch (Forney 1977; Swenson 1977).

The frequency of feeding is related to time of year and size of prey item consumed. Forney (1977) found that in June and July most stomach contents of walleye were evacuated by the afternoon; by August and September, however, remains were visible in the early evening. Water temperature was similar but the ration size increased which accounted for the longer presence of food. Swenson and Smith (1976) found that the feeding rate of walleye was 0.5 to 4.1% of body weight day^{-1} although the relationship was limited by prey abundance. Kelso (1972) found that food conversion was neither affected by ration size nor temperature but decreased with increasing walleye size. Assimilation efficiencies depended on diet type as well as walleye body size; fish had the highest assimilation efficiencies (> 97%) and invertebrates the lowest (82%).

Growth:

Growth of walleye, juveniles and adults, varies within and among populations. In northern U.S., first year's growth is usually attained by October (Forney 1966; Priegel 1970), little growth occurs later in the fall and winter. Young walleye attained a total length of 120 and 150 mm by October during two years of study in Michigan (Eschmeyer 1950). In Oneida Lake, Forney (1966) found first year growth ranged from 119 to 165 mm and in Lake Winnebago, and Priegel (1970) reported that walleyes ranged from 130 to 175 mm. Rawson (1957) found that the mean size of walleye in Lac LaRonge, Saskatchewan was 109 mm. Walker and Applegate (1976) found that walleyes attained a length of 167 mm in a South Dakota prairie pothole. These data demonstrate the variability of first year growth in walleye.

Variation in growth has been correlated with abiotic and biotic factors. Forney (1966) suggested that water temperatures in Oneida Lake determine the rate of growth in early summer. Priegel (1970), however, observed no such relationship between temperatures and growth in Lake Winnebago. No correlation was found between yellow perch abundance and walleye growth in Lake Winnebago. Forney (1966) found that growth of young walleye was more rapid when walleye fed on fish and slower when invertebrates were consumed. Early growth (0 and I) has been inversely correlated with the density of stocking in Iowa (Carlander and Payne 1977). Thus, a variety of factors affect early growth in walleye; these factors vary geographically from one lake to another within the same geographical area, and within a population.

Age and growth of walleye have been commonly investigated throughout the range of this species. Growth usually varies between males and females whereas females comprise most of the larger fish (> 48 cm) in the population (Priegel 1970). Age and growth relationships reflect habitat suitability. It is interesting to note that growth of walleye from Lake Roosevelt is comparable to that from other waters within the native range (Table 1). The largest walleye collected by angling was caught in Hickory Lake, Tennessee; 104 cm (41 inches) long and weighed 11.4 Kg (25 pounds) (Scott and Crossman 1973).

Table 1. Comparison of walleye growth from several U.S. lakes. Lengths were back calculated from scale measurements.

Location	I	II	III	IV	V	VI
Virginia[1]	254	394	508	610	673	711
Iowa[2]	158	292	386	444	488	533
Michigan[3]	107	241	305	356	406	419
Utah[4]	302	423	492	604	778	
Washington[5]	203	328	412	498	541	577

[1] Roseberry 1951 (Total length)

[2] Carlander and Whitney 1961 (Standard length)

[3] Eschmeyer 1950 (Total length)

[4] Hepworth and Gloss 1976 (Total length)

[5] Nielsen 1975 (Fork length)

Size at sexual maturity and longevity in walleyes varies geographically and between sexes. In a Missouri River impoundment, 100% of male walleye were sexually mature at age V whereas 100% of females were mature at age VII (Gabel 1974). Size at sexual maturity in males is about 280 mm and 360 mm in females. Maximum age reported for walleye is 26 years (Schneider et al. 1977).

Diel migrations and distribution in reservoirs is controlled by light conditions. Walleye attain maximum population sizes in shallow, large, turbid lakes (Scott and Crossman 1973). Light is the primary abiotic factor in the environment that affects temporal and spatial distribution of feeding and reproduction. Walleye will actively feed all day when water transparency is 1-2 m, as determined by Secchi disc (Scott and Crossman 1973), although in clear lakes, walleye retain contact with the substrate (Ryder 1977). This is why activity periods of walleye are reported to be during nighttime in shallow and deep areas (Lawler 1969) with peak activity at dusk and dawn (Kelso 1976). Long movements or periods of extensive activity have been correlated with periods of cloud cover, precipitation, and wind speed and direction (Holt et al. 1977).

The physiological mechanism that regulates negative phototaxis in walleye is the tapetum lucidum. This light sensitive layer is found in the ventral region of the walleye retina (Ali and Anctil 1977) which enhances visual acuity during low ambient light conditions (Ali et al. 1977). For this reason, walleye activity is controlled by light conditions. The overall consequences of this intolerance to bright light precludes walleye from inhabiting large streams or rivers that have high transparency at times other than following reproduction. For approximately one week, the negative phototaxis response is masked, possibly through hormonal changes (Ryder 1977).

The strength of the light response can be attenuated by water quality conditions. For example, walleye will select a preferred light regime during the day even if the temperature is not preferred. This response to light, however, can be modified by low levels of dissolved oxygen and high concentrations of free carbon dioxide. Dissolved oxygen and carbon dioxide concentrations from about 2-4 mg/l and 15 mm Hg, respectively, resulted in walleye abandoning their desired light level (Scherer 1971). Under suitable water quality conditions, however, light is the principal environmental variable that affects behavior.

Other abiotic factors can also affect walleye abundance. Carlander (1977) found that walleye were most abundant in large unstratified lakes where the annual growing season has from 500 to 720 degree days above 12.8 C. Another requirement for walleye abundance is having a tributary suitable for spawning or when the problems of fluctuating water levels can be minimized (Marshall 1977).

Walleye exhibit diel and seasonal migrations in response to biotic and abiotic conditions. As mentioned earlier, early spring spawning migrations, either to a tributary stream or lake shoal, are common. Diel vertical movements, primarily for feeding have been also mentioned. Walleye migrations in response to temperature or food have been reported (Scott and Crossman 1973). Walleye in large impoundments and rivers have been collected up to 142 Km from the tagging site (Wolfert 1963) although the majority are collected within 3 Km (Schoumacher 1965).

The ubiquity and success of walleye attests to the adaptability of this species. In the native range of the walleye, northern pike (*Esox lucius*) is probably the most significant predator although sauger predation and competition have been considered significant in regulating walleye populations. Yellow perch and smallmouth bass prey on juvenile walleye as well as other predatory species which help in controlling walleye populations. Water temperatures (Forney 1966), stream flow (Priegel 1970), and wind (Eschmeyer 1950) are also important in regulating walleye populations. Fry mortality up to 99% is probably the major controlling factor of walleye populations (Scott and Crossman 1973).

In many parts of the introduced range, walleye populations may go "unchecked" from biotic pressures such as predation. If abiotic factors are suitable, walleye populations may expand rapidly to the detriment of the indigenous fish community. Desirable fishes may be seriously predated and/or their food supply eliminated. For this reason, planned introductions of walleye must be carefully and expertly evaluated before an interminable condition is attained.

Walleye Impact on Salmonid Fishes

Walleye are very voracious fish predators. Various food habit studies have shown that walleye commence feeding on fish at a small size and then may feed exclusively on fish when available. This piscivorous feeding habit has concerned fisheries biologists throughout the introduced range of walleye because of their potential adverse affect on other fishes. On the other hand, fisheries biologists have taken advantage of this voracious feeding habit and introduced walleye to contribute additional predation pressures on undesirable fishes and increase creel diversity (Prentice et al. 1977).

Yellow perch are an important food item for walleye often comprising greater than 80-90% of the diet in the northern part of its range while gizzard shad constitute a large portion of the diet in the south. The original range of walleye coincides with the original range, in part, of yellow perch and gizzard shad (*Dorosoma cepedianum*). Feeding by walleye on desirable fishes, however, is a large problem when the forage base is inadequate. Under these conditions, walleye production occurs to the detriment of existing fisheries. For this reason, several fish management agencies, after scrutiny, have resisted pressures to introduce walleye in waters under their jurisdiction.

Walleye and steelhead trout have been coexisting in Watauga Reservoir, a 2,400 ha (6,000 ac) reservoir managed by the Tennessee Wildlife Commission. This reservoir is managed as a two story reservoir; that is, coldwater and warmwater fish stocks coexist in the reservoir. Steelhead and walleye were found to be separated, during summer stratification, by about 5 m. Walleye do not seriously compete or appear to be detrimental to the steelhead except that the trout stock, which is maintained by stocking, can be seriously depleted if fish smaller than 23 cm (9 inches) are stocked (Price Wilkins, Tennessee Wildlife Commission, Personal Communication). Trout populations in other southern reservoirs that support two story fisheries including walleye are currently being maintained by stocking trout longer than 20 cm (8 inches). Walleye are not the only predators in these reservoirs; largemouth and smallmouth bass, and white bass (Morone chrysops) are abundant predators that also feed on these stocked trout. Estimates of survival of stocked trout in Watauga Reservoir were similar to those in reservoirs without walleye. Also of importance to walleye in Watauga Reservoir, is that gizzard shad are abundant and constitute a suitable forage base. Therefore, predation on the stocked salmonids is "buffered" by the presence of gizzard shad.

More direct adverse interactions between walleye and salmonid fishes have been observed in Wyoming. At the present time, Wyoming has 16 reservoirs, 1/3 of these have problems with walleyes preying on salmonid fishes. Walleye were first observed in the North Platte drainage in Wyoming in 1962. Approximately 10 years passed before walleye became abundant; the abundance of walleye occurred to the detriment of the salmonid fishes. Rainbow, brown (S. trutta) and cutthroat have been adversely impacted either through competition or predation. Walleye sampled from these reservoirs subsequent to releases of hatchery reared trout have been satiated with these fish. The intensity of walleye predation in Wyoming reservoirs has been acute. For example in Seminoe Reservoir, the uppermost reservoir on the North Platte, walleye nearly eliminated crayfish, longnose sucker (Catostomus catostomus), and white sucker (C. commersoni). Brown trout were consumed while those remaining became emaciated from the disappearance of their food base. Larger brown trout are, consequently, forced to feed on recently stocked salmonid fishes because of the paucity of food. Of the salmonid fishes studied, cutthroat trout may survive better under the walleye influence than other trouts (Jack McMillan, Wyoming Department of Fish and Game, Personal Communication).

Presently, researchers in Wyoming are evaluating survival of various salmonid fishes under walleye predation, developing stocking procedures to reduce predation on newly stocked salmonids, and considering the introduction of forage fish(es). Because of the lack of small fish and crayfish in Seminoe Reservoir, juvenile trout are the most abundant food item for walleye. Stocking a suitable forage species may divert some predation pressure from the salmonid fishes. Species currently being considered are the gizzard shad, emerald shiner (Notropis atherinoides), and mayflies (Hexogenia sp.) (McMillan 1977). These species are readily consumed by walleye.

Walleye were first introduced into the Sacramento River, California, in 1874. At this time, 16 adult walleye from Vermont were planted. Shortly following stocking, one walleye was captured, the others did not apparently survive.

Public pressures in California in the late 50's to reintroduce walleye precipitated a brief survey of literature and professional biologists. The results of these surveys were as follows (Kimsey 1958):

1. Existing fisheries (salmonid fishes) in northern California impoundments could be damaged if walleye were introduced.
2. Walleye will survive and maintain moderately large sized populations in the Sacramento-San Joaquin river systems.
3. Further control (dams of the Sacramento-San Joaquin system could favor the increase in the walleye population.
4. The effect of walleye on king (chinook) salmon is a function of the density of the walleye population but, because of coinciding times of movement, "catostrophic" potential exists.

5. Impact on steelhead would be a function of walleye densities and be less than that on king salmon because steelhead in the Sacramento-San Joaquin system have a protracted emigration time.

6. Other species of fishes would be adversely affected less than salmon and steelhead (catfish, Ictalurus sp.; striped bass, Morone saxatilis; shad, Alosa sapidissima).

This information contributed to the decision made by the California Department of Fish and Game not to introduce walleye north of the Tehachapis Mountains to protect the salmonid resources of the San Joaquin and Sacramento drainages (Miller 1967). Introductions were made into warmwater reservoirs, however, south of the Tehachapis Mountains to control centrarchid panfish populations and provide a trophy fishery. Although walleye did not provide effective control of centrarchid panfish, walleye grew faster and attained sexual maturity earlier than within parts of the native range of this species (Miller 1967).

These investigations indicate that introductions of walleye may be to the disadvantage of desirable species, especially salmonid fishes. Voracious feeding habits of walleye can have adverse affects on stability, productivity, and creel diversity. The intensity of walleye predation on salmonid fishes is probably related to the availability of suitable sized forage items; predation and salmonid fishes may be diverted when adequate forage is available. Without an adequate alternative food supply, walleye predation on salmonid fishes may be so severe that the latter may be functionally eliminated from the fish community.

OCCURRENCE OF WALLEYE IN THE SNAKE AND COLUMBIA RIVERS

To document the occurrence of walleye in the Snake and Columbia rivers, fishery resource management and research agencies were asked for data on walleye collections from field and creel checks sampling efforts. Personnel from the following agencies were contacted:

Washington Department of Game

U.S. Army Corps of Engineers

Battelle Northwest Laboratories

U.S. National Marine Fisheries Service

U.S. Fish and Wildlife Service

Idaho Department of Fish and Game

Oregon Department of Fish and Wildlife

As indicated earlier, the first introduction of walleye in the Snake and Columbia river systems was probably made in Roosevelt Lake in the 1940's or 1950's. Approximately a decade passed before walleye became sufficiently abundant to contribute significantly to the sport fisherman's creel. From this original stocking in Roosevelt Lake, walleye have spread downstream in the Columbia River system. Of particular interest to Idaho is the abundance of walleye in the lower Columbia River which would provide direct access to the lower Snake River system.

The occurrence of dams on the Columbia and Snake rivers has increased the amount of suitable habitat for walleye. Based on the available literature, walleye are more abundant in reservoir systems than free flowing rivers with moderate to high gradient. Also, alteration in water temperature has occurred as a result of impoundment. Consequently, the resulting lacustrine habitats are more suitable to walleye and other warmwater species than before impoundment.

Fishways and locks at each of the lower Columbia and lower Snake River dams provide walleye access to upstream and downstream reservoirs. Although few walleye have been observed from fish counting windows ascending the fishways on the lower Snake River (John McKern, U.S. Army Corps of Engineers, Personal Communication), it is not known the numbers that may enter the locks which provide opportunities for migration from Bonneville to above Lower Granite Dam.

Walleye Abundance

Lower Columbia Reservoirs:

Few walleye have been seen in Bonneville Reservoir, the furthest downstream impoundment on the Columbia River (Fig. 2). Although National Marine Fisheries Service personnel reported observing walleye in this reservoir, walleye were not seen during 1978 which suggests that walleye abundance in Bonneville is low.

The Dalles, the next upstream impoundment on the Columbia River, has a walleye population larger than that in Bonneville. Biologists of the Oregon Department of Fish and Wildlife report that the fishery has increased in the last 5 years from almost nothing to a moderately important sport fishery to a small segment of the sports fishermen (Allan Lichens, Oregon Department of Fish and Wildlife, Personal Communication). The few fishermen participating in the walleye fishery in The Dalles Reservoir have realized good fishing. Walleye have been reportedly caught by Indian gill net fishermen also. Walleye as large as 4 Kg (~ 9 lbs) have been collected from this reservoir. This information suggests that the walleye stock in The Dalles Reservoir has been increasing and walleye are moderately abundant.

John Day Reservoir, the next reservoir upstream from The Dalles, has a walleye stock that has been gradually increasing in abundance (James Phelps, Oregon Department of Fish and Wildlife). Although a walleye sport fishery currently exists around Umatilla, Oregon, information provided by personnel

Columbia and Snake River

Dam and Reservoir Developments

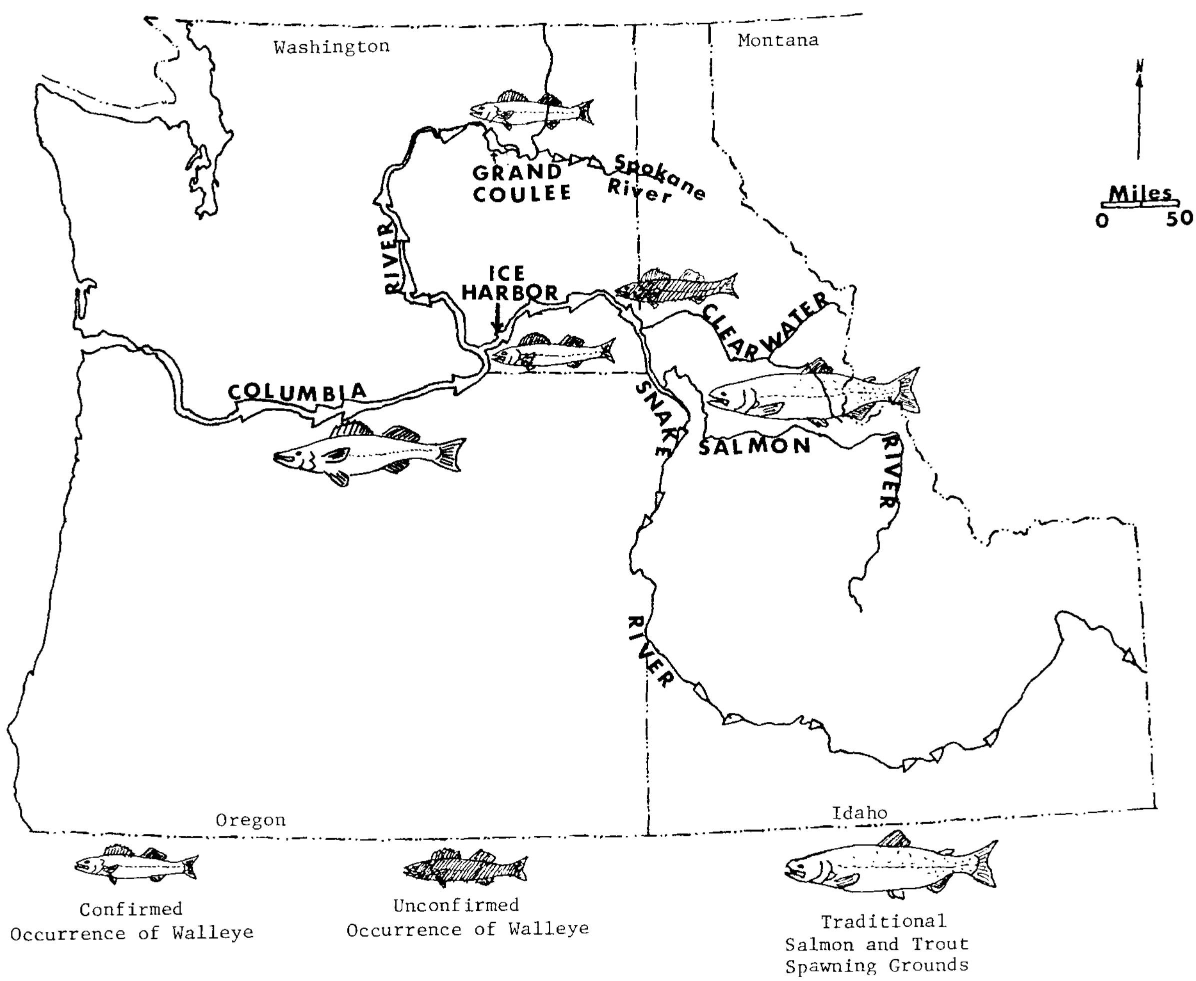

Figure 2. Distribution of walleye in the Columbia and Snake river systems. Distributional accounts are based on literature citations and personal contacts with fisheries management and research personnel.

from the National Marine Fisheries Service indicated the walleye abundance was lower than in The Dalles Reservoir.

Walleye abundance in McNary Reservoir, which has impounded water in the Columbia and Snake rivers, appears to be lower than in The Dalles and John Day reservoirs. A few incidental walleye have been collected and observed in the McNary pool in the last 15 years. Washington Department of Game random creel checks of sport fishermen from 1970 to 1978 have included walleye in the species listing (Curt Vail, Washington Department of Game, Personal Communication). Numbers of walleye creeled have been low, however, and the catch is probably representative of walleye abundance. One walleye has been observed ascending the McNary fish ladder to Ice Harbor Reservoir (John McKern, U.S. Army Corps of Engineers, Personal Communication).

Walleye have been collected in the Columbia River near the Department of Energy's Hanford Reach. Gray and Dauble (1977) collected walleye at river kilometer 557 to 566 (RM 348-354) which is upstream of the impounded waters of McNary Reservoir.

Lower Snake Reservoirs:

Walleye abundance in Ice Harbor, Lower Monumental, Little Goose and Lower Granite is considered low, based on the reports from biologist's and enforcement personnel who have worked these waters for several years. In Ice Harbor, Conservation Officer, Morris Owen, from the Washington Department of Game, reports that he has not seen any walleye in 10 to 12 years in the area around Dayton, Washington. Although walleye have not entered the fishery in Ice Harbor, National Marine Fisheries Service personnel observed a few walleye below Ice Harbor Dam. These data suggest the presence of walleye in Ice Harbor although stock densities are apparently low.

Mr. Stephen Dauma, Conservation Officer for the Washington Department of Game, reported he heard two walleye were caught, one each in Little Goose and Lower Monumental. He did not personnally see these fish, however, which suggests identification of these fish could have been erroneous. Personnel of the National Marine Fisheries Service have not seen walleye in Little Goose and Lower Granite reservoirs. Several local anglers who were ardent walleye fishermen in midwestern U.S. reported that they have not caught or seen walleye being caught neither in Little Goose nor Lower Granite reservoirs. Consequently, the presence of walleye in these lower Snake River reservoirs remains unknown at the present time although direct access is available from downstream reservoirs.

Estimators of walleye abundance in the lower Snake River reservoirs used in this study could be biased. The first source of bias is that the "average" angler who fishes the lower Snake River reservoirs may not be able to identify walleye from yellow perch. To an untrained eye, both species are similar in appearance and the probability of an erroneous identification is high. Another problem in estimating abundance from sport catches is that sport fishing techniques used for other warmwater (largemouth bass, Micropterus salmoides; smallmouth bass, M. dolomieui; black crappie, Pomoxis nigromaculatus, etc.) and coldwater (steelhead trout, Salmo gairdneri; rainbow trout, chinook salmon, Oncorhynchus tshawytscha, etc.) game fishes are not usually those that are successful in collecting walleye. Some scientific gear appears to have a similar potential bias. Purse seining catches, used by National Marine Fisheries Service personnel to study survival of emigrating steelhead and chinook salmon smolts, may not collect walleye. Therefore, walleye presence and abundance in the lower Snake River reservoirs based on these two measures may be biased. Actual walleye stock densities may be considerably higher than these estimators suggest.

Walleye stock densities may be low at the present time, but based on available data, densities will probably increase in the next two decades.

Walleye populations required about 10-15 years to increase in abundance in Washington (Nielsen 1975), Michigan (Eschmeyer 1950), and Wyoming (Jack McMillan, Wyoming Department of Fish and Game, Personal Communication) to a time when walleye were providing a significant sport fishery. If a similar pattern of increasing abundance occurs in the lower Snake River reservoirs, the frequency of capture of walleye either by sport fishing or scientific collecting methods will probably increase until they may become a major predator in the fish community.

Stock abundance and the presence of walleye in lower Snake River reservoirs can, at best, be speculated at the present time. Intensive sampling for walleye is needed to ascertain their level of abundance because of their potential adverse impacts on anadromous salmonid fish smolts.

LITERATURE REVIEW

Literature on walleye is abundant in unpublished and published sources. In the early 1970's, two bibliographies were published on the genus *Stizostedion*. Addison and Ryder (1970) list 2,028 references on North American *Stizostedion* while Robins (1970) lists 581 published reports on the genus *Stizostedion*. Robins' review includes citations from a broader geographical area than North America. A third literature review, by White (1977), is an excellent source of unpublished information on walleye. Although a request for information on walleye was sent to 47 state Departments of Fish and Game, only 19% (9) responded. Because of the completeness of these reviews, greater emphasis was placed on obtaining published works appearing after Addison and Ryder's and Robins' reviews. The bibliography included in this report is supplemental to the previous reviews.

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Future of Walleye in Idaho

Walleye have inhabited three selected waters in southern Idaho since 1973 when they were introduced by Department of Fish and Game biologists. Careful study revealed that these waters were either "closed" aquatic ecosystems or coalesce with waters having established walleye populations (Bear River, Utah); consequently, the threat of natural entry into other systems from these stockings was minimal. All indications to date, suggest that the success of these stockings was low as only a few walleye have appeared in the sport catch. If natural reproduction occurs in these waters, however, walleye populations will increase and the resulting sport fishery will be enhanced and diversified. Suitable habitat appears to exist and walleye populations will probably flourish similar to those in Lake Roosevelt. The only apparent disadvantage of these populations is that their presence amplifies the threat of illegal walleye introductions into waters fishery biologists would consider to be less desirable locations. If illegal introductions into additional Idaho waters can be curtailed, the future of walleye in selected "closed" waters appears bright.

Walleye populations in the Columbia River reservoirs will probably serve as a source for natural stocking of the lower Snake reservoirs. Populations in Ice Harbor, the furthest downstream reservoir on the lower Snake River, will probably increase slowly due to low densities and, after approximately 10 to 20 years, attain maximum densities (Fig. 3). Based on the development of walleye in other waters, walleye numbers will probably follow a similar pattern of population growth in each of the lower Snake reservoirs although require a greater number of years.

Migration of walleye in the Snake River will probably extend upstream to Hells Canyon Dam on the Snake River. Of these upstream areas, largest

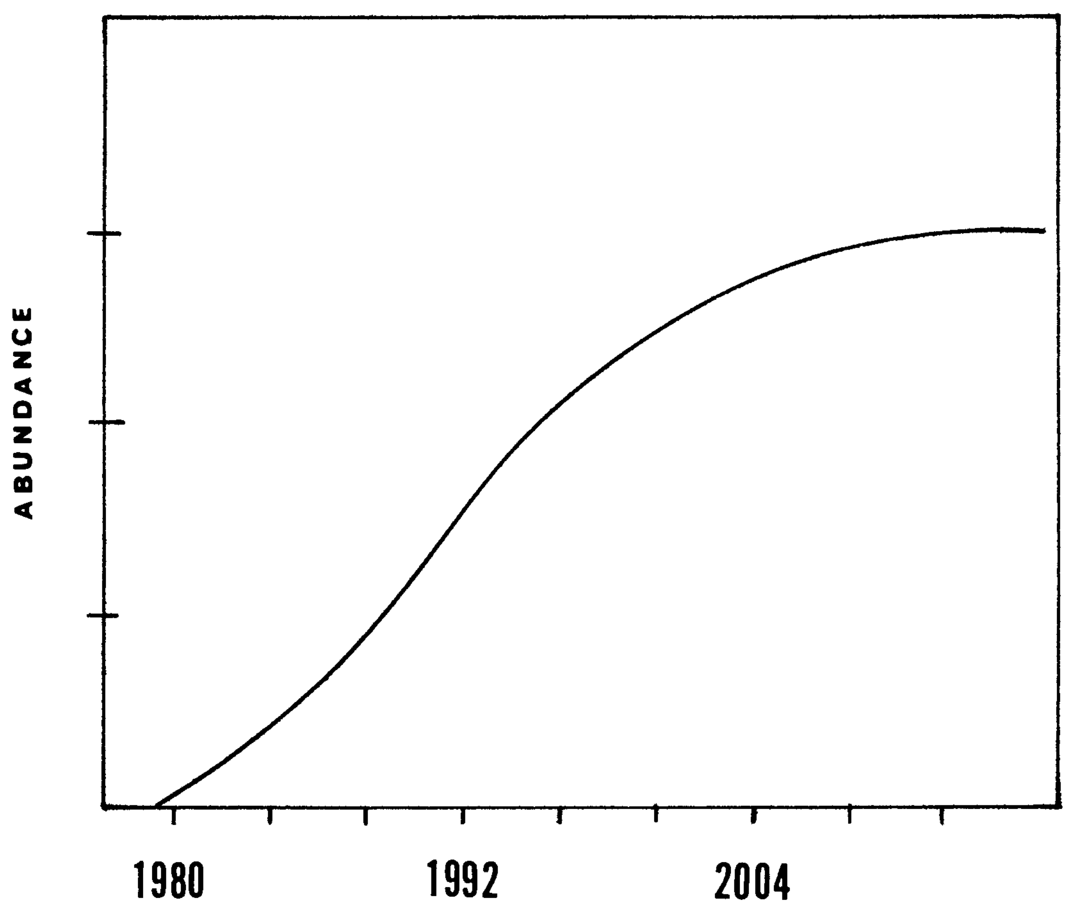

Figure 3. Probable increase in walleye abundance in Ice Harbor reservoir in the next two decades.

populations will be restricted to the impounded waters of Lower Granite Reservoir. High water transparency in shallower streams and rivers accessible from the Snake River (Salmon, Clearwater, Grand Ronde, etc.) will probably preclude walleye from permanently residing in these waters with possible exception in deeper pools.

Walleye probably will not permanently reside in the Salmon, Clearwater and Grand Ronde rivers due to their intolerance to light but may utilize these running waters for spawning. Although walleye usually avoid waters with high transparency, they do spawn in clear waters as a result of their reduced sensitivity to light during the spawning season (Ryder 1977). Also the high gradient in most sections of these rivers will not provide the necessary habitat for walleye rearing. If successful spawning does occur in these rivers, however, walleye fry will probably migrate downstream to Lower Granite Reservoir to obtain the necessary planktonic food for early growth.

Probable Impact of Walleye on Salmonid Fishes

The impact of walleye on waters supporting resident salmonid fishes is potentially significant. Severe predation and competition can occur when walleye are introduced into waters containing salmonid fishes. Based on available data, introductions of walleye into "open" waters and waters containing salmonid fishes should be discouraged. Introductions of walleye into additional waters in Idaho only should be made after careful study by professional fisheries biologists. A strong information and education program must be conducted to assure that illegal introductions by sportsmen are not made.

The presence of walleye in the lower Snake reservoirs and deeper pools of tributary streams and rivers should concern fishery biologists in Idaho, Oregon and Washington. Based on information in the literature, walleye spawning periods will probably overlap the time when steelhead and chinook salmon smolts are emigrating from the Snake and Columbia rivers to the Pacific Ocean (Fig. 4). This temporal overlap during the walleye spawning season will probably be the time of greatest potential adverse impacts on anadromous salmonid fishes. Based on limited information, salmonid smolt emigrations through the Snake and Columbia reservoirs occur primarily during the daytime. At night, smolts appear to curtail migrating and may move to shore (Howard Raymond, National Marine Fisheries Service, Personal Communication). Therefore, the timing of smolt migration and the concentration of walleye along the shoreline while spawning strongly suggests that temporal and spatial overlaps between walleye and salmonid fish smolts will probably intensify predation on the latter. Also based on all available information on prey size and species selectivity, walleye have the potential to prey heavily on salmonid smolts at night. During the daytime, however, walleye predation on smolts should be reduced, since walleye are inhabiting deeper waters to avoid higher light intensities, while smolts are migrating near the surface and probably following the highest velocities through the reservoirs. Unfortunately, these data suggest that increased predation on salmonid fish smolts could result in further declines in returning adult steelhead and chinook salmon to Idaho.

Although increasing density of walleye and their predation on salmonid fish smolts only can be speculated at the present time, fishery resource management agencies should investigate alternative programs to minimize further depredation of salmonid fishes. The transportation program, initiated by the National Marine Fisheries Service, to transport steelhead and chinook salmon smolts below Bonneville Dam should be strongly supported based on my findings. Collection of the majority of emigrating smolts at Lower Granite and Little Goose dams and their transport to the ocean would minimize the

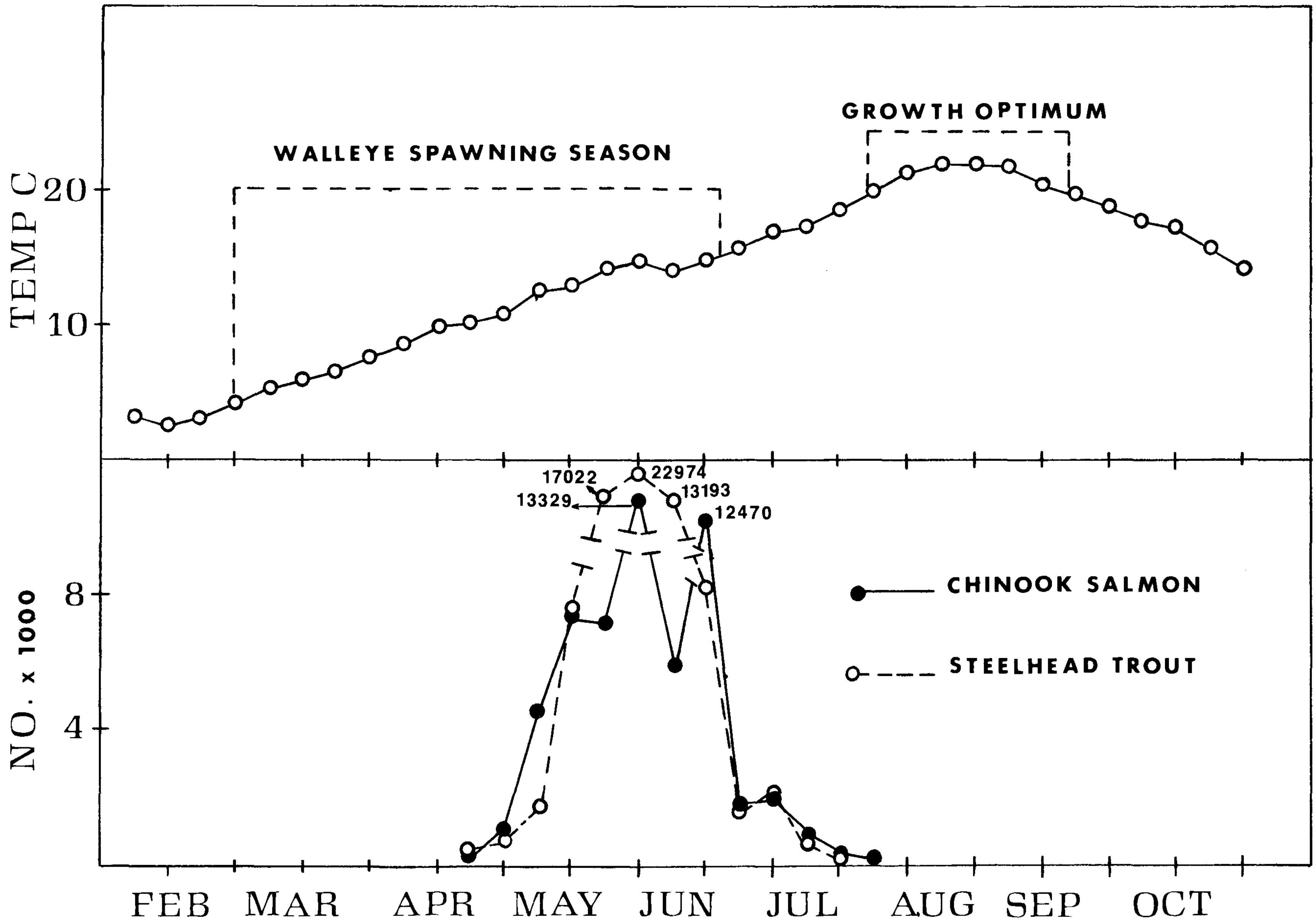

Figure 4. Relationship between water temperature (U.S. Army Corps of Engineers 1973), walleye spawning and optimum growth periods, and emigration of chinook salmon and steelhead trout smolts. Smolt count (Raymond et al. 1973) and water temperature measurements were made at Ice Harbor Dam on the Snake River during 1973.

potential impacts of walleye predation on anadromous fishes. Walleye are expected to have minimal affects on returning adult chinook salmon and steelhead trout.

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