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Comparison of Walleye: Stizostedion Vitreum Vitreum (Mitchell), Ecology and Biology From Three Discrete Areas of Lake Sakakawea, North Dakota

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COMPARISON OF WALLEYE, STIZOSTEDION VITREUM VITREUM (MITCHILL), ECOLOGY AND BIOLOGY FROM THREE DISCRETE AREAS OF LAKE SAKAKAWEA, NORTH DAKOTA.

by
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This thesis submitted by Randy J. Hiltner in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota is hereby approved by the Faculty Advisory Committee under whom the work has been done.

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This thesis meets the standards for appearance and conforms to the style and format requirements of the Graduate School of the University of North Dakota, and is hereby approved.

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ABSTRACT

Various aspects of the ecology and biology of the walleye were examined from three discrete areas of Lake Sakakawea during the summer of 1982. Spatial distribution, predator-prey relationships and species association data were procured by simultaneously placing experimental and 0.5 in mesh gill nets at three depth ranges: 0-10 ft, 11-20 ft and 21-40 ft. Temporal distribution data were collected by lifting and resetting the gill nets approximately every six hours. Four time periods were used: 0600-1200 h, 1200-1800 h, 1800-2400 h and 2400-0600 h. Walleye age, growth and food habit data were also collected from the fish caught.

The Van Hook Area produced the largest numbers of walleye and rainbow smelt, *Osmerus mordax* (Mitchill). The 0-10 ft range produced the largest catches of walleyes for all areas. The total rainbow smelt catch was the largest in the 21-40 ft range. The Williston Area had the largest rainbow smelt catch in the 0-10 ft range. The total catch of walleye and rainbow smelt was significantly correlated for the 12 sampling periods. Walleyes and rainbow smelt numbers were also significantly correlated in the 11-20 ft range. More saugers, *Stizostedion canadense* (Smith), were caught in the Williston Area than walleyes. The differences in the total walleye and rainbow smelt catch among time periods were small. The 2400-0600 h period produced the largest number of walleyes of the four time periods, while the 1800-2400

h period was the most productive for rainbow smelt. The largest catches of walleye and rainbow smelt came during the 1200-1800 h period in the Williston Area. There was a positive relationship between walleye and rainbow smelt during the 1800-2400 h and 0600-1200 h periods. Ten age classes were found for the total walleye catch. Age classes III and VII were the largest for the total walleye catch. There were few age I and II walleye caught. The weight-length relationship for all of the walleye was explained by the equation: $\log W = -5.793 + 3.299 \log L$. The mean coefficient of condition for the total walleye catch was 1.04. The walleyes caught in the Van Hook Area had significantly higher condition factors than did the other two areas. Rainbow smelt was the only forage species that was identified in the walleye stomachs. The stomachs of walleyes caught in the 11-20 ft range contained the greatest number and volume of rainbow smelt per stomach.

Area morphometry, water temperature, light penetration and prey density are factors which may explain the larger numbers and faster growth rates of walleye caught in the Van Hook Area. The large catch of walleyes in the 0-10 ft range appear to be related to water temperature. Year class strength of walleyes is apparently closely related to water levels during spawning. Walleyes probably feed heavily on rainbow smelt because they are abundant, soft-rayed and easily caught.

INTRODUCTION

Lake Sakakawea is currently one of the best producers of walleye in the upper midwest. The Lake Sakakawea walleye fishery is very important as it produces large revenues and many recreational hours within the state.

Considering the economic and recreational value of this fishery, there has been relatively little research on the walleye population. Wahtola et al. (1972) and Cassity (1979) examined growth rates, age composition, and condition factors. Berard (1978a) conducted a limited walleye food habits study for a two week period during the spring of 1976, and presented comparative growth data before and after the introduction of of rainbow smelt.

There is a lack of data concerning the ecology of walleye in this reservoir. There has also been no research into intra-reservoir variance in walleye age and growth.

This study was initiated to collect and compare ecological and biological data on the walleye population from three discrete areas of this large reservoir. These data may be important in providing behavioral insight, which will aid in the management and understanding of the walleye in this system.

Ecological data, including walleye and rainbow smelt distribution and predator-prey relationship, food habits of walleyes, and associations of walleyes with other fish species were examined between the different areas, depth ranges and time periods. Current age and growth data on the walleye were also collected from the three discrete areas.

DESCRIPTION OF STUDY AREA

Lake Sakakawea, in west-central North Dakota, is the largest reservoir on the Missouri River. The Garrison Dam was closed in 1953 forming Lake Sakakawea. Lake Sakakawea was built and is operated by the U.S. Army Corps of Engineers for flood control, hydroelectric power, recreation and to provide water for irrigation.

Lake Sakakawea is approximately 180 miles long with an average width of three miles and has about 1,600 miles of shoreline. With the surface elevation at 1850 ft above mean sea level (msl) the reservoir has about 368,000 surface acres and a storage capacity of 24,620,000 acre ft. The maximum depth is 180 ft in the old river channel near the dam. (U.S. Army Corps of Engineers 1977)

Lake Sakakawea is a very dynamic reservoir in terms of water level fluctuations. Water levels fluctuated between 1838.5 ft above msl in March to 1854.8 ft above msl in July of 1975; a total of 16.3 ft (Berard 1980). Much of the rise in water levels can be attributed to the spring runoff of melting mountain and local snow that ultimately flows into the Missouri River. Heavy rains in the watershed also contributed to the rising water levels. Aquatic macrophytes cannot become established in the reservoir because of the dynamic water levels.

The geological composition of the area around Lake Sakakawea and its shore consists of Tertiary Fort Union deposits that are covered with glacial till. The Fort Union formation consists of sedimentary mixtures of clays, silt and lignites with areas of "scoria" (sediments that are baked when underlying lignite coal seams burn). During the Kansan and Wisconsin glaciation , till consisting of primarily sand and gravel was deposited on the north and south sides of Lake Sakakawea. Heavy glacial till was deposited on the north side by both the Kansan and the Wisconsin glaciation. Thin glacial till was deposited on the south shore by the earlier Kansan glaciation. Larger glacial rocks are found primarily near the lower end of the reservoir. (Benson 1980)

The glacial till acts to stablize the shoreline, thus armoring the erodible Fort Union deposits. The energy given off by the waves has developed a sand, gravel and rocky shoreline along much of the reservoir (Stanley et al. 1973).

The shoreline of Lake Sakakawea has been modified considerably by hydrodynamic processes, primarily during the first 20-25 years of impoundment. The shoreline modification during these years has produced changes in fish species composition. Walleye spawning and nursery areas have increased in quality and quantity and the relative abundance of walleyes has increased as a result of the exposure of glacial till. (Benson 1980)

Short-grass prairies dominate the surrounding terrain. Low hills exist as remnants of the Pleistocene glaciation. There are "breaks" that dissect the rolling plains. Most of the existing trees and shrubs thrive in these low-lying areas. The valley of the Missouri River varies from one to ten miles in width. The uplands are several hundred ft higher than the Missouri River trench. (U.S. Fish and Wildlife Service 1952)

The climate in this part of the state is semi-arid. Average annual precipitation at Williston, North Dakota is approximately 15 inches. There can be extended periods of drought. Temperatures vary dramatically from winter to summer and can be as high as 110.0 ^{o}F in the summer and as low as -50.0 ^{o}F in the winter. The mean January temperature is 7.9 ^{o}F and in July the mean temperature is 69.4 ^{o}F. The average growing season (frost free period) is 133 days. Winds are often strong, with gusts commonly reaching 25 miles per hour.

There has been 48 species of fish identified from Lake Sakakawea (Berard 1980). The more common fish species are: goldeye *Hiodon alosoides* (Rafinesque), walleye, yellow perch *Perca flavescens* (Mitchill), sauger, carp *Cyprinus carpio* Linneaus, white sucker *Catostomus commersoni* (Lacepede), channel catfish *Ictalurus punctatus* (Rafinesque), rainbow smelt, and northern pike *Esox lucius* Linneaus.

Lake Sakakawea was test netted during the summers 1978 and 1980 using a variety of nets. Goldeye and walleye were ranked first and second in terms of percent composition for both years in the 250 foot experimental gill nets. Goldeye averaged 47.93 % of the total catch. Walleyes averaged 20.80 percent of the total number. The percentage of other species dropped dramatically during both years. Saugers averaged 7.39 %, northern pike 4.77 %, yellow perch 4.30 %. (Berard 1980; 1981)

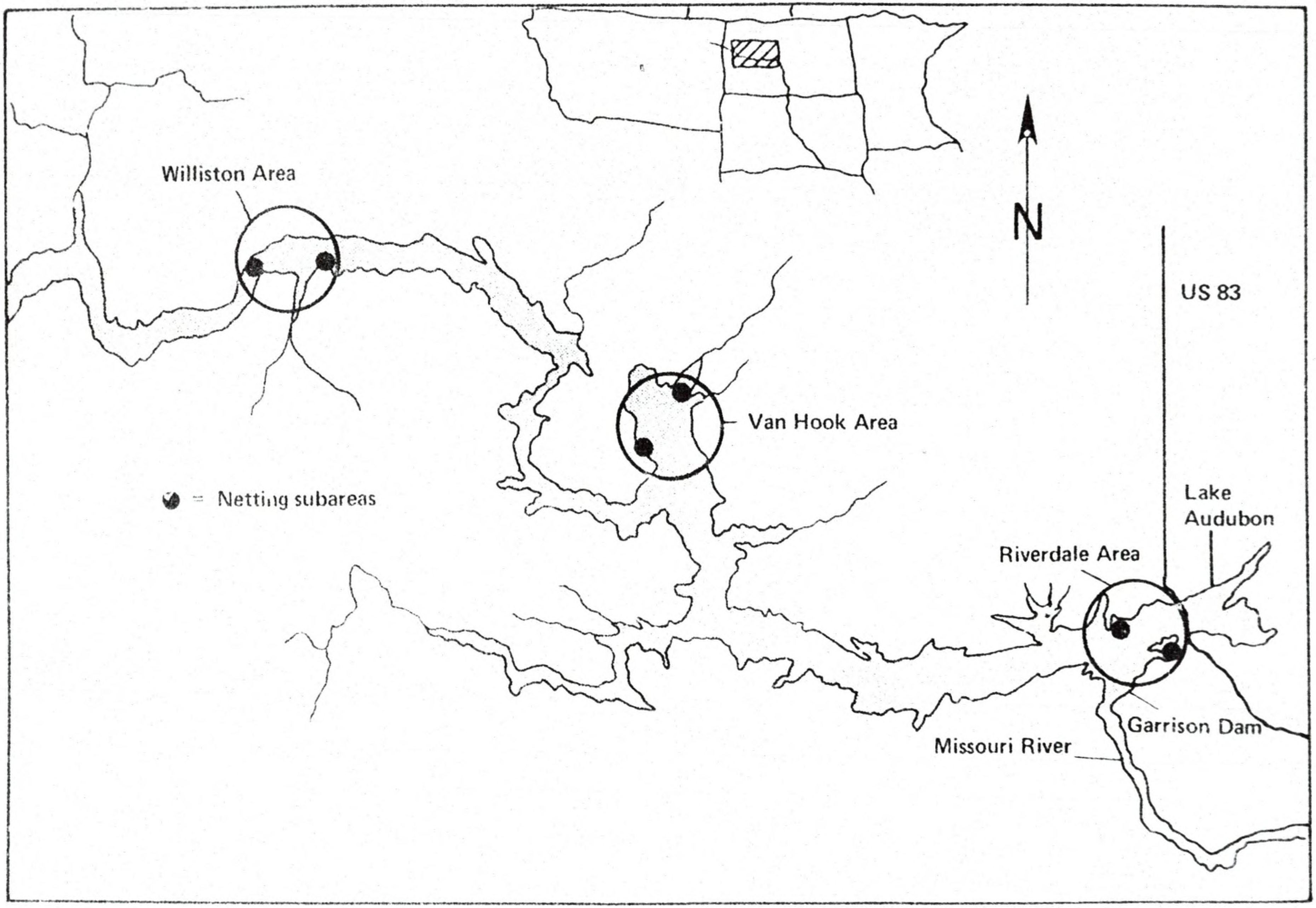
During 1979 and 1980 rainbow smelt made up the largest percentage of the catch in the one-half inch mesh gill nets, composing 33.28 % of the total catch. Yellow perch and goldeye were ranked second and third at 31.90 and 28.94 % respectively. (Berard 1981)

DESCRIPTION OF THE THREE SAMPLING AREAS

Walleye data were procured from three discrete areas of Lake Sakakawea during the summer of 1982. The three areas were designated as the Riverdale Area, the Van Hook Area, and the Williston Area. The Riverdale Area is in the lower end of the reservoir near the dam. The Van Hook Area is located in a large bay, approximately at the midpoint of the reservoir. The Williston Area is in the upper end of the reservoir. Each of the three areas were further divided into two subareas (Fig. 1). The Riverdale Area was subdivided into the Wolf Creek and De Trobriand Bay Subareas, the Van Hook Area into the Shell Bay and the Little Field Bay Subareas and the Williston Area into the Tobacco Garden and Lewis and Clark Bay Subareas.

The Riverdale Area is characterized by cold, clear and deep water. The shoreline is often steep and there are abrupt changes in water depth only a short distance out from the shore. The mean shore slope for this downstream area was reported to be 6-8 % (Benson 1980). This area is approximately three miles wide. Power (1983) measured several limnological parameters for each of the three sampling areas. The mean depth for the Riverdale Area was 84.7 ft in cross-section (depths at 1840 msl). The mean surface temperature of the water ranged from 45.4 ^{o}F on 18 May to 68 ^{o}F on 19 July. Temperatures at 13.0 ft of depth ranged from 43.0 ^{o}F on 18 May to 65.3 ^{o}F on 19 July. Water clarity was measured in terms of percent incident light penetration. At 6.5 ft the incident light ranged from 30.1 % on 18 May to 28.0 % on 19 July and at 13.0 ft from 12.0 to 7.4 %. Needham (1961) measured light penetration with a secchi disc and recorded average readings of 13.3 ft for this area.

Figure 1: Sampling areas and subareas in Lake Sakakawea.


Williston Area
Van Hook Area
N
US 83
Netting subareas
Lake Audubon
Riverdale Area
Garrison Dam
Missouri River

The Van Hook Area is a large wind-swept bay that extends northward of the main river channel for approximately 12 miles. This bay is approximately six miles in width. The shoreline has a gradual slope, but drop-offs are found near the abundant sunken and partially submerged islands. The Van Hook water temperature, clarity and depth are intermediate compared to the Riverdale and Williston Areas. The Van Hook Area has a mean depth of 40.6 ft. The mean surface temperature ranged from 56.3 °F on 26 May to 73.6 °F on 26 July. Temperatures at 13.0 ft ranged from 53.8 °F on 26 May to 72.4 °F on 26 July. The percent of incident light penetration at 6.5 ft ranged from 17.6 % on 26 May to 23.3 % on 1 August and at 13.0 ft from 7.7 % to 6.3 %. (Power 1983) Secchi disc readings averaged 3.9 ft for the area (Needham 1961).

The Williston Area is the most riverine of the three areas. There was a noticeable current produced by incoming run-off waters. There are many submerged and floating trees, which are a result of the inundation of riparian vegetation. The Williston Area is approximately two miles wide, making it the most narrow of the study areas. The shore slopes are the steepest in this part of the reservoir, ranging from a mean slope of 12-16 % (Benson 1980). In 1982 the water in this area warmed quickly as the surface temperatures ranged from 58.8 °F on 1 June to 76.5 °F on 2 August. Temperatures at 13.0 ft ranged from 57.0 °F on 1 June to 73.0 °F on 2 August. The incident light penetration at 6.5 ft ranged from 0.7 % on 1 June to 2.0 % on 2 August and at 13.0 ft there was no incident light penetration. The mean depth for this area was 33.4 ft, making it the shallowest of the three areas

(Power 1983). Water clarity is very poor in this area due to the suspended particles, primarily small, flattened clay particles (Neel et al. 1963).

LITERATURE REVIEW

RANGE

The walleye is a common fish of the northern United States and much of Canada. The natural range of the walleye extends northwest to Great Bear Lake and to Labrador in the northeast, south to Alabama and west into Nebraska (Niemuth et al. 1972). Walleyes have been introduced successfully on the eastern seaboard and in most of the states west of its natural range (Scott and Crossman 1973).

HABITAT

Walleyes are tolerant of many types of habitat, but show a preference for large, shallow and semi-turbid lakes (Colby et al. 1979). The most suitable lakes are usually over 900 acres and are classified limnologically as mesotrophic. These lakes must have suitable spawning grounds of rubble, gravel or sand, an adequate forage base, depths of at least 30 feet and maximum water temperatures of between 60-80 ^{o}F. Conditions found in eutrophic and oligotrophic lakes are not optimum for the walleye (Regier et al. 1969).

REPRODUCTION

Walleyes begin spawing shortly after the ice breaks up on the lake, usually with water temperatures between 42-52 °F (Scott and Crossman 1973).

Spawning temperatures may be a function of the thermal history and maturation of the stock (Colby et al. 1979). Rawson (1957) found walleye spawning runs began at a warmer temperature in earlier runs than when spawning was delayed by cold weather.

Spawning occurs at night in shallow water from a few inches to six feet deep (Colby et al. 1979). Spawning substrate consists of primarily rock, rubble and gravel found in streams, on offshore reefs and along lake shorelines (Eschmeyer 1950). Priegal (1970) found that the walleyes in Wolf River, Wisconsin spawned over mats of vegetation. Sand substrate was utilized but was not preferred when areas of rock and rubble are present (Eschmeyer 1950; Johnson 1961).

The absence of suitable spawning substrate is an important factor limiting establishment of walleye populations in eutrophic waters (Moyle 1954). Eutrophic lakes often have low oxygen levels at the mud-water interface which precludes egg survival (Colby and Smith 1967). Fine substrates of the Missouri River main stem reservoirs may also reduce egg survival (Benson 1968).

Other abiotic and biotic factors affect the mortality of walleye eggs. Water level, temperature, flow velocity and predators may influence egg survival. Eggs have been stranded on shore as water levels decreased. High winds were observed to wash significant numbers of walleye eggs onto shore (Priegal 1970). Walleye eggs and fry can withstand large temperature fluctuations (a 4.4 °C increase over the base temperature for a four hour period) without mortality. The predominance of river spawning populations of walleye suggests fry and eggs are tolerant of considerable temperature fluctuations (Allbaugh and Manz 1964). Water velocity may be important for oxygen transfer and distribution of fry to nursery areas (Colby et al. 1979).

Several species of fish including carp, yellow perch, white sucker, spottail shiners Notropis hudsonius (Clinton) have been reported to feed on walleye eggs (Wolfert et al. 1975). Regier et al. (1969) stated that the yearling and older fish of pelagic, plankton feeding species, i.e., rainbow smelt and alewives would be the most effective predators on walleye fry.

Walleyes have a high fecundity, as many as 612,000 eggs have been reported from a large walleye in Lake Erie (Scott and Crossman 1973). Eschmeyer (1950) estimated that there were 28,112 eggs per pound of body weight. Other estimates in the literature ranged from 12,916 to 60,000 eggs per pound of body weight.

The rate of egg developement varies directly with the incubation temperatures (Johnson 1961). Incubation periods ranging from four days at 75 °F to 33 days at 40 °F have been recorded (Colby et al. 1979). Niemuth et al. (1972) found the eggs hatched in 26 days when the water temperature was 40 °F, in 21 days when 50-55 °F and seven days at a mean temperature of 57 °F.

SPATIAL AND TEMPORAL DISTRIBUTION

Larval walleye leave the spawning grounds a few hours after hatching and are carried by currents to pelagic waters. At a length of approximately one inch the fry become benthic and move inshore. As the summer progresses all age groups move deeper (Colby et al. 1979). Johnson (1969) found that yearling and older walleyes moved back inshore in September as water temperatures decline.

Adult walleye are usually found in relatively shallow water near boulder shoals and rock outcroppings. Walleyes are usually found between 3-50 ft (Colby et al. 1979). Rawson (1957) captured more walleye per set in gill nets set at 0-16 feet than any of the deeper depth ranges in Lac La Ronge, Saskatchewan. Johnson (1969) recorded the greatest trawl catches between 4 and 12 feet from June to early August and again in mid-September in Lake Winnibigoshish and Cutfoot Sioux Lake, Minnesota.

Depth distribution of walleyes is affected by many abiotic and biotic directive factors, i.e., water temperatures, light penetration and prey location influence walleye location in a particular body of water. Walleyes can survive in a wide temperature range of 32 ^{o}F to 86 ^{o}F (Colby et al. 1979). Ferguson (1958) found the preferred temperature range for walleye was 68-73 ^{o}F. Regier et al. (1969) stated the optimum range was 70-72 ^{o}F. In Saskatchewan, Rawson (1957) caught the majority of walleye in water between 59 and 64.5 ^{o}F. Spangler et al. (1977) stated that water temperatures may be one of the most important factors in determining the distribution of walleye in Lake Huron. He found that walleyes were distributed within the 59 $^{\circ}$F surface isotherm. Walleyes moved to deeper waters in the summer where the most fish were captured at 26 feet with water temperatures ranging from 65 to 67 $^{\circ}$F. Johnson (1969) also found walleyes move into deeper water as the surface temperatures rose above 70 $^{\circ}$F. Walleyes will spend time in water above the preferred temperature range if cover is available (Scott and Crossman 1973). This suggests an affinity to remain in the shallow water, possibly for foraging purposes. Neill and Magnuson (1974) observed yellow perch, a common percid, would make feeding forays in water warmer and cooler than the preferred range, however, they concluded that the thermoregulatory behavior was not overridden by feeding behavior.

Ambient light penetration is apparently an important stimulus in determining diel depth distribution of walleye. Scherer (1976) found adult walleyes to be negatively phototropic. This agrees with the inverse relationship between the number of walleyes observed and light transparency levels found by Ryder (1977). To avoid intense light, walleyes characteristically are found in deeper water during the daytime, migrating to the shallow areas at night (Niemuth et al. 1972). Walleyes that remain in shallow water utilize protective shelter, i.e., boulders, logs and weedbeds to shield their eyes from the incoming light (Ryder 1977). Rawson (1957) caught 89 % of the total number of walleye during a time period beginning at 1900 h and ending at 0700 h, capturing only 11 % from 0700 h to 1900 h. Swenson and Smith (1973) also caught significantly more walleye during the night than during the daylight hours in Lake of the Woods, Minnesota. Feeding activity increases as a response to the lower light levels of crepuscular and nocturnal periods

(Swenson and Smith 1973; Ryder 1977). Wind action on the lake, cloudy conditions and turbid water also reduce the ambient light penetration which increases diurnal feeding activity in shallow water (Colby et al. 1979).

Walleyes can tolerate a wide range of dissolved oxygen levels. Scherer (1971) observed little behavioral change in water with dissolved oxygen between 8.5 and 1.5 mg/l in the laboratory, but at 0.6 mg/l a lack of coordination was observed. Dissolved oxygen levels of at least 3 mg/l are necessary for walleye to become abundant (Dendy 1948). Depth distribution could be affected when lakes stratify and dissolved oxygen levels in the hypolimnion are reduced (Regier et al. 1969).

Walleye distribution has been associated with location of prey species. Rawson (1957) suggested the movement of walleye into deeper waters of Lac La Ronge, Saskatchewan was not in response to increases in water temperature but to the location of ciscoe, Coregonus artedi Lesueur. Johnson (1969) found walleyes at the same depth range as Johnny darters Etheostoma nigrum (Rafinesque), their preferred forage fish in June. Young of the year yellow perch, an important late summer forage were also netted along with walleye in depths from 5-15 ft in July, August and September.

AGE AND GROWTH

Walleye growth rates vary widely depending on the geographic location, sex and age. Walleye tend to grow faster in the southern areas of its distribution, with slower growth rates in the northern areas (Colby et al. 1979).

Females usually have faster growth rates than do males after a certain age (one to three years, Carlander 1945; Eschmeyer 1950; Niemuth et al. 1966; Ragan 1972).

The growth of walleyes varies considerably during the first year, ranging in average total length from 64 mm in Kellens Reservoir, Montana to 383 mm in Lake Meredith, Texas (Kraai and Prentice 1974). Priegal (1970) found that young of the year walleyes averaged 76 mm over a nine year period at the beginning of August, completing 62 % of the growth for the seaso in this time. Relative growth rates usually decrease in the second year and continue decreasing until the fifth or sixth year, after which growth rates are irregular (Colby et al. 1979).

There has been considerable variation reported in growth rates between year classes and even within the same year classes (Eschmeyer 1950). Colby et al. (1979) attributes much of this variation to errors made in aging the fish. Carlander (1969) found that over 30 % of the 671 walleye scales aged for a second time did not agree with the first reading.

Adult walleye growth rates are greatest in the northern latitudes from July to October (Kelso and Ward 1972). The increases appear to be a function of increased metabolism and food intake.

Average condition factors K(TL) usually increase with age in most walleye populations (Priegal 1969a). In most lakes there is no significant difference in the condition factors between sexes. Condition factors depend primarily on whether or not forage fish are abundant (Colby et al. 1979).

An inverse relationship between walleye density and growth has been found in many lakes (Carlander 1948). Moenig (1975) observed an increase in walleye growth in an experimentally exploited walleye population in Dexter Lake, Ontario.

Walleyes have a life span ranging from 5-20 years depending on the latitude. Northern walleyes commonly live to be 12-15 years old, whereas walleyes in the southern part of their range usually live 5-7 years (Colby et al. 1979). Females are usually longer lived than males.

FOOD HABITS

Walleyes usually feed from evening to early morning. However, there are data that show walleye feed throughout the day in turbid lakes (Ryder 977). Walleye usually feed near the bottom (Colby et al. 1979). Walleyes and other percids feed primarily by sight (Disler and Smirnov 1977). Other senses, i.e., the lateral line system, hearing and smell also must aid in food procurement in turbid water and at night (Regier et al. 1969).

Most feeding activity takes place in the summer and fall. Food consumption rates of adult walleye increased from June to August, then stabilized in September in the Lake of the Woods, Minnesota (Swenson and Smith 1973). As forage density increased food consumption also increased, stabilizing at 30 mg/g/day (Swenson and Smith 1976). Low forage density is the primary factor limiting food consumption.

During the first six weeks of life walleyes feed on diatoms, copepods, and fish (Scott and Crossman 1973). Hurley (1972) observed cannibalism among walleye larvae.

Adolescent walleyes change from an aquatic insect-crustacean diet to fish (Colby et al. 1979).

Adult walleyes are primarily piscivorous, feeding on many different species. Invertebrates do, however, form a large part of the diet of walleyes in late spring and early summer in many lakes and in lakes that lack suitable numbers of forage fish. The most important invertebrates are mayfly nymphs and amphipods (Eschmeyer 1950; Kelso 1972).

The relative amount of prey species consumed may be a function of the availability (Scott and Crossman 1973). When available and abundant, yellow perch seem to be the predominant prey species in the northern and central regions of the walleye's distribution (Eschmeyer 1950; Maloney and Johnson 1957; Forney 1966; Dobie 1966). However, Wagner (1972) found alewives Alosa pseudoharengus (Wilson) and rainbow smelt were the predominant prey species in Lake Michigan even though yellow perch were abundant. He suggested that alewives and rainbow smelt buffered the predation on the yellow perch. Similiar results were found by Payne (1963) in the Bay of Quinte, alewives and rainbow smelt were preferred over the abundant yellow perch. He suggested that these data indicate a true preference and are not a function of availability. Rainbow smelt and alewives also dominated the walleye stomach contents in Lake Huron where yellow perch were again abundant (Spangler et al. 1977). These data may indicate a preference or perhaps the yellow perch were more evasive. Regier et al. (1969) stated that soft-rayed fish seem to be preferred when available.

Size preference may also be important in the selection of a specific prey. As walleyes increase in length, the mean length of preferred prey species also increases (Parsons 1971). When there are several prey species in the optimum size range, then the most abundant species is usually the predominant prey (Wagner 1972).

METHODS AND MATERIALS

SAMPLING DESIGN

The data were collected from the Riverdale, Van Hook and Williston Areas during the summer between 15 May and 7 August, 1982. Sampling was subdivided into 12 periods, or four periods for each of the designated areas. Each area was sampled at three week intervals in a fixed sequence (Table 1). Each area had two subareas that were sampled twice during the summer on an alternating schedule.

Two types of monofilament nets were used to capture fish for this study. One was a 125 x 6 ft experimental gill net with five panels 25 ft in length with 0.75, 1.0, 1.5, 1.75 and 2 in bar mesh primarily to sample walleye. The second net was 125 ft in length with 0.5 in mesh and was used to sample rainbow smelt. The two nets were fastened together to form a 250 ft sampling device.

In each of the 12 sampling periods the depth and time of the gill net sets were controlled. Three standard depth ranges, "shallow", "medium" and "deep" were established. A shallow set was represented by the 0-10 ft range with the bottom of the gill net always between six and ten feet. The medium depth set was from 11-20 ft with the bottom of the gill net between 16-20 ft. The bottom of the the gill net was set between 16-20 ft so it would not overlap with the 0-10 ft range. The deep set was made in 21-40 ft of water with the bottom of the gill net between 26-40 ft.

TABLE 1

The netting schedule for the 1982 season, showing the 12 sampling periods.

Date	Areas		
	Riverdale	Van Hook	Williston
May 15-22	X		
May 23-29		X	
May 30-June 5			X
June 6-12	X		
June 13-19		X	
June 20-26			X
June 27-July 3	X		
July 4-10		X	
July 11-17			X
July 18-24	X		
July 25-31		X	
August 1-7			X

A 250 ft gill net was set at each depth range. The nets were set primarily in bays or other relatively shallow flats where an even depth contour could be located. By using areas with an even contour, all 250 ft of each net was kept at approximately the same depth. A Lowrance 1510b graph depth recorder was used in order to find and keep the nets at the indicated depths. The nets were set parallel to the shoreline in a staggered configuration (Fig. 2). The nets were kept as close together in terms of lateral position as possible without overlapping, usually under 50 yards.

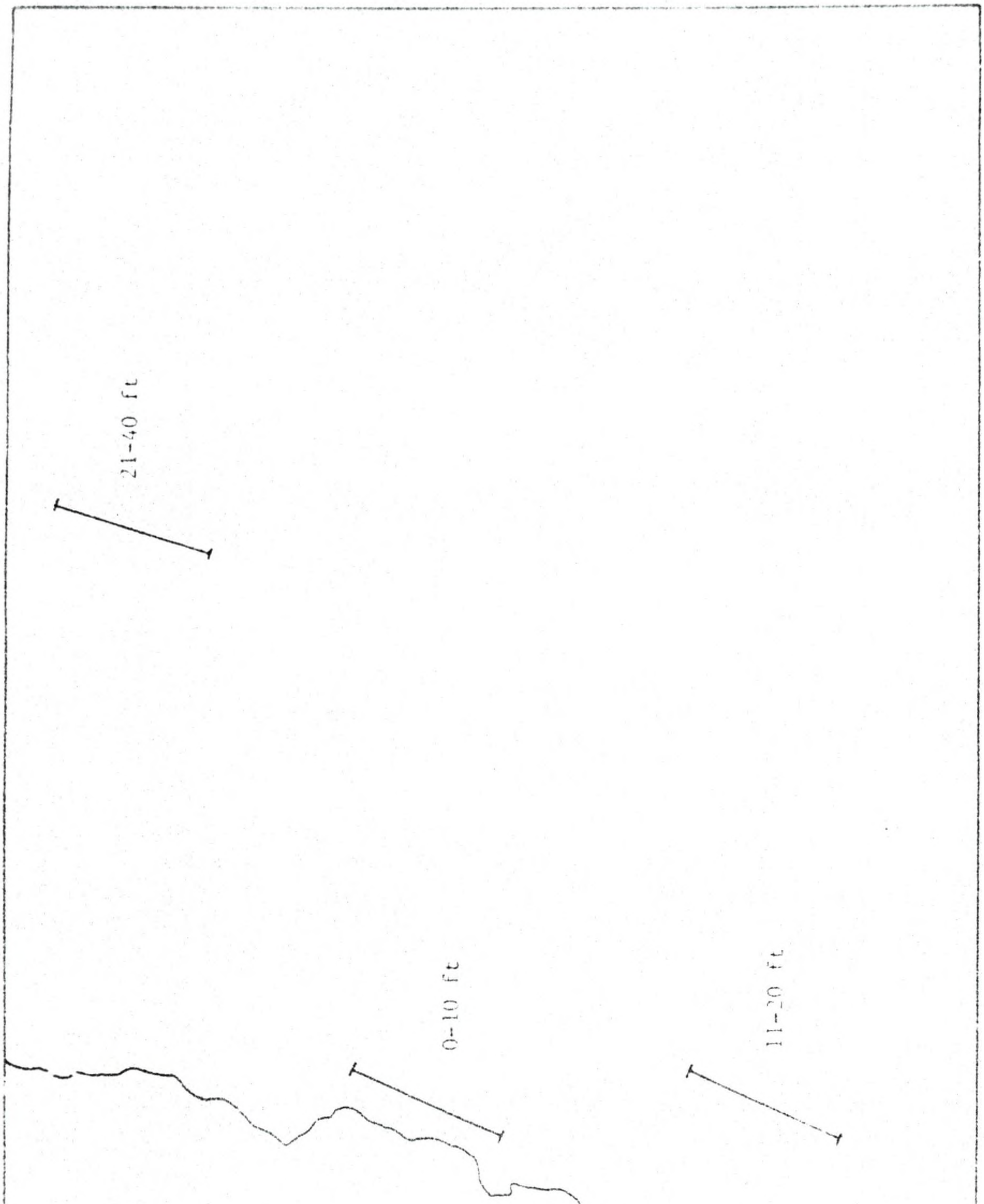
Upon returning to a specific subarea, the nets were set as close to the first set location as possible. Rapidly rising water levels dictated the exact position of the individual sets during different sampling periods.

The entire netting period at each subarea covered approximately 24 hours. This period was divided into four, approximately six-hour sampling periods. The four, six-hour periods were designated as: 1200-1800 h, 1800-2400 h, 2400-0600 h, and 0600-1200 h.

The three nets were always initially set at the beginning of the 1200-1800 h time period and always removed from the water at the end of the 0600-1200 time period (24 h). The deep set was always set first, followed by the medium depth set and the shallow set. At the end of a time period, the deep set was always lifted first, followed by the medium set and the shallow set. Using this methodology, the sampling periods were kept very close to six hours in length.

Because of the time required to remove the fish from the three nets and to reset the nets it was necessary to begin lifting and resetting the nets approximately one-half hour earlier and be completed one-half hour later than the time schedule indicates. For example, during the 1200-1800 time period the deep set was lifted at 1730 h, the fish were removed and the net was reset. The same procedure was used for the medium and then the shallow set, with the shallow set then reset by 1830 h. All of the fish caught were considered under the 1200-1800 time

Figure 2: Typical position of gill net sets at the different depth ranges.


21-40 ft
0-10 ft
11-20 ft
N

eriod. There was approximately a one hour overlap between each of the our netting periods. The exact amount of overlap was a function of the umber of fish caught during any given netting period. With the netting ffort used and composition and density of the fishery in Lake akakawea, approximately one hour was needed to remove the fish from the hree nets with three workers. The overlap was necessary in order to mpty and reset the three nets and still maintain a relatively constant etting effort. The fish captured during any six hour period were rouped into that specific time range.

At the end of each time period the fish were removed from the nets, egregated by depth and type of net (variigated or one-half inch mesh) d placed in tubs. Each of the nets were reset immediately after the sh had been removed. The fish of each species were then counted and ecorded on the sampling forms (Fig. 3).

ATIAL AND TEMPORAL DISTRIBUTION

The data concerning spatial and temporal distribution of walleye, inbow smelt and other fish species were taken from the sampling forms d were statistically analyzed using a multiple regression appoach. key's test was used on an a posteriori basis to examine differences tween group means. All of the statistical analyses used were computed ing the computer system at the University of North Dakota.

Figure 3: Form used for recording the catch in the field.

LAKE SAKAKAWEA NETTING DATA

DATE__________ AREA______ TIME PERIOD FISHING______________

	VARIGATED GILL NETS			½ INCH GILL NETS		
	DEPTH RANGES (ft)					
FISH SPECIES	0-10	10-20	20-40	0-10	10-20	20-40
WALLEYE						
RAINBOW SMELT						
GOLDEYE						
NORTHERN PIKE						
YELLOW PERCH						
SAUGER						
BLACK BULLHEAD						
CARP						
OTHER FISH SPECIES						

COMMENTS ON SET LOCATION ______________

AGE AND GROWTH

The walleyes were measured to the nearest millimeter (total length) and weighed to the nearest gram. Scales for aging were taken from each fish from an area below the lateral line and slightly posterior to the pectoral fin.

In the laboratory, scale samples from 277 walleyes were pressed on cellulose acetate slides with a roller press using the method described by Smith (1954). A microfiche projector was used to magnify the scales, making it easier to distinguish the annuli and subsequently age the fish. Each scale sample was examined twice, three times if a discrepancy occurred. A ruler was placed against the screen of the projector and positioned at the focus extending to the anterior margin of the projected scale image. The distance in mm to each annulus and to the edge of the scale was then measured and recorded for each scale sample. The scale length and body length values were then used as variables in the regression equation: $L = a + bS$, to find the Y-intercept, where a = the Y-intercept, b = the regression coefficient, and S = the scale length (Lagler 1952). The Y-intercept was then used as a correction factor for calculating the total body length at any given annulus. This is accomplished by implementing the correction factor into the formula: $Ln = \frac{Sn\,(Lc - a)}{Sc} + a$, where Ln = the body length at the time of annulus formation, a = the Y-intercept, Sn = the distance from the focus to annulus n, Sc = scale measurement (mm) from focus to scale edge and Lc = the length of the fish at the time of capture (Lagler 1952).

The coefficient of condition (K(TL)) was calculated for each walleye using the formula: $K(TL) = 100\ 000 \times W/L^3$, where W = the weight of the fish in grams, L = the total length of the fish in millimeters, and 100,000 = a factor to bring the value of K near unity.

Body weight-length relationships were determined for all fish by regression analysis. The regression equation: $\log W = \log a + n \log L$ explains the relationship between body weight and length, where W = the predicted weight of a fish, a = the Y-intercept, n = the regression coefficient (slope), and L = the total length of the fish.

STOMACH ANALYSIS

In the field, walleye stomachs were removed and emptied into collection jars containing 10 % formalin. In the laboratory, the contents were removed from the jars and examined under a binocular scope. The contents were separated, counted and identified. Stomach items were identified using general body morphology, teeth structure and peritoneum color pattern (Scott and Crossman 1973). Volumetric values were obtained from the displacement of a known amount of water in a graduated cylinder.

RESULTS

SPATIAL DISTRIBUTION

Areas

A total of 334 walleyes and 1341 rainbow smelt were netted from the three areas in 1982. The total walleye catch averaged 28 fish per 24 h sampling period (PSP) for the three areas. Rainbow smelt catches averaged 112 fish for the three areas. Walleyes had a total mean catch per unit effort (CPE- no. fish/125 ft net/h) of 0.33. Rainbow smelt CPE averaged 1.56 for the three areas.

The majority of walleye and rainbow smelt were netted from the Van Hook Area (Fig. 4). The largest number of walleyes (68 % of the total number) were caught in the Van Hook Area with a mean of 57 fish PSP. The Riverdale Area produced the second highest walleye catch (22 %) with a mean of 19 fish PSP. The Williston Area was the poorest for walleye, producing 10 % of the total and a mean of one fish PSP.

Walleye and rainbow smelt CPE were the greatest in the Van Hook Area (Fig. 5). Walleyes had a mean of 0.68. Catches were lower in the Riverdale Area with the CPE averaging 0.24. Williston catches were the lowest with a mean CPE of only 0.08.

Statistical comparisons of the total walleye catch were made between the areas. There were significant differences found between the number of walleye caught at each area ($p < 0.05$). Significantly more walleyes were netted from the Van Hook Area than from the Riverdale Area

Figure 4: Total catch of walleye and rainbow smelt from each area.

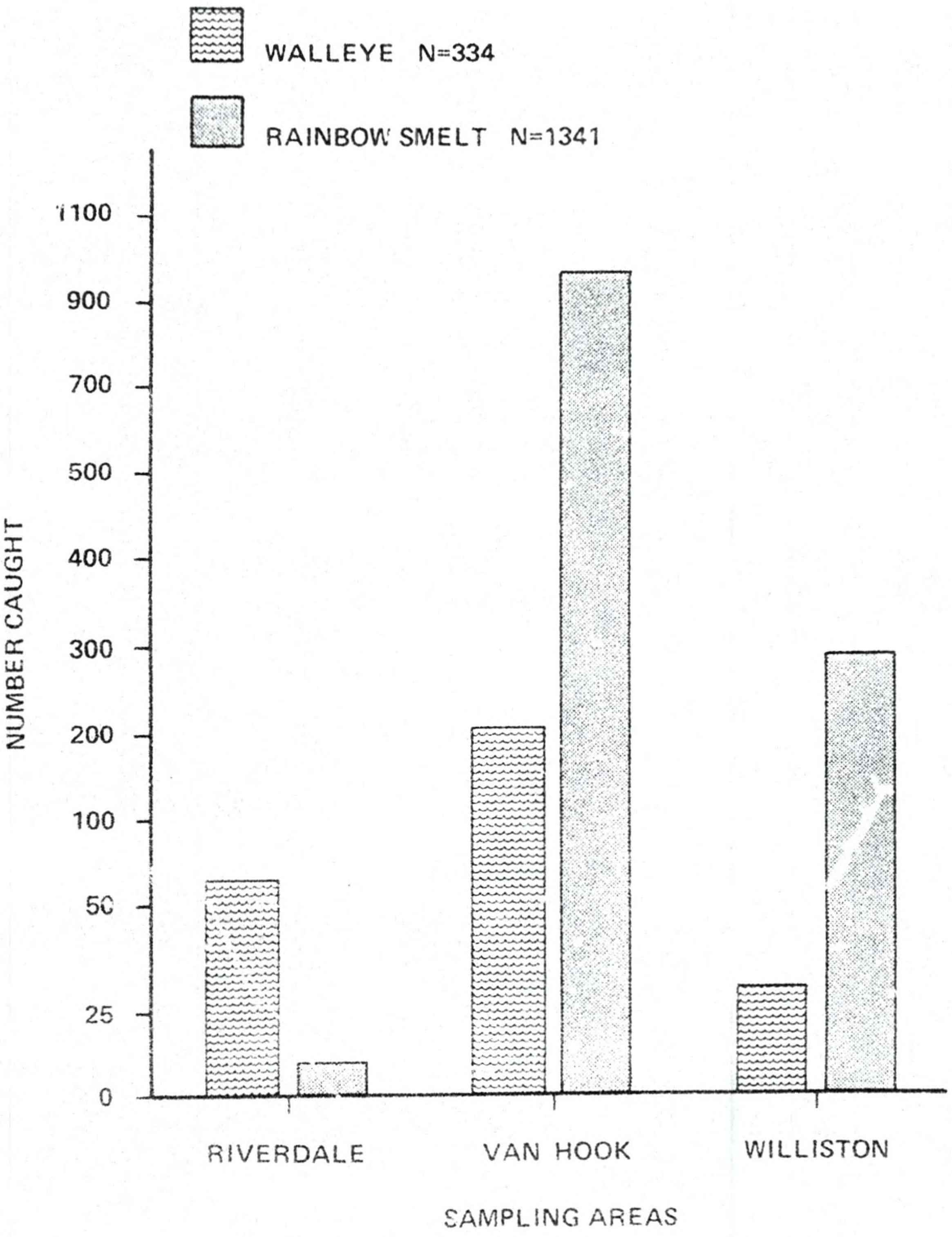
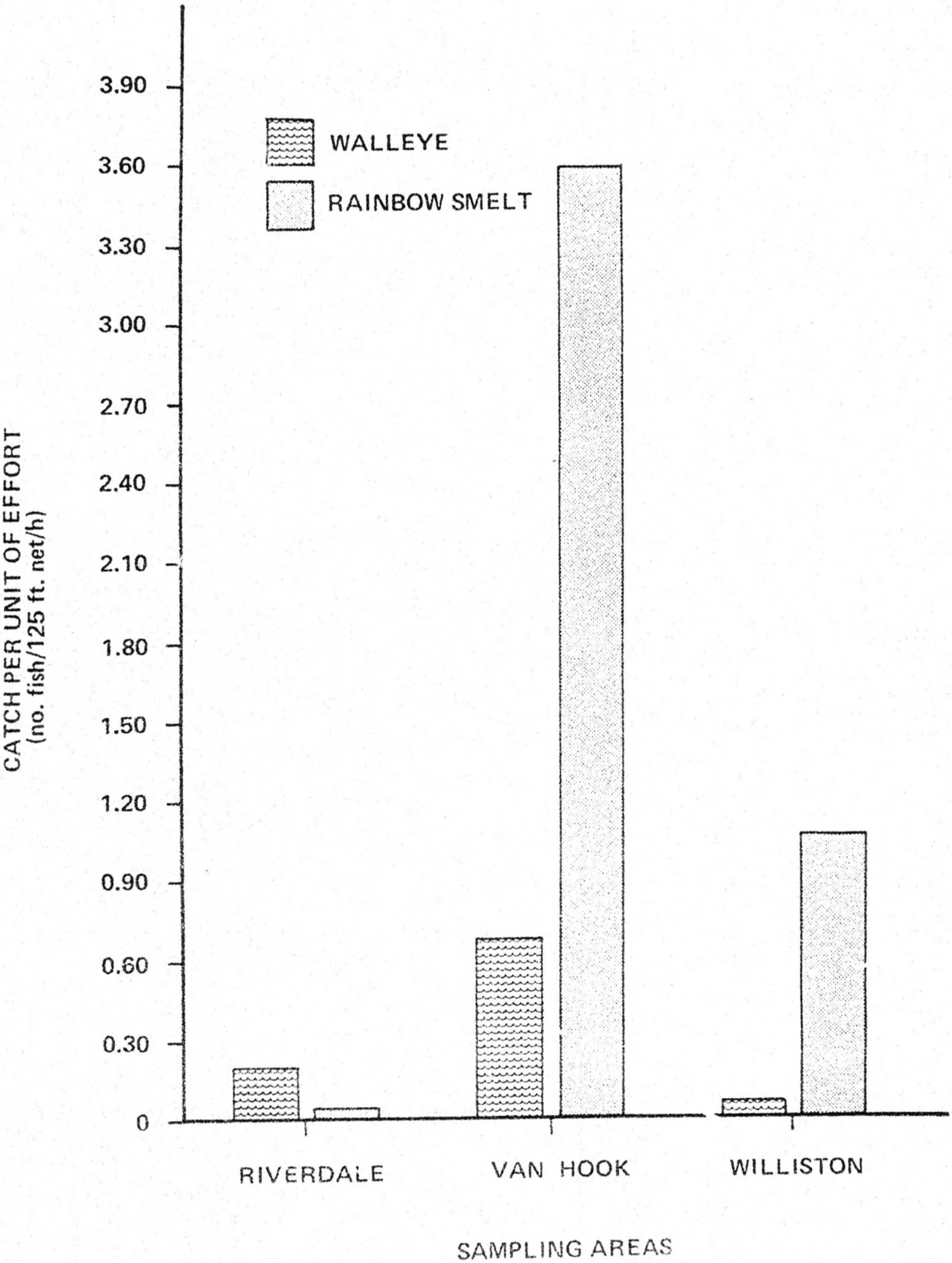

WALLEYE N=334
RAINBOW SMELT N=1341
NUMBER CAUGHT
1100
900
700
500
400
300
200
100
50
25
0
RIVERDALE
VAN HOOK
WILLISTON
SAMPLING AREAS

Figure 5: Walleye and rainbow smelt catch per unit effort for the three areas.



WALLEYE
RAINBOW SMELT
CATCH PER UNIT OF EFFORT
(no. fish/125 ft. net/h)
3.90
3.60
3.30
3.00
2.70
2.40
2.10
1.80
1.50
1.20
0.90
0.60
0.30
0
RIVERDALE
VAN HOOK
WILLISTON
SAMPLING AREAS

($p < 0.05$) and the Williston Area ($p < 0.01$). There were no significant differences found in the number of walleye caught between the Riverdale and Williston areas.

Walleye CPE was significantly greater for the Van Hook Area than for the Riverdale and Williston areas ($p < 0.001$). The CPE was not significantly different between the Riverdale and Williston areas.

Rainbow smelt catches were also the largest in the Van Hook Area, where 76 % of the total number and a mean of 255 fish PSP were netted. The Williston Area produced 23 % of the total with a mean catch of 78 fish PSP. Very few rainbow smelt were caught in the Riverdale Area only 1 % of the total number with a mean of 10 fish PSP.

Rainbow smelt CPE was the greatest in the Van Hook Area with a mean of 3.60. Catch rates declined in the Williston Area to a mean of 1.06. The Riverdale Area had a very low catch rate at 0.03.

There were significantly more rainbow smelt netted from the Van Hook Area than from the Riverdale Area ($p < 0.05$). No other significant differences were found in the number of rainbow smelt between any combination of areas.

Rainbow smelt CPE was significantly greater for the Van Hook Area than for the Riverdale Area ($p < 0.01$) and the Williston Area ($p < 0.05$). There were no significant differences between the Riverdale and Williston areas.

Comparisons among areas at each depth range

Walleye catches at the 0-10 ft range the Van Hook Area catch dominated with 72 % of the total and a mean of 38 fish PSP. The

Riverdale Area followed with 19 % of the total and a mean of 10 fish PSP. The Williston Area had the lowest catch at 0-10 ft (9 %) with a mean of 5 fish PSP.

The differences between areas were significant for the 0-10 ft range ($p < 0.01$). The walleye catch from the Van Hook Area was significantly larger than the Riverdale catch ($p < 0.05$) and the Williston Area ($p < 0.01$). No significant differences were found between the the Riverdale and Williston areas.

The Van Hook Area also dominated the 11-20 ft catch with 66 % of the total and a mean catch of 17 fish PSP. The Riverdale Area contributed 22 % of the total with an average of 6 fish PSP. The Williston Area had the smallest catch at 11-20 ft (12 %) with a mean of 3 fish PSP. No significant differences were found between the three areas at the 11-20 ft depth range.

The Riverdale Area produced the most walleyes from the 21-40 ft range (65 %) with a mean of 3 fish PSP. The Van Hook Area followed 35 % of the catch and a mean of 2 fish PSP. No fish were caught in the 21-40 ft range from the Williston Area. The differences between the areas at 21-40 ft were not significant.

The largest number of rainbow smelt came from the Van Hook Area (97 %) at the 21-40 ft range with a mean of 186 fish PSP. The other areas only contributed 3 % of the total catch at this depth range.

There were significant differences between the areas for rainbow smelt at the 21-40 ft range ($p < 0.05$). The Van Hook catch was significantly larger than the Riverdale or Williston areas ($p < 0.05$).

The Van Hook Area also produced the most rainbow smelt at the 11-20 ft range (74 %) with a mean of 55 fish PSP. The Williston Area followed with a catch of 25 % of the total and a mean of 19 fish PSP. The Riverdale Area only contributed 1 % of the total with a mean of 0.75 fish PSP.

There were significantly more rainbow smelt netted from the Van Hook Area than from the Riverdale Area at the 11-20 ft ($p < 0.05$). No other significant differences were found between areas.

The Williston Area was the most productive for the 0-10 ft range, catching 82 % of the total with a mean of 56 rainbow smelt PSP. The second highest catch (18 %) came from the Van Hook Area with a mean of 13 fish PSP. No rainbow smelt were netted from the 0-10 ft range at the Riverdale Area. The differences between areas at the 0-10 ft range were not significant.

Depth Selection

The total walleye and rainbow smelt catch was inversely related in terms of depth preference (Fig. 6). The largest number of walleyes (63 %) were netted from the 0-10 ft range with a mean of 18 fish PSP. The 11-20 ft range followed with 32 % of the total catch and a mean of nine fish PSP. The deep set (21-40 ft) was the least productive with 5 % of the total catch and a mean of one fish PSP.

Walleye and rainbow smelt CPE were also inversely related in terms of depth preference (Fig. 7). The walleye CPE was the greatest for the 0-10 ft range with a mean catch of 0.60. Mean catch rates declined with increased depth, from 0.36 at 11-20 ft to 0.06 at 21-40 ft.

Figure 6: Total catch of walleye and rainbow smelt for each depth range.

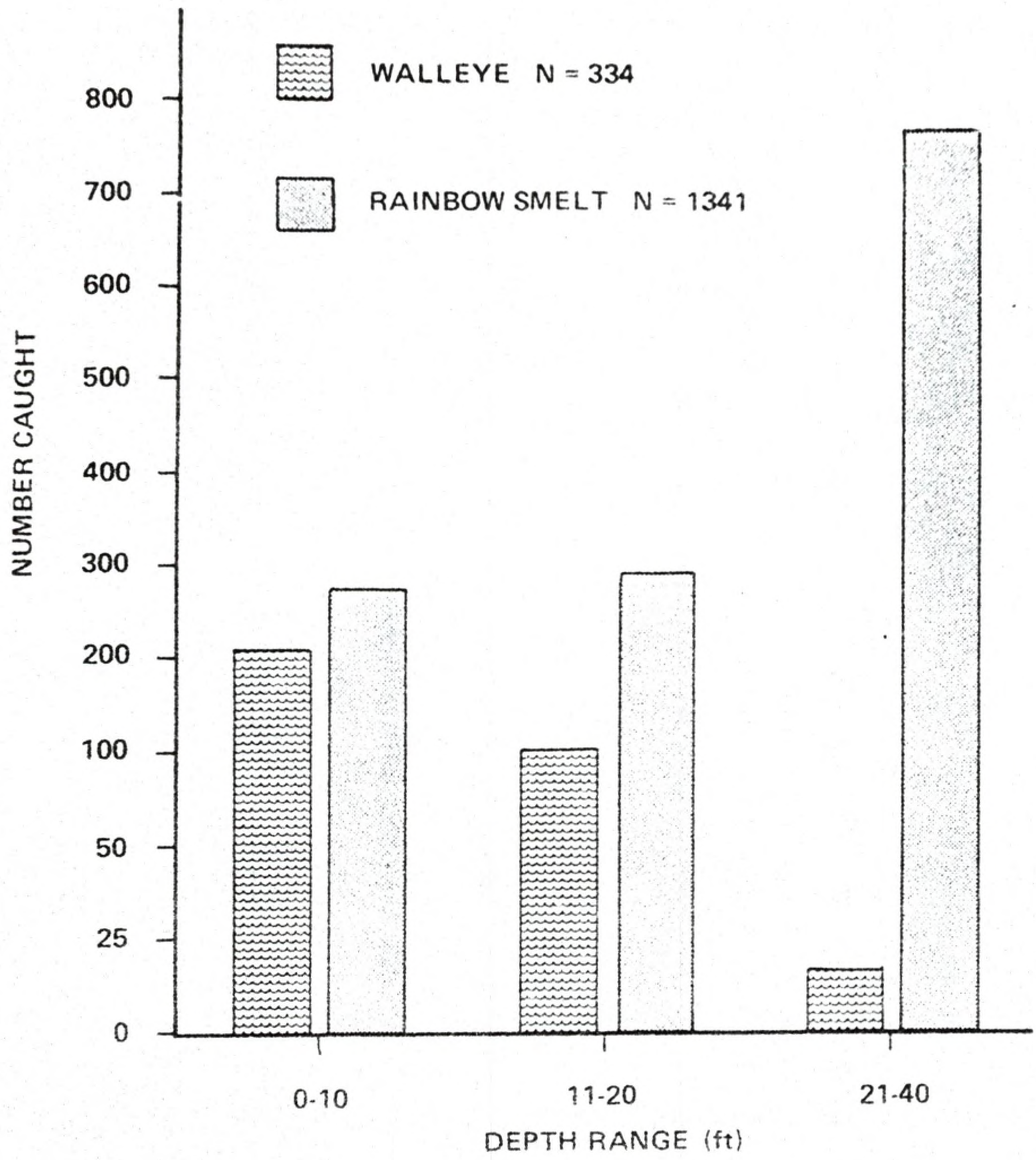
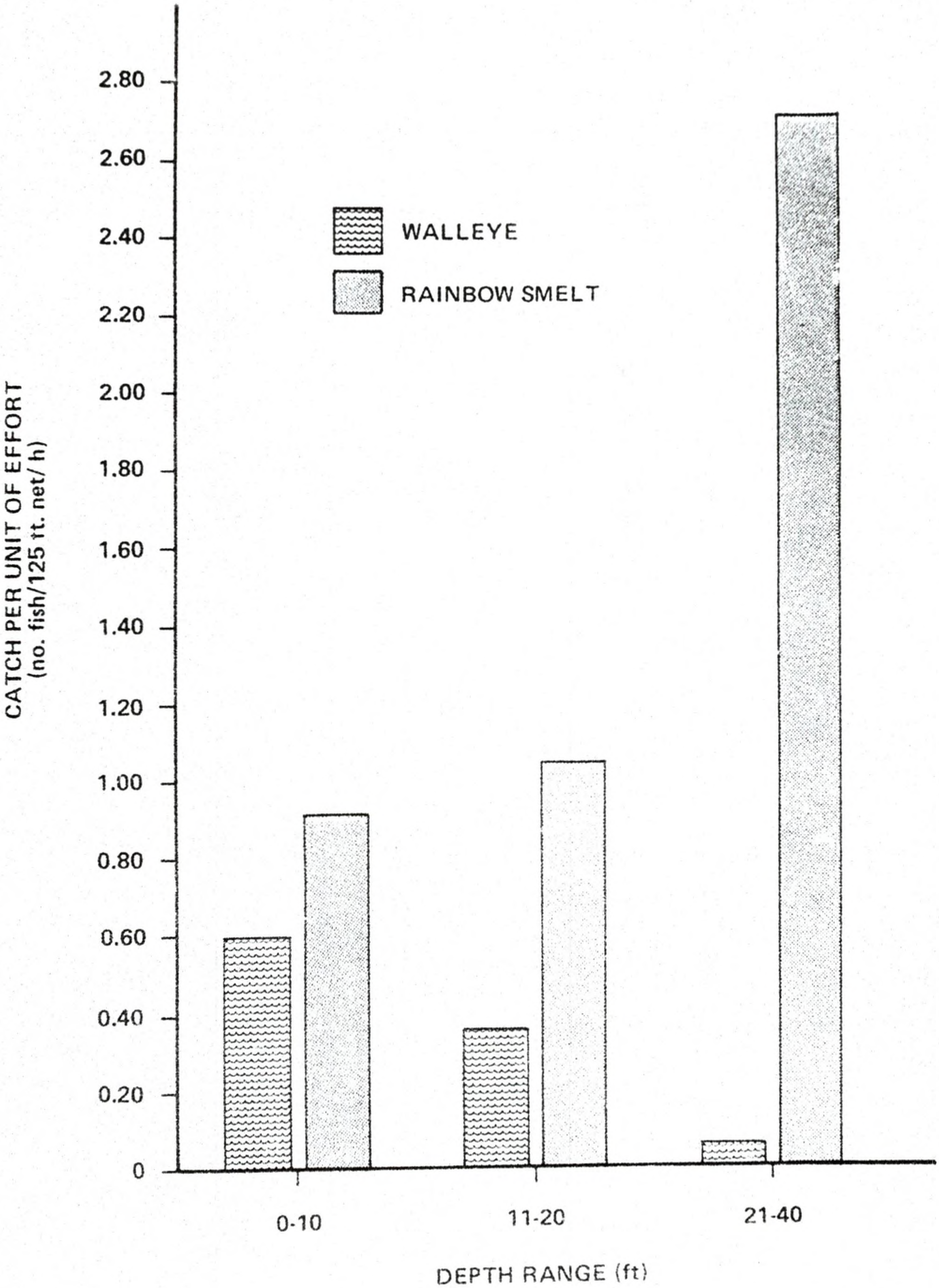

WALLEYE N = 334
RAINBOW SMELT N = 1341
800
700
600
500
400
300
200
100
50
25
0
NUMBER CAUGHT
0-10
11-20
21-40
DEPTH RANGE (ft)

Figure 7: Walleye and rainbow smelt catch per unit effort for the three depth ranges.


2.80
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0
WALLEYE
RAINBOW SMELT
CATCH PER UNIT OF EFFORT
(no. fish/125 ft. net/h)
0-10
11-20
21-40
DEPTH RANGE (ft)

The walleye catch was significantly different for the three depth ranges ($p < 0.01$). The 0-10 ft range had a catch significantly larger than the 21-40 ft range ($p < 0.01$). Even though the means were quite different there were no significant differences between the means of the 0-10 ft and 11-20 ft range or between the 11-20 ft and the 21-40 ft range. Small sample size was partially responsible for the lack of statistical significance.

Walleye CPE in the 0-10 ft range was significantly greater than in the 11-20 ft range ($P < 0.05$) and the 21-40 ft range ($p < 0.001$). The CPE in the 11-20 ft range was also greater than in the 21-40 ft range ($p < 0.05$).

Rainbow smelt were found in deeper water than the walleyes as 57 % of the total number and a mean of 64 fish PSP were netted from the 21-40 ft range. The 11-20 ft range followed with 23 % of the catch and a mean of 24 fish PSP. The shallow set (0-10 ft) caught the fewest rainbow smelt (20 %) with a mean catch PSP of 23 fish.

Rainbow smelt CPE was the greatest in the 21-40 ft depth range with a mean of 2.71. The 11-20 ft range followed with 1.05 and the lowest catch rate came from the 0-10 ft range at an average of 0.92.

There were no significant statistical differences found for the number of rainbow smelt between the three depth ranges. However, the mean number of fish and the CPE were much higher for the 21-40 ft range than for the other depth ranges. Again, small sample size and several non-typically large catches in the shallower ranges affected the differences among group means.

Comparisons among depth ranges at each area

The 0-10 ft depth range was the most productive for walleye at the Riverdale Area, comprising 55 % of the total catch for this area. The 11-20 ft range followed with 31 % and the 21-40 ft range catch was the lowest at 14 %. The differences in numbers of walleyes caught in the Riverdale Area at the different depths were not significant.

The largest number of walleye (67 %) caught in the Van Hook Area also came from the 0-10 ft range. The 11-20 ft range comprised 31 % of the total. Only 2 % of the walleye caught in this area were from the 21-40 ft range.

The differences in catch between the depths were significant for the Van Hook Area ($p < 0.05$). There were significantly more walleyes netted in the 0-10 ft range than the 21-40 ft range ($p < 0.01$). The differences between any other combination of depths were not significant.

The same pattern of decreasing catch was also evident for the Williston Area. The 0-10 ft range produced 58 % of the walleye captured in this area. The 11-20 ft range contributed the remaining 42 %.

The group means were also significantly different for the Williston Area ($p < 0.01$). The differences between 0-10 ft and 21-40 ft were significant ($p < 0.01$). No differences were found between any other combination of depth ranges.

Rainbow smelt catches were the greatest for the 21-40 ft depth range in the Riverdale Area, comprising 70 % of the total with a mean of only two fish PSP. The 11-20 ft range made up the other 30 % of the catch with a mean of one fish PSP. The differences between the depth ranges in the Riverdale Area were not significant.

The majority of rainbow smelt (73 %) caught from the Van Hook Area came from the 21-40 ft range with a mean catch of 186 fish PSP. The 11-20 ft range followed with 22 % of the total and a mean of 56 fish PSP. The shallow set (0-10 ft) produced only 5 % of the total with an average catch of 13 fish PSP. With a sample size of 12, the group means for the depth ranges were not significantly different for the Van Hook Area.

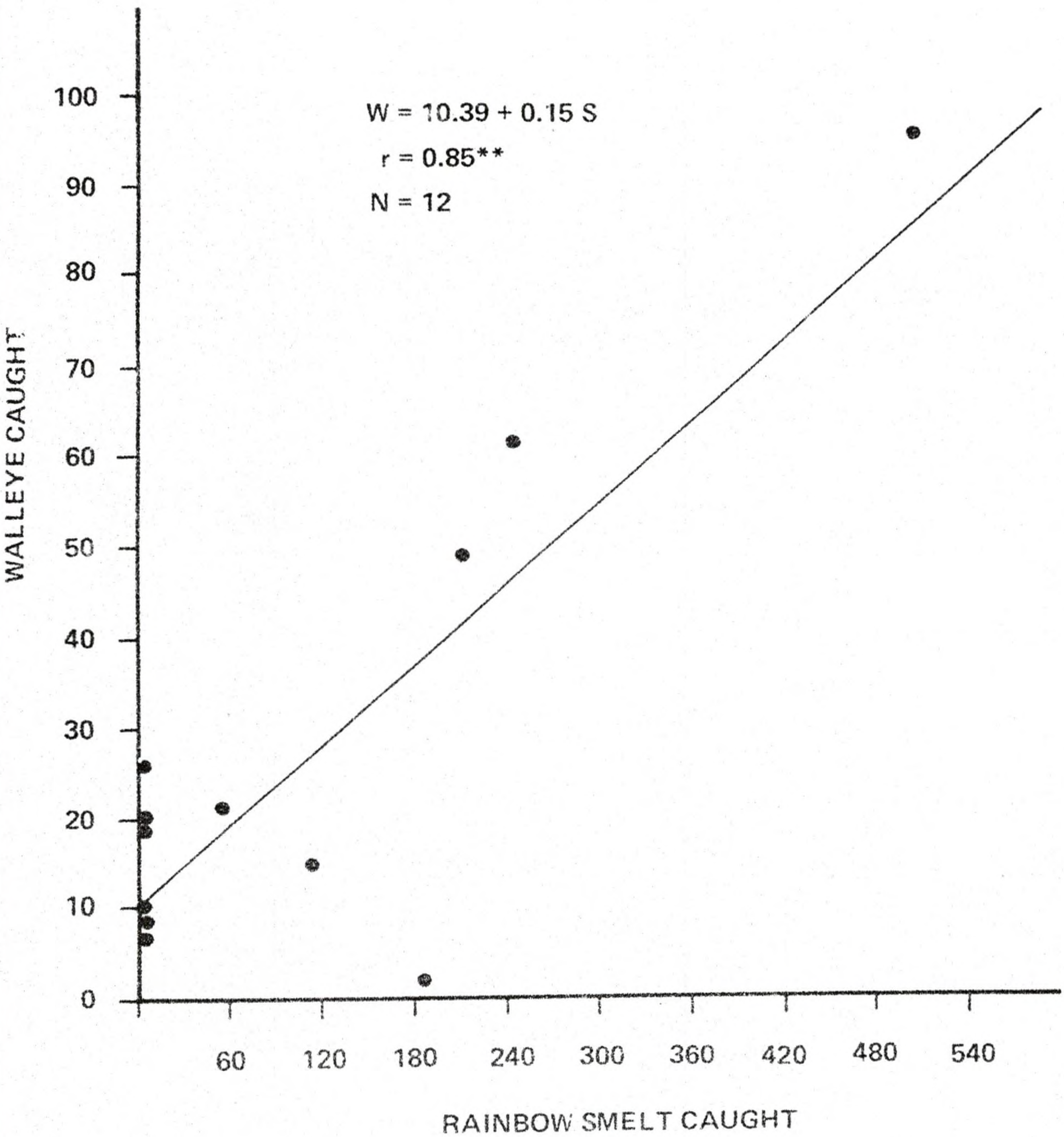
The Williston Area differed from the other two areas in that most of the rainbow smelt (72 %) came from the 0-10 ft set having a mean of 56 fish PSP. The 11-20 ft range followed with 24 % of the total and an average catch of 19 fish PSP. Only 3.5 % of the total number of rainbow smelt caught in the Williston Area came from the 21-40 ft depth range with a mean of four fish PSP. No significant statistical differences in the catch of rainbow smelt at the different depths were found in the Williston Area.

Correlations between Catches of Walleye with Other Fish

There was a significant correlation ($r = 0.85$; $p < 0.01$) between the total number of walleyes and rainbow smelt caught at all depth ranges and time periods during the 12 netting periods (Fig. 8).

There was a slightly negative relationship ($r = -0.20$) between the number of walleyes and rainbow smelt caught at the 0-10 ft range. Walleyes and rainbow smelt were significantly correlated ($r = 0.68$; $p < 0.05$) at the 11-20 ft range. No significant correlation existed between walleye and rainbow smelt numbers at the 21-40 ft range ($r = 0.22$).

Figure 8: Number of walleyes taken during the 12 sampling periods as a function of the number of rainbow smelt.


W = 10.39 + 0.15 S
r = 0.85**
N = 12
WALLEYE CAUGHT
0
10
20
30
40
50
60
70
80
90
100
60
120
180
240
300
360
420
480
540
RAINBOW SMELT CAUGHT

The numbers of walleyes and rainbow smelt caught were also compared for a specific area at all depths. The Van Hook Area had a negative relationship ($r = -0.42$) between walleyes and rainbow smelt. The other areas showed very little correlation between the two species at the three depth ranges ($r = 0.21, -0.09$).

Walleye and sauger total numbers for the 12 netting periods showed little correlation ($r = -0.06$). There were no significant correlations between walleye and saugers at any of the three depth ranges.

Total walleye and sauger numbers were separated for each area, there were no significant correlations between the two species. The Van Hook Area had the only negative correlation ($r = -0.61$) of the three areas.

Relationships between the total number of walleye and northern pike taken during the 12 netting periods were examined. Walleye and northern pike catch numbers were also correlated for each of the depth ranges, no significant relationships were observed. There was no significant correlation between the total numbers of the two species.

Total catches of walleye and yellow perch were also compared. There was a significant correlation between these two species ($r = 0.55$; $p < 0.05$). There was also a significant correlation between the catch of the two species at the 0-10 ft range ($r = 0.58$; $p < 0.05$). A nonsignificant relationship was observed for the other depth ranges ($r = 0.32, 0.33$). Walleye and goldeye numbers were not significantly correlated at any of the depth ranges.

TEMPORAL DISTRIBUTION

Three-Week Intervals

The total number of walleyes and rainbow smelt caught between the four, three-week intervals were compared. The largest number of walleyes were caught during the last three-week period (18 July-7 August) with a mean of 43 fish PSP. The third period produced the fewest fish with a mean of 16 fish PSP for the three areas.

The rainbow smelt catch was also the greatest for the last three-week interval with a mean of 174 fish PSP. The third three-week period also produced the least number of rainbow smelt with an average catch of 20 fish PSP. The differences in the walleye and rainbow smelt catches were not significant between the four, three-week intervals.

Six-Hour Periods

The total walleye and rainbow smelt catch showed some interesting variation among the four time periods (Fig. 9). The nocturnal time periods contributed the most walleyes. The 2400-0600 h period produced 34 % of the total with a mean of nine fish and the 1800-2400 h period added 24 % with a mean of seven fish per six-hour period. The 0600-1200 h and the 1200-1800 h periods followed with 22 % and 20 % of the total, respectively.

The walleye CPE was the greatest during the 2400-0600 h period, while the rainbow smelt CPE was the highest during the 1800-2400 h time period (Fig. 10). Walleyes had an average CPE of 0.44 during the 2400-0600 h period. The 1800-2400 h period followed with a mean of CPE of 0.35. The 0600-1200 h period contributed 0.30 and the lowest CPE was

Figure 9: Total catch of walleye and rainbow smelt for each time period.

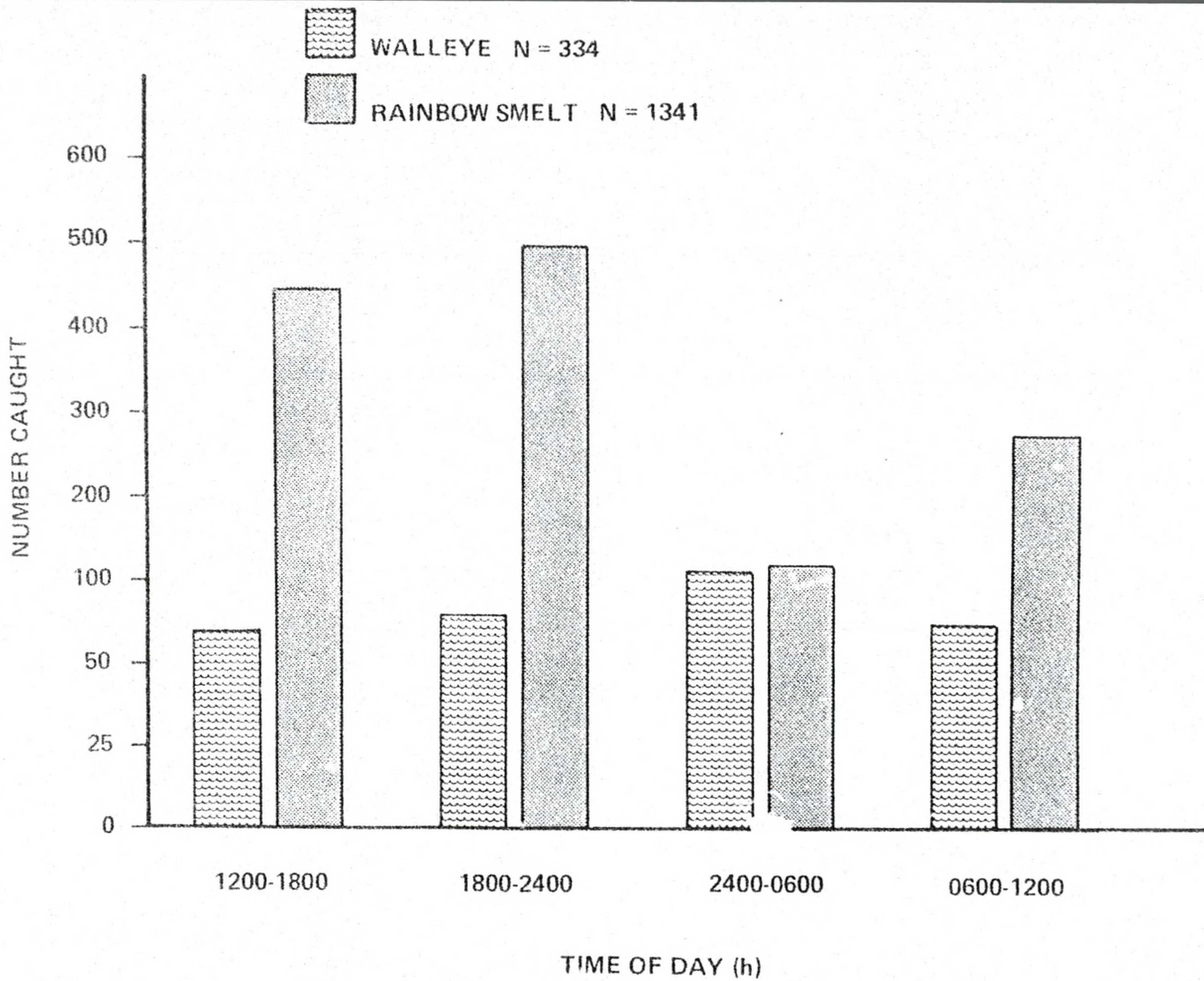
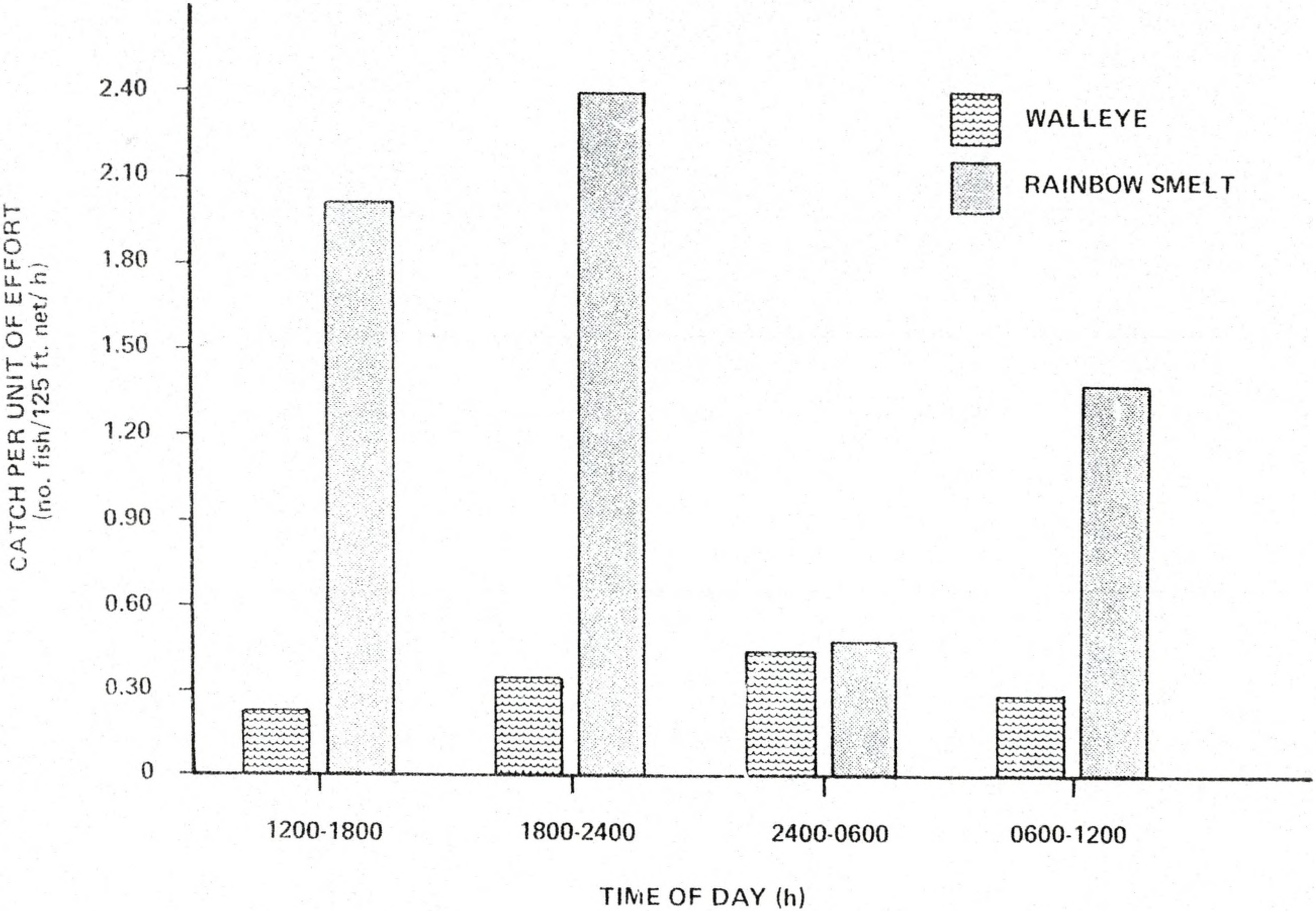

WALLEYE N = 334
RAINBOW SMELT N = 1341
NUMBER CAUGHT
600
500
400
300
200
100
50
25
0
1200-1800
1800-2400
2400-0600
0600-1200
TIME OF DAY (h)

Figure 10: Walleye and rainbow smelt CPE for the four time periods.


WALLEYE
RAINBOW SMELT
CATCH PER UNIT OF EFFORT
(no. fish/125 ft. net/ h)
2.40
2.10
1.80
1.50
1.20
0.90
0.60
0.30
0
1200-1800
1800-2400
2400-0600
0600-1200
TIME OF DAY (h)

recorded for the 1200-1800 h period. The differences in walleye numbers and CPE between the time periods were not significant.

Rainbow smelt catches were the greatest during the 1800-2400 h time period, when 37 % of the total were netted with a mean of catch of 41 fish. The 1200-1800 h period followed with 33 % and a mean catch of 37 fish. The 2400-0600 h period was least productive for rainbow smelt, where only nine percent of the total and a mean of 10 fish were netted.

The rainbow smelt CPE was the greatest in the 1800-2400 h period at 2.39. The 1200-1800 h period had the second highest CPE at 2.00. The 0600-1200 h period had a CPE of 1.36. The lowest CPE was recorded for the 2400-0600 h period at only 0.50. Again, there were no significant differences between rainbow smelt numbers or CPE for the four time periods.

Comparisons among areas during each time period

The Van Hook Area produced the most walleyes for any specific time period with [illegible] % of all fish caught at 1200-1800, 76 % at 1800-2400, 68 % at 2400-0600 and 62 % of the total at 0600-1200 h. The Riverdale Area followed with 18 %, 22 %, 27 % and 20 % respectively. The Williston Area contributed the fewest walleyes during [illegible] of the time periods.

The differences among areas were significant for the 1200-1800, 1800-2400 and the 2400-0600 h time periods ($p < 0.05$). No significant differences were found between areas during the 0600-1200 h period.

Rainbow smelt catches were also the largest during all time periods at the Van Hook Area with 58 % of the total catch during the 1200-1800 h, 93 % during 1800-2400 h, 70 % during the 2400-0600 h and 75 % during the 0600-1200 h time period. The Williston Area comprised the second largest catches of rainbow smelt for each time period with 41 %, 6 %, 30 % and 23 % of the total catch from the time periods above. There were no significant differences in the number of rainbow smelt between areas for any of the time periods.

Comparisons among time periods at each area

The largest numbers of walleyes (41 % and 34 %) at the Riverdale and Van Hook Areas were caught during the nocturnal period from 2400-0600 h. The Williston Area produced the largest number of walleyes (33 %) from the 1200-1800 h period.

The Riverdale and Van Hook Areas produced the largest catches of rainbow smelt (40 % and 45 %) during the 1800-2400 h period. Very few rainbow smelt (0 % and 8 %) were caught at these areas during the 2400-0600 h period. The Williston Area differed again from the other two areas with the largest catches (58 %) coming during the 1200-1800 h period. The differences for walleye and rainbow smelt caught among time periods were not significant for any of the areas.

Comparisons among depths during each time period

The 0-10 ft range produced the most walleye (78 %) during the 1200-1800 h period. The 11-20 ft range followed with 19 % of the catch.

The differences of catch among depth ranges during the 1200-1800 h period were significant ($p < 0.01$). There were significantly more walleyes netted from the 0-10 ft range than the 11-20 ($p < 0.05$) and the 21-40 ft range ($p < 0.01$).

A similiar pattern of decreasing catch with an increase in depth existed for the 1800-2400 h period, 51 % of the catch came from 0-10 ft. The 11-20 ft range contributed 38 % of the total. There were no significant differences among depth ranges during the 1800-2400 h period.

The 0-10 ft range also had the largest catch during the 2400-0600 h period with 63 % of the total. The 11-20 ft range produced 34 %.

The differences were significant between depth ranges during the 2400-0600 h period ($p < 0.05$). The 0-10 ft range catch was significantly larger than the 21-40 ft range ($p < 0.05$). No differences were found between any other combination of depth ranges.

The shallow set also produced the most walleyes (64 %) during the 0600-1200 h period. The 11-20 ft range produced 34 % of the total. The differences among depth ranges were also significant for the 0600-1200 h period ($p < 0.05$).

Comparisons among time periods at each depth

The 2400-0600 h period had the largest mean of five walleye per six hour period at the 0-10 ft range. The 1200-1800 h period followed with a mean of four fish. The 0600-1200 h period produced the fewest walleyes with a mean of three. The largest catches came during the nocturnal periods with means of three fish for the 11-20 ft range. Of the few walleyes caught in the 21-40 ft range, the most were taken during the 1800-2400 h period.

The largest mean catch (13) of rainbow smelt came during the 1200-1800 h period for the 0-10 ft range. The 1200-1800 h period was also the most productive for the 11-20 ft range with an average of 12 fish. The 21-40 ft range had the largest catch during the 1800-2400 h period with a mean of 27. Very few rainbow smelt (16 %) were taken during the 2400-0600 h period at this range. There were no significant differences between time periods at any of the depths for walleye or rainbow smelt.

Correlations between Catches of Walleye with Other Fish

Total walleye and rainbow smelt numbers from the 12 netting periods were correlated for each time period. The 1200-1800 h and the 2400-0600 h period showed very little correlation ($r = 0.23, 0.44$). However, there were significant correlations found during the 1800-2400 h period ($r = 0.88$; $p < 0.01$) and the 0600-1200 h period ($r = 0.70$; $p < 0.01$) between the two species.

Walleye catches were also correlated with numbers of sauger, northern pike, yellow perch and goldeye taken in each time period. The only significant correlation found was between walleyes and goldeyes during the 1800-2400 h period ($r = 0.62$; $p < 0.05$).

AGE AND GROWTH

Population Structure

A total of 277 walleyes were aged from all three areas. A total of 10 age classes were found. There appears to be a bimodal distribution of age class strength (Fig. 11). Age class VII constituted the largest total number of walleye ([illegible] %) caught from all areas. Age class III represented 25 % of the total. The third largest age class was VI, comprising 19 % of the total. There were no one and two year old fish found except in the Williston Area.

Figure 12 shows a breakdown of the age class strength for each area. The Riverdale Area was represented by 77 fish in seven age classes. Age classes III and VII were dominant for this area, making up 73 % of the total. No age I or II fish were netted from this area. The Van Hook Area was represented by 176 walleyes in eight age classes. This area produced the most fish for each age class except for I and II. The III, VI and VII age classes made up 75 % of the total catch in this area. No age I or II fish were found in this area. Ten age classes were found for the 30 walleyes aged from the Williston Area. There were no large differences in age class strength for this area. The only age I and II fish came from this area.

Figure 11: Distribution of age class strength for the 277 walleyes aged from all of the sampling areas.

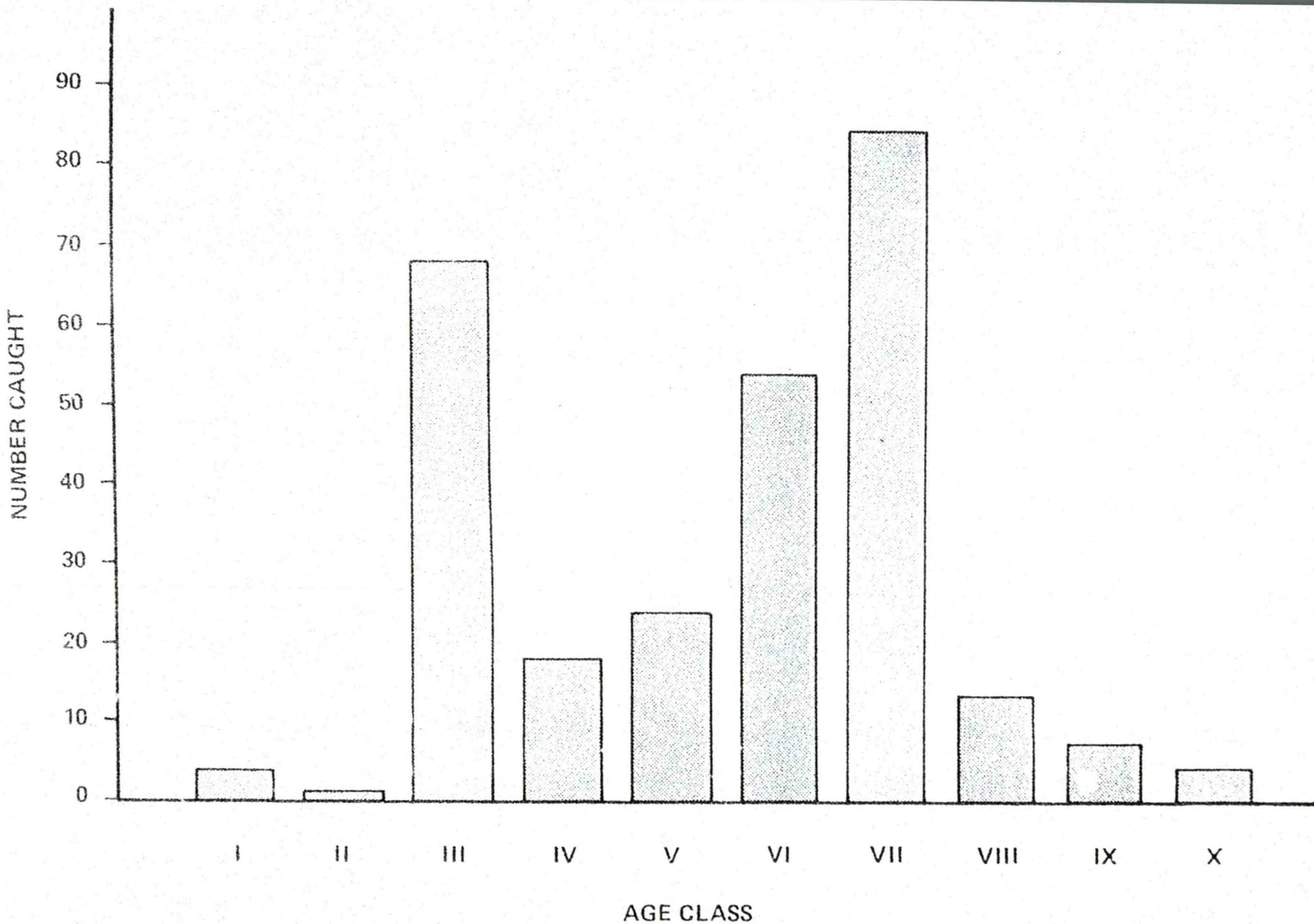
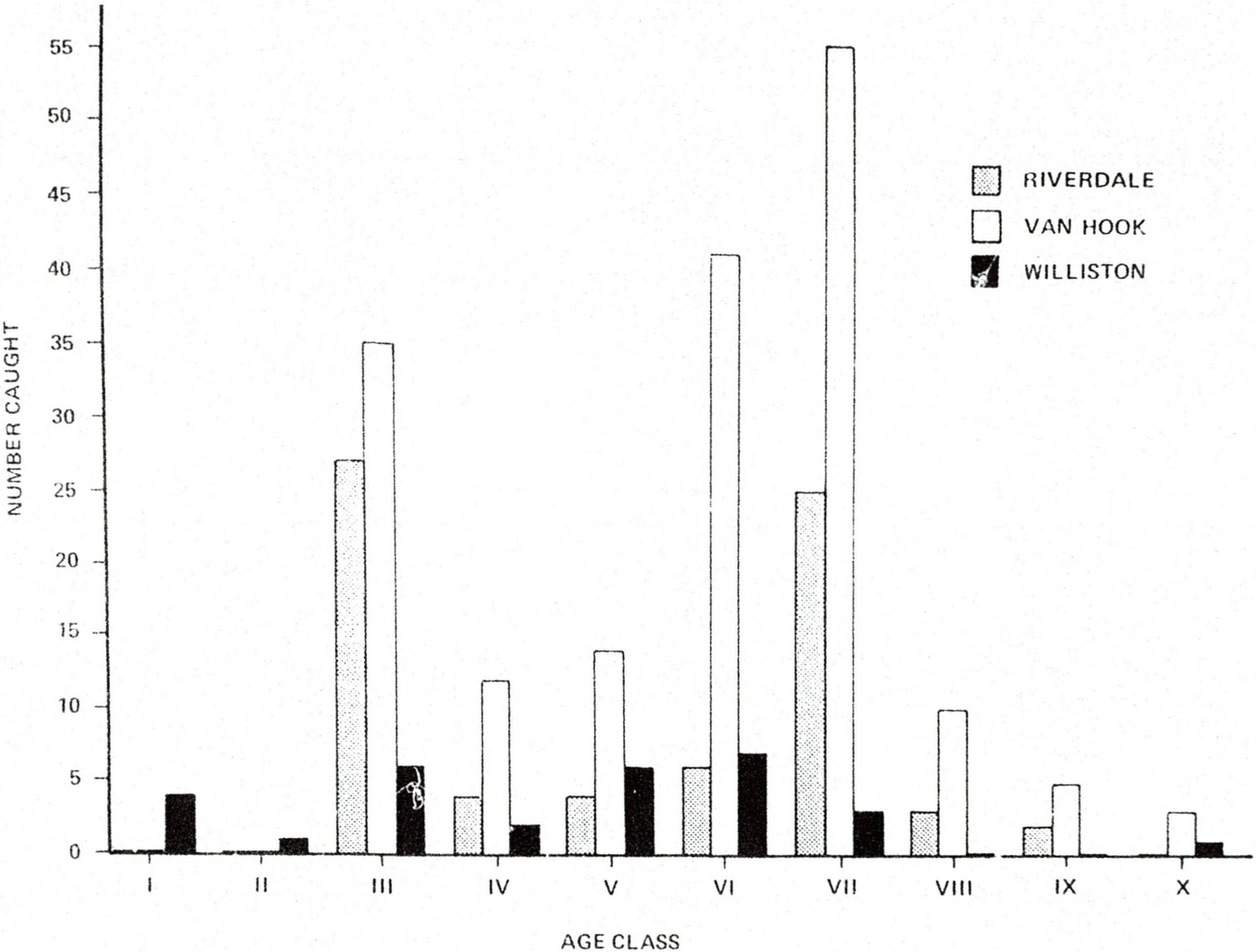

NUMBER CAUGHT
0
10
20
30
40
50
60
70
80
90
I
II
III
IV
V
VI
VII
VIII
IX
X
AGE CLASS

Figure 12: Distribution showing the relative strength of age classes for each sampling area.



NUMBER CAUGHT
55
50
45
40
35
30
25
20
15
10
5
0
RIVERDALE
VAN HOOK
WILLISTON
I
II
III
IV
V
VI
VII
VIII
IX
X
AGE CLASS

Growth

The average total length at each annulus was back-calculated for each age class for the 277 fish (Table 2). The greatest mean growth increment was between age classes I and II. Except for age class growth rates declined steadily in subsequent years.

The weight-length relationship for the total number of walleye was expressed by the regression equation: $\log W = -5.793 + 3.299 \log L$, with $r = 0.99$. There is close association between the predicted weights and the mean empirical weights for each age class (Fig. 13).

The mean condition factor for all of the walleye captured in this study was 1.04. The coefficients generally increased with age. Age class VI and VIII were exceptions to the trend.

The mean weight of all walleyes caught was 1533 g. The minimum weight recorded was 25 g and the maximum 4360 g. The median weight for all of the walleye was 1567 g.

The mean total length was 507 mm for all walleyes. The minimum total length was 155 mm and the maximum was 715 mm. The median total length for all fish was 530 mm.

Growth data were compared among the three areas (Tables 3, 4 and 5). The mean growth increment for all year classes was the largest between age classes I and II for the Riverdale and Van Hook Areas. The walleyes from the Williston Area showed the greatest growth between age III and IV. The mean calculated lengths for all year classes were approximately equal for age classes I-III for the Riverdale Area and Van Hook Area. The Williston Area walleyes were not as large during the first three years of life as were the fish from the other areas. Age

TABLE 2

Mean body lengths calculated for 277 walleyes taken from Lake Sakakawea during the summer of 1982.

Year Class	Mean Length (mm)	Mean Weight (g)	Number of Fish	Annulus I	II	III	IV	V	VI	VII	VIII	IX	X
1981	159	25	4	156									
1980	255	160	1	190	249								
1979	395	628	68	192	270	375							
1978	462	1080	18	214	297	385	448						
1977	502	1380	24	198	279	368	444	491					
1976	542	1728	54	194	270	342	423	489	532				
1975	573	2061	84	193	262	321	405	482	533	564			
1974	614	2464	13	193	277	334	397	458	514	568	604		
1973	622	2706	7	195	272	332	383	439	492	554	594	614	
1972	666	3244	4	1[illegible]9	265	327	382	450	497	539	583	620	642
Mean calculated length				192	271	348	412	468	514	556	594	617	642
Mean annual increment				192	79	77	64	56	46	42	38	23	25

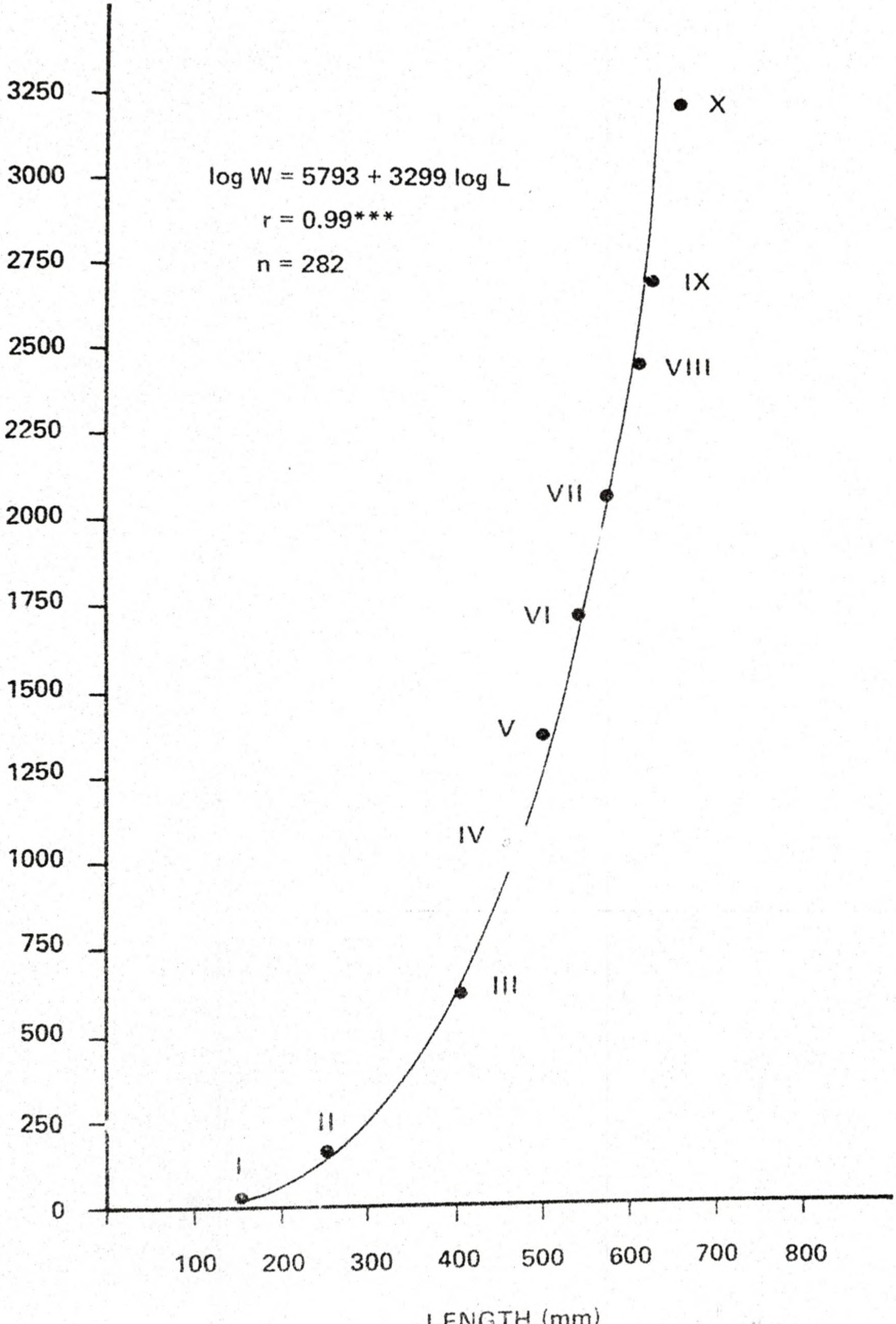
classes IV-VI had the largest mean calculated length in the Riverdale Area, followed by the Van Hook and Williston Areas. The Van Hook walleyes had the largest mean calculated length for age classes VII-X.

The mean empirical lengths for each age class for the three areas is shown in figure 14. The Van Hook Area walleyes had the largest mean total length for all age classes except VII and IX.

Condition factors were compared among areas for each age class (Table 6). The Van Hook Area walleyes had significantly higher condition factors than did the Riverdale and Williston Area walleyes ($p < 0.001$). There were no significant differences found between the Riverdale and Williston Areas. Condition factors were compared between male and female walleyes. A total of 46 fish could be sexed confidently. The females showed a slightly higher condition (1.08) than did the males (1.04). The difference was not significant.

Walleye weight and length data were examined for the three areas (Table 7). The Van Hook Area had the largest mean and median weight and length of the three areas. The Williston Area produced the smallest walleyes and the Van Hook Area produced the largest walleye.

Figure 13: Weight-length regression for the total number of walleye measured. The points indicate mean empirical weights for each age class.



3250
3000
2750
2500
2250
2000
1750
1500
1250
1000
750
500
250
0
log W = 5793 + 3299 log L
r = 0.99***
n = 282
I
II
III
IV
V
VI
VII
VIII
IX
X
100
200
300
400
500
600
700
800
LENGTH (mm)

Figure 14: Mean total body lengths of each age class for the three sample areas.

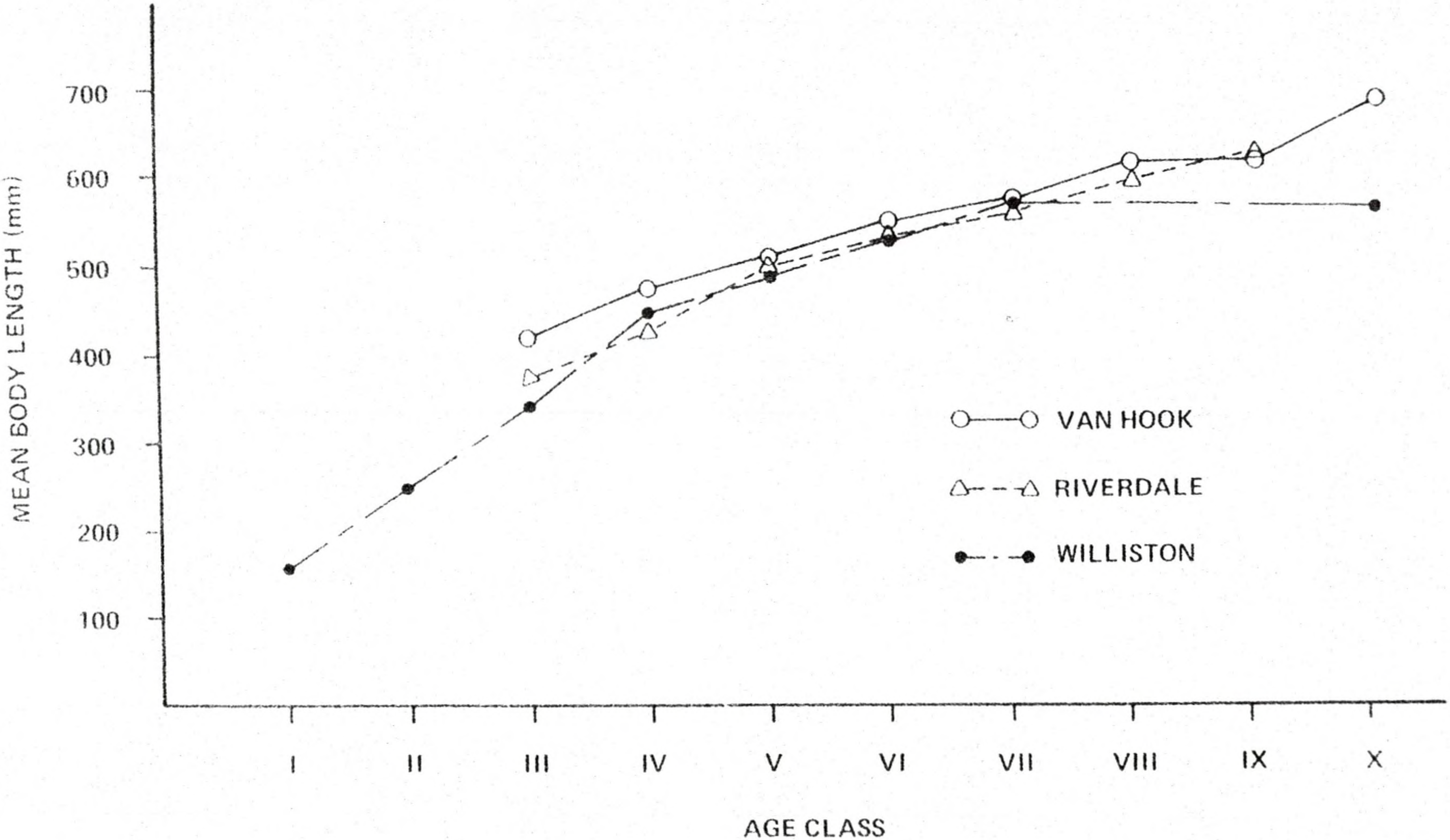

MEAN BODY LENGTH (mm)
700
600
500
400
300
200
100
I
II
III
IV
V
VI
VII
VIII
IX
X
AGE CLASS
VAN HOOK
RIVERDALE
WILLISTON

TABLE 3

Mean body lengths calculated for 71 walleyes taken from the Riverdale Area of Lake Sakakawea.

Year Class	Mean Length (mm)	Mean Weight (g)	Number of Fish	I	II	III	IV	V	VI	VII	VIII	IX	X
1981	ND	ND	0	ND									
1980	ND	ND	0	ND	ND								
1979	373	487	27	188	263	362							
1978	428	764	4	208	271	349	419						
1977	498	1258	4	196	290	379	447	488					
1976	537	1544	6	190	272	338	423	492	530				
1975	566	1908	25	195	265	328	416	489	534	561			
1974	599	2128	3	193	287	361	439	490	520	552	593		
1973	629	2655	2	219	293	355	404	470	518	571	598	619	
1972	ND	ND	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Mean calculated length				198	277	353	425	486	526	561	596	619	
Mean annual increment				198	79	76	72	61	40	35	35	23	

ND = no data

Mean body lengths calculated for 176 walleyes taken from the Van Hook Area of Lake Sakakawea.

Year Class	Mean Length (mm)	Mean Weight (g)	Number of Fish	I	II	III	IV	V	VI	VII	VIII	IX	X
1981	ND	ND	0	ND									
1980	ND	ND	0	ND	ND								
1979	421	769	35	195	279	393							
1978	476	1196	12	215	307	398	458						
1977	509	1464	14	198	278	369	448	498					
1976	545	1800	41	195	270	344	424	492	536				
1975	576	2126	56	192	261	318	401	479	533	565			
1974	618	2564	10	193	274	326	385	443	512	573	608		
1973	619	2726	5	185	263	324	376	426	481	547	580	612	
1972	698	3820	3	208	284	350	395	473	529	574	623	664	687
Mean calculated length				198	277	353	412	469	518	565	604	638	687
Mean annual increment				198	79	76	59	57	49	47	39	34	49

ND = no data

TABLE 5

Mean body lengths calculated for 30 walleyes taken from the Williston Area of Lake Sakakawea.

Year Class	Mean Length (mm)	Mean Weight (g)	Number of Fish	I	II	III	IV	V	VI	VII	VIII	IX	X
1981	159	25	4	156									
1980	255	160	1	190	249								
1979	344	439	6	189	254	339							
1978	449	1020	2	211	280	371	430						
1977	487	1266	6	199	275	358	435	477					
1976	529	1467	7	191	268	337	421	469	515				
1975	578	2142	3	182	258	308	396	473	521	568			
1974	ND	ND	0	ND	ND	ND	ND	ND	ND	ND	ND		
1973	ND	ND	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	
1972	570	1575	1	173	210	260	345	380	399	436	460	486	507
Mean calculated length				186	256	329	405	450	478	502	*	*	*
Mean annual increment				186	70	73	76	45	28	24	*	*	*

* Calculated values were omitted because of the small sample size.

ND = no data

TABLE 6

Coefficient of condition (K(TL)), for each age class in the three areas, the numbers in parentheses are the number of walleye in each age class.

Age Class	Area: Riverdale	Van Hook	Williston	Total
I	ND	ND	0.63(4)	0.63(4)
II	ND	ND	0.96(1)	0.96(1)
III	0.93(27)	0.99(35)	1.05(6)	0.97(68)
IV	1.02(4)	1.08(12)	1.13(2)	1.08(18)
V	1.02(4)	1.09(14)	1.08(6)	1.08(24)
VI	0.99(6)	1.07(41)	0.98(7)	1.05(54)
VII	1.04(25)	1.10(56)	1.09(3)	1.08(84)
VIII	0.99(3)	1.09(10)	ND	1.06(13)
IX	1.06(2)	1.14(5)	ND	1.12(7)
X	ND	1.12(3)	1.14(1)	1.12(4)
Mean K(TL) =	0.99	1.08	1.01	1.04

TABLE 7

Walleye weight and length data from the three areas of Lake Sakakawea.

Area	Mean		Minimum		Maximum		Median	
	Weight (g)	Length (mm)	Weight	Length	Weight	Length	Weight	Length
Riverdale N=73	1250	482	315	320	3030	665	1205	510
Van Hook N=179	1724	531	310	320	4360	715	1709	540
Williston N=30	1024	424	25	155	2600	612	1033	464
Total N=282	1533	507	25	155	4360	715	1567	530

STOMACH ANALYSIS

Stomach contents of 119 walleyes containing food were analyzed. Only one species of fish was recognized as a walleye food item during this study. The walleyes showed an obvious predilection for rainbow smelt (Table 8).

Differences in food selection were examined between the three areas (Table 9). Most of the walleye stomachs with food (64 %) came from the Van Hook Area. The Riverdale Area contributed 26 % and the remaining stomachs (10 %) came from the Williston Area. The Riverdale Area had the largest mean number of rainbow smelt per stomach but the lowest mean volume per stomach of the three areas. The Van Hook Area

TABLE 8

Stomach contents of 119 walleye containing food from Lake Sakakawea. Numerals in parentheses indicate percentage of the total.

Item	Stomach Contents		
	Rainbow Smelt	Unidentifiable Fish	Total Fish
Total number	267(84)	50(16)	317(100)
Total Volume (ml)	1865(93)	132(7)	1997(100)
Average Number/Stomach	2.24	0.42	2.66
Average Volume/Stomach (ml)	15.67	1.11	16.78
% Frequency of Occurrence	87	13	100

had the lowest mean number of rainbow smelt per stomach and the second highest mean volume per stomach. The Williston Area was ranked second in the mean number of rainbow smelt per stomach and first in mean volume per stomach. There were no significant differences found in the number and volume of contents per stomach from the three areas.

The highest percent frequency of occurrence for rainbow smelt was in the Williston Area, followed by the Riverdale and Van Hook Areas.

Walleye stomach contents from the three depth ranges were compared (Table 10). Most of the stomachs containing food (56 %) came from the 0-10 ft range. The 11-20 ft range contributed 37% of the samples and

TABLE 9

Walleye stomach contents from the three areas of Lake Sakakawea. Numerals in parentheses indicate percentage of total.

	Area								
	Riverdale			Van Hook			Williston		
Item	Rainbow Smelt	Unident. Fish	Total Fish	Rainbow Smelt	Unident. Fish	Total Fish	Rainbow Smelt	Unident. Fish	Total Fish
Total Number	88(28)	11(3)	99(31)	149(47)	37(12)	186(59)	30(9)	2(1)	32(10)
Total Volume (ml)	419(21)	30(1)	449(22)	1126(56)	96(5)	1222(61)	320(16)	6(1)	326(17)
Average Number/Stomach	2.84	0.34	3.18	1.96	0.49	2.45	2.50	0.16	2.66
Average Volume/Stomach (ml)	13.53	0.97	14.55	14.82	1.26	16.08	26.66	0.51	27.17
% Frequency of Occurrence	87	26	100	82	34	100	100	8	100

TABLE 10

Walleye stomach contents from the three depth ranges. Numerals in parentheses indicate percentage of total.

	Depth(ft)								
	0-10			11-20			21-40		
Item	Rainbow Smelt	Unident. Fish	Total Fish	Rainbow Smelt	Unident. Fish	Total Fish	Rainbow Smelt	Unident. Fish	Total Fish
Total Number	153(48)	29(9)	182(58)	108(34)	14(4)	122(38)	6(2)	7(3)	13(4)
Total Volume (ml)	1062(53)	76(4)	1138(57)	766(38)	35(2)	809(41)	29(2)	21(1)	50(2)
Average Number/Stomach	2.28	0.44	2.72	2.45	0.32	2.77	0.75	0.88	1.63
Average Volume/Stomach (ml)	15.86	1.13	16.99	17.41	0.80	18.39	3.63	2.62	6.25
% Frewuency of Occurrence	87	30	100	86	20	100	63	75	100

only seven % came from the 21-40 ft range. The stomachs of walleyes caught in the 11-20 ft range contained the largest mean number and volume of rainbow smelt per stomach. The 0-10 ft range had the second largest mean number and volume per stomach. The walleye captured in the 21-40 ft range had very small means for these two criteria. The differences in the number and volume of fish per stomach among the three depth ranges were not significant.

Percent frequency of occurrence for rainbow smelt was the highest for the Riverdale and Van Hook Areas. The small sample size from the 21-40 ft range showed the lowest percentage of occurrence.

The walleye stomach contents were also examined for differences among the four time periods (Table 11). The largest number of stomachs containing food (34 %) came during the 2400-0600 h time period and the 0600-1200 h period (26 %). The mean number of rainbow smelt per stomach was the largest for the 0600-1200 h period, but the the 2400-0600 h period had the largest mean volume per stomach. The differences in the number and volume of fish per stomach among the four time periods was not significant.

Rainbow smelt occurred in the highest percentage of walleye stomachs during the 2400-0600 h and the 0600-1200 h period. The 1200-1800 h period had the lowest percent frequency of occurrence.

TABLE 11

Walleye stomach contents from the four time periods. Numerals in parentheses indicate percentage of total.

Item	Time (h): 1200-1800 Rainbow Smelt	1200-1800 Unident. Fish	1200-1800 Total Fish	1800-2400 Rainbow Smelt	1800-2400 Unident. Fish	1800-2400 Total Fish
Total Number	43(14)	17(5)	60(19)	47(15)	13(4)	60(19)
Total Volume (ml)	264(13)	42(2)	306(15)	270(13)	34(2)	304(15)
Average Number/Stomach	1.86	0.74	2.60	1.96	0.54	2.50
Average Volume/Stomach (ml)	11.47	1.82	13.29	11.20	1.42	12.62
% Frequency of Occurrence	65	52	100	83	42	100

TABLE 11

Continued.

Item	Time (h) 2400-0600 Rainbow Smelt	Unident. Fish	Total Fish	0600-1200 Rainbow Smelt	Unident. Fish	Total Fish
Total Number	96(30)	12(4)	108(34)	81(26)	8(2)	89(28)
Total Volume (ml)	804(40)	25(2)	829(42)	527(26)	31(2)	558(28)
Average Number/Stomach	2.35	0.29	2.64	2.60	0.26	2.86
Average Volume/Stomach (ml)	19.60	0.60	20.20	16.99	1.00	17.99
% Frequency of Occurrence	93	17	100	90	19	100

DISCUSSION

SPATIAL DISTRIBUTION

Areas

The Van Hook Area was by far the most productive in terms of walleye densities. Several abiotic and biotic factors may explain the higher catches from this area. Walleyes reach their greatest abundance in large, shallow and semi-turbid lakes with suitable spawning substrate. The Van Hook Area is closer morphometrically to these criteria than are the other two areas. The width (ft) to mean depth (ft) ratio is approximately 780 for the Van Hook Area, which is much higher than the other two areas.

Other important abiotic factors affecting walleye location are water temperatures and ambient light penetration. The surface water temperatures at the Van Hook and Williston Areas were within the optimal range for most of the sampling period. The Riverdale Area surface temperatures were cooler than the optimum for much of the sampling period.

Light penetration has been determined as an important factor affecting the location of walleyes. This factor was probably the most important at the Williston Area, as there was essentially no light penetration below 6.5 ft for most of the sampling period. The other areas had much better water clarity at this depth.

Biotic factors also help to explain the higher numbers of walleyes in the Van Hook Area. This area had the highest trophic energy flow of the three areas. There were significantly more phytoplankton (producers) and zooplankton (first level consumers) sampled from the Van Hook Area than from the other areas ($p < 0.05$; Power 1983). The primary forage species for walleye, rainbow smelt (second level consumers), also reached the highest numbers for the depths sampled at this area. All of the trophic levels in the walleye (tertiary consumer) food chain had the greatest amount of energy at the Van Hook Area. These abiotic and biotic data may explain the high numbers of walleye found in this area and the lower numbers found in the other areas.

The total Riverdale Area walleye catch was probably greater than the Williston Area catch because of an increase in water clarity and reduction in competition with saugers.

The greatest number of rainbow smelt came from the Van Hook Area. The high zooplankton densities in the depths sampled were probably the most important factor that influenced the rainbow smelt concentrations at this area. I believe the low rainbow smelt catches at the Riverdale Area were not representative of the densities for all depths. The deepest net was relatively shallow in comparison to the total water depth of up to 170 ft. Rainbow smelt usually utilize deeper and cooler water when available for most of the summer. Dahlberg (1981) netted the largest catches of rainbow smelt at 100 ft in Cayuga Lake, New York. Wells (1968) also caught most of the rainbow smelt between 30 and 90 ft in southeastern Lake Michigan.

Depth Selection

Many walleyes in Lake Sakakawea apparently spend much of their time between 0-10 ft from 15 May to 2 August. The largest percentage of the catch from the three areas was from this depth range. These catch data are difficult to assess in this system when one considers the abiotic and biotic factors at this depth range. The light penetration is the most intense in this depth range. The rainbow smelt density was the lowest. Water temperature was the only factor that appeared to be favorable for walleye at this depth range. The walleyes appeared to prefer the warmest water throughout the sampling period, which was found in the 0-10 ft range. The largest catch of the sampling period came from the 0-10 ft range on 27 July with a water temperature of 73 ^{o}F.

Many hypotheses may be conjectured to explain why the walleyes are consistently occupying the seemingly inappropriate depth range. One possibility is, there are enough rainbow smelt in the 0-10 ft range to adequately feed the walleye population and the amount of incoming light at this depth range is not excessively bothersome to the walleyes. In light of the catch data and the depth and thermal requirements reported in the literature for rainbow smelt, this explanation appears weak. Another possibility is that the walleyes move into deeper waters to forage on the more abundant rainbow smelt and then return to the warmer shallow waters to more quickly metabolize the bolus. If this actually occurred then the question is, why was there such a small walleye catch at the 11-20 ft and the 21-40 ft range? The lower catches in the deeper ranges may be in part due to the lower proportion of the six foot high gill net to the total water column. Suspended, feeding walleyes would not have been caught in the deep water. A combination of these and other events may actually have occurred.

The large catches of rainbow smelt in the 21-40 ft range is consistent with the data in the literature that show rainbow smelt prefer deeper, cooler water than do walleyes. The rainbow smelt densities may have been greater in waters deeper than 40 ft but that water was not sampled. The largest catches of rainbow smelt came from waters ranging from 50-69 ^{O}F with a mean of 59 ^{O}F for the entire sampling period. Dahlberg (1981) found the preferred temperature range of rainbow smelt was 51-58 ^{O}F in Lake Cayuga, New York. Wells (1968) sampled down to 210 ft from February to November and found a preferred range of 43-57 ^{O}F. It appears the water temperature is important in the spatial distribution of rainbow smelt in Lake Sakakawea. Light intensities and zooplankton concentrations are also important factors in determining depth selection.

Correlations between Catches of Walleyes with Other Fish

The significant positive correlation found between the total number of walleyes and rainbow smelt captured during the 12 sampling periods reflects the important predator-prey relationship that exists between the two species in all of the areas of Lake Sakakawea.

Walleye and sauger catches were not significantly correlated for the total period, between depth ranges or for each area. However, the Williston Area was the only area to produce more sauger than walleye. This is due to the ability of saugers to thrive in waters with a heavy load of suspended solids and warmer water temperatures Scott and

Crossman 1973). There was a negative correlation between the two species at the Van Hook Area. This may indicate the presence of interspecific competition in the deepers waters where most of the saugers were netted.

Walleye and northern pike apparently coexist with little interaction in Lake Sakakawea, as there were no significant correlations between the species. There was a significant relationship between walleye and yellow perch. I do not believe the correlation is important in terms of a predator-prey relationship as yellow perch were not abundant in the catch or found in the walleye stomachs. The relationship may indicate a similiar habitat preference of these related fish.

TEMPORAL DISTRIBUTION

Three-Week Intervals

The temporal distribution of walleye and rainbow smelt was examined for the four, three-week netting intervals. The last interval was the most productive. The larger catches may partially be explained by the warmer water temperatures that increased the metabolic activity of the fish. I have no explanation of the small catch for the third netting interval. Many factors, i.e., changing water temperatures, wind direction, food location and the limited sampling effort probably influenced the relative catches for each interval.

Six-Hour Periods

The largest catches of walleyes came from the two nocturnal time periods. This is consistent with the findings of other researchers. If a "fish out" phenomenon existed for the net locations as each successive time period passed, then the catch data for the nocturnal periods would have been even larger. If the niche of the walleye is one of a primarily nocturnal piscivore, this would explain the increased activity and the large catches during these time periods. The Williston Area was the only area to produce more walleyes during the 1200-1800 h period than the nocturnal periods. The poor water clarity in this area may reduce incoming light enough to be directly responsible for the increased catch during the daytime. Competition with saugers may also be a factor that influences the diel feeding behavior of walleyes in this area.

The largest number of walleye caught from the 0-10 ft range came during the 2400-0600 h period. This data further emphasizes the increased activity at night in the shallow water.

Diel differences in the rainbow smelt catch were also examined. Most of the rainbow smelt were caught between 1800-2400 h. Ferguson (1965) stated that light was the factor that affected the vertical distribution or rainbow smelt. The 1800-2400 h period is a crepuscular period that may initiate feeding activity among rainbow smelt. The rainbow smelt catches were very low from the 2400-0600 h period. The reasons for the low catches during this period are unknown. The Williston Area differed from the other areas producing the largest catches during the 1200-1800 h period. As with the walleyes, the rainbow smelt are able to feed in the shallow, turbid water of this area during the day in the early summer.

The largest mean catch of rainbow smelt at 0-10 ft and 11-20 ft came during the 1200-1800 h period. The catch was the highest during this period because of the large numbers netted from the shallow water of the Williston Area. Most of the rainbow smelt netted from the 21-40 ft range were caught during the 1800-2400 h period. This suggests feeding activity is taking place in the deeper water during crepuscular periods, mostly at the Riverdale and Van Hook Areas.

Correlations between Catches of Walleyes with Other Fish

Total walleye and rainbow smelt numbers for the 12 netting periods were correlated for each time period. The 1800-2400 and the 0600-1200 h periods showed a positive significant relationship between the two species. These data suggest that there is an increase in activity for both species at the depths sampled during these time periods.

Walleyes showed little relationship with other species during the four time periods, indicating that the changes in numbers of the other species has little effect on the walleyes during the four time periods.

AGE AND GROWTH

Population Structure

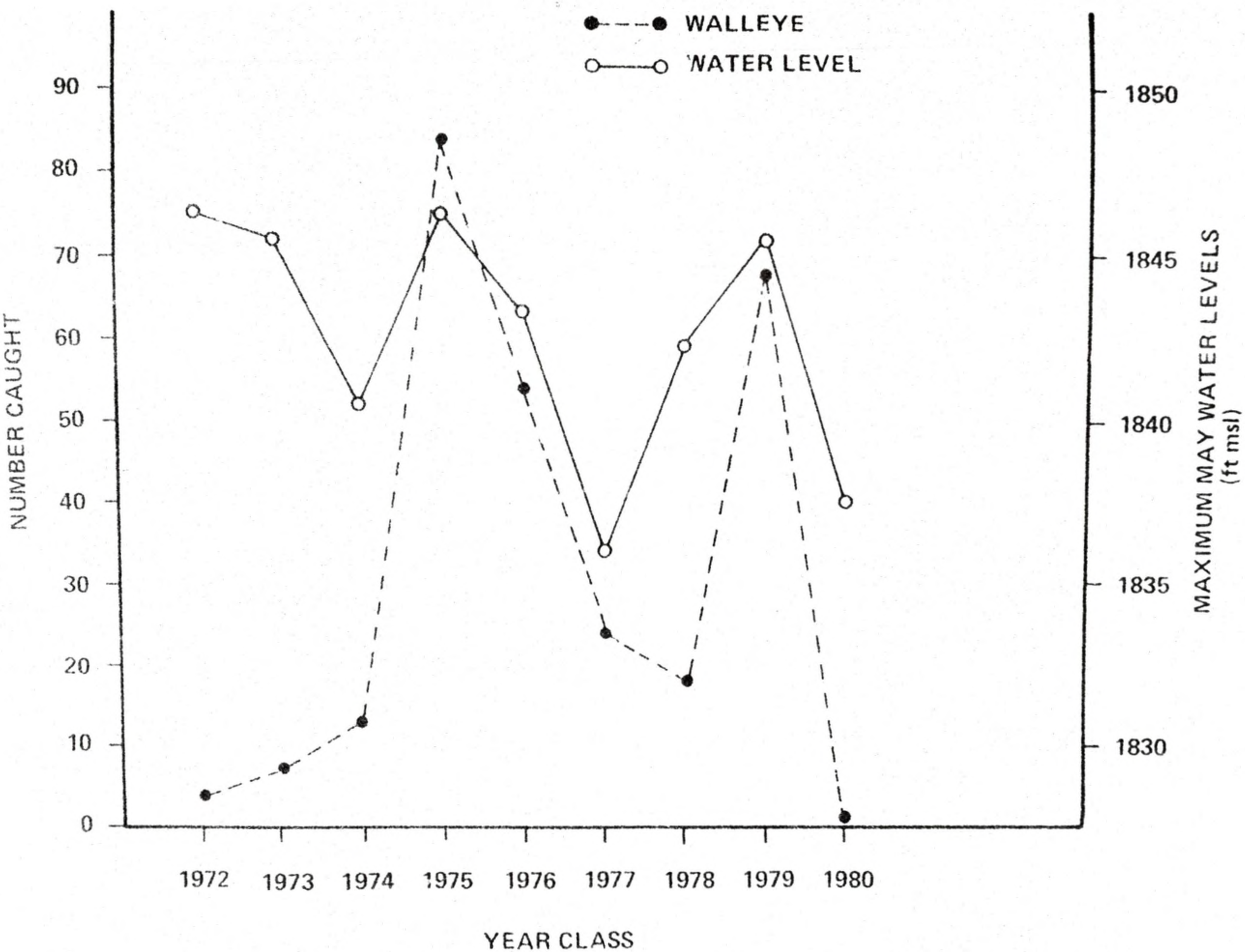
The population structure of walleyes in Lake Sakakawea appears to be closely related with the May water levels in the year of hatch (Fig. 5). Most of the strongest year classes (1975 and 1979) were produced during high water years. Successful reproduction appears to be a function of the increased water levels that inundate rock and gravel, which is the preferred spawning substrate of walleyes in most areas.

The 1978 year class appears to be an exception to the high water trend. The reason for the apparently weak year class is not clear, but there are several possibilities. There might have been some error in the aging of the fish, as there was an apparent false annulus for some fish between ages II and III. If the annulus was weak, but indeed true, then some of the fish aged as III would have actually been age IV. The catch also may not have been representative of the entire population. Weather conditions during spawning and other factors may have affected the success of the 1978 year class although the water levels were high. At any rate, there does appear to be two or three strong age classes present in the reservoir.

There was a noticable lack of age I and II fish in this study. This suggests poor reproductive success during 1980 and 1981.

The Riverdale and Van Hook Areas had essentially the same strong age classes, III and VII. but the Van Hook Area produced a moderately strong age VI class. There were no dominant age classes found for the Williston Area, small sample size was a problem for this area.

Figure 15: Walleye year class strength and corresponding May water levels (monthly highs) in the year of hatch.



WALLEYE
WATER LEVEL
NUMBER CAUGHT
0
10
20
30
40
50
60
70
80
90
MAXIMUM MAY WATER LEVELS (ft msl)
1830
1835
1840
1845
1850
1972
1973
1974
1975
1976
1977
1978
1979
1980
YEAR CLASS

Growth

The regression coefficient (n-value) of 3.299 for the total number of walleyes for the weight-length equation in this study is much higher than that found in 1978. Cassity (1979) found an n-value of 3.0 for the walleye in Lake Sakakawea in 1978. The higher n-value in the present study indicates the fish are heavier per unit of length now than they were in 1978. The increasing densities of rainbow smelt would supply the best explanation for the increas n growth.

The mean K(TL) of 1.04 for this study is also much higher than those found in earlier studies on the reservoir, and higher than some other locations across the United States (Table 12). The present high K(TL) can also be attributed to the increase in the rainbow smelt densities and to the large number of fish that were taken from the more productive Van Hook Area.

Growth data were compared among the three areas. The mean growth increment between ages I and II was the largest at the Riverdale and Van Hook Areas, but largest between ages III and IV at the Williston Area. There may be a lack of suitable sized prey in the Williston Area, resulting in poor growth between ages I and II.

It is unknown why the age IV-VI fish had larger mean calculated lengths for the Riverdale Area than for the other areas. The sample was too small for each age class to make any definitive conclusions. The VII-X ages had the largest mean calculated length at the Van Hook Area. These larger fish are feeding on the more abundant rainbow smelt in this area and are attaining a greater growth rate.

TABLE 12

A comparison of walleye condition factors (K(TL)), from the different regions of the United States.

Source	Location	K(TL)
Hiltner (1983 present study)	Lake Sakakawea, North Dakota	1.04
Cassity (1979)	Lake Sakakawea, North Dakota	0.85
Wahtola (1968-69)	Lake Sakakawea, North Dakota	0.86
Farmer (1974)	Lake Ashtabula, North Dakota	0.96
Smith and Pycha (1961)	Red Lakes, Minnesota	0.89
Priegal (1969a)	Lake Winnebago, Wisconsin	0.81
Lewis (1970)	Canton Reservoir, Oklahoma	1.03
Van Oosten and Deason (1957)	Mississippi River (Iowa)	1.11
Seward (1967)	Lake Erie (Sandusky Bay)	1.10

The Van Hook Area had the largest mean empirical body lengths for each age class, except VII and IX. The Williston Area had a slightly higher average length at age VII, but only three fish were measured at this age from this area. These data further reinforce the hypothesis that the walleyes are growing larger and at a faster rate in the Van Hook Area because of the higher energy levels of the food chain.

Condition factors were also compared among the areas for each age class. This criterion of growth had a significantly higher mean value for all age classes at the Van Hook Area. Again, these data reflect the greater productivity of the area. The walleyes were in the best condition in the Van Hook Area for all age classes except III and IV, where the Williston values were higher. The reason for the higher condition for those age classes in the Williston Area is not clear.

Mean and median weight and length were also the largest for Van Hook walleyes. The values are totals of all of the age classes. It should be noted, that the differences in the number of fish found in each age class for each area varied considerably, which affected the total statistics.

STOMACH ANALYSIS

The apparent predilection of walleye for rainbow smelt in this ecosystem appears to be a function of availability, preference and possibly a lack of evasiveness of the prey. Rainbow smelt are the most abundant and apparently available prey species in the reservoir according to the catch data. They are also the most preferred species, this agrees with the findings of Payne (1963), Regier et al. (1969), Wagner (1972), and Spangler (1977). These researchers all found that the soft-rayed species (rainbow smelt and alewife) were selected by walleyes over the abundant yellow perch. Yellow perch were available and of the suitable prey size. They, however, were not found in any of the walleye stomachs. I believe these data reflect the availability of, walleye preference for, and lack of evasiveness of the rainbow smelt. Although suitable sized goldeye were abundant in the shallow water, they were not utilized as a prey species. This avoidance of the goldeye suggests that the rainbow smelt are either the preferred soft-rayed prey species or they are less evasive or both.

The small differences found among areas in the mean number and volume of rainbow smelt per stomach are probably not very important as the data were potentially influenced by several factors such as differences in water temperature, and differences in time of prey consumption before capture.

Differences in the mean number and volume among the depth ranges were also small. The 11-20 ft range had the largest mean number and volume of rainbow smelt. These data may lend credence to the hypothesis that the walleyes move deeper to feed on the rainbow smelt. This depth may be a transition zone between the two species where the walleyes feed.

It is interesting that the walleyes captured in the 21-40 ft range had very small numbers and volumes of rainbow smelt in their stomachs. The walleyes may have just moved deeper to begin foraging on rainbow smelt when netted at this depth.

Night feeding seems to be favored by the walleyes in Lake Sakakawea, as the largest number of stomachs containing food came during the 2400-0600 time period. This period also had the largest mean volume of rainbow smelt per stomach and the highest frequency of occurrence.

I hope the ecological and biological data presented in this manuscript provides useful information as a reference in organizing future studies and managing the economically important walleye population in Lake Sakakawea. Currently, there is a research project on the life history of rainbow smelt in the Van Hook Area of Lake Sakakawea. This study will provide additional spatial and temporal distribution and also food habits data on the rainbow smelt population.

A research project concerning the location of new walleye spawning areas may provide information that would be useful to better predict year class strength of walleye in Lake Sakakawea.

Water level regulation during and after the walleye spawning period is apparently important and should be considered seriously.

With the large numbers of walleye caught in the shallow water during this study there appears to be an attractive potential for expanding the salmonid fishery in Lake Sakakawea. The deeper areas of the reservoir would provide copious forage and minimal feeding competition with the abundant walleye.

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