Fish Use of the Rocky Creek Fishway and the Reader-Root Wetland Complex with Special Consideration for Northern Pike

by

Derek S. Kroeker

A Thesis
Submitted to the Faculty of Graduate Studies
In Partial Fulfillment of the Requirements for the Degree of

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ABSTRACT

As a result of a winterkill of juvenile northern pike (*Esox lucius*) near the Rocky Creek fishway in December 2001, an exploratory study was conducted in 2003 and spring 2004 to examine the function of the fishway as well as the characteristics of the fish community using the fishway and the Reader-Root wetland complex. To determine fishway use, the fishway was converted into a fish trap to intercept fish moving downstream to spawn, as well as fish returning upstream. The fish community in the Reader-Root wetland complex was sampled primarily with experimental gill nets.

The Rocky Creek fishway was used by northern pike, white sucker (*Catostomus commersonii*), and three *Notropis* species. Northern pike and white sucker passed upstream and downstream through the fishway at rates exceeding 200 fish per hour during spring. Results of the fish community investigations indicated that the Reader-Root wetland complex had an abundant fish community dominated by northern pike.

Fish use of the Rocky Creek fishway and Reader-Root wetland complex was highly variable. Further research is necessary under different water levels and flow conditions to determine if environmental conditions are correlated to changes in fish abundance or species diversity.

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1.0 INTRODUCTION

1.1 Issue Statement

Fish are integral components of ecosystems in many North American wetlands, however, their role in wetland ecology is poorly understood. While wetland habitat is essential for some fish species, little information about the extent, timing, and duration of wetland use exists. Wetlands provide spawning or rearing habitat for some larger fish species as well as a more broad range of habitat requirements for smaller species (Randal et al. 1996). Wetland habitat loss can be correlated to the decline of important recreational and commercial fish stocks (Inskip 1982, Hayes et al. 1996, Mitsch and Gosselink 2000). As a result, there is an increasing need for fish resource information in wetlands.

The rate of loss of wetlands in North America has increased with demands from agriculture, industry, and urban sprawl. In the Canadian Prairie Provinces, more than 50% of wetlands have been drained in both the prairie pothole and parkland regions (Mitsch and Gosselink 2000). In addition, many freshwater coastal wetlands have been degraded by pollution and water level regulation (Janusz and O'Connor 1985, Lougheed et al. 1998). Many remaining wetlands are managed for specific avian or mammalian communities, or for industrial and agricultural use, resulting in management decisions that may not account for the unique ecology of wetlands. Maintaining healthy fish populations in regulated wetlands is difficult, despite management practices such as prescribed flooding and drought cycles. Management actions are typically targeted at a local scale, and wetlands are often partitioned with dykes and water control structures. Chick et al. (2004) showed that fish communities are influenced by spatial scale of management actions. Wetland fish communities are often comprised of species adapted to warm water, low oxygen, and periodic drying (Snodgrass and Burger 2001). In northern latitudes, wetland fish species have also adapted to annual freezing of wetlands (Magnuson and Karlen 1970). Despite the relatively harsh conditions that wetlands may impose on fish species, high levels of primary production support complex food webs resulting in diverse and abundant fish communities (Batzer et al. 2000). Some fish species, such as northern pike (*Esox lucius*), depend heavily on wetland habitat for both spawning and rearing of juvenile life stages (Bry 1996, Grimm and Klinge 1996). Because of the ephemeral use of wetlands by most fish species, wetlands connected to deepwater refugia typically have more diverse fish communities than those without refugia connections (Snodgrass and Burger 2001). Limited connectivity between a wetland and adjoining more permanent water bodies is detrimental for most fish species that use wetlands (Snodgrass and Burger 2001).

Effective management of wetland resources depends on an understanding of both the habitat requirements and the functional role of species in the watershed. Connectivity is important to temporary marsh residents so individuals can move between wetlands and deepwater refugia. The hydrology of natural wetlands poses little threat to fish communities because the species present are adapted to natural cycles of inundation and desiccation. Physical barriers and altered hydrological characteristics may alter fish species composition or abundance in wetlands (Ovidio and Phillipart 2002, Danylchuk and Tonn

2003). Fish passage devices and structures have been developed for a variety of barrier-types in streams and rivers, but have only recently been investigated (Odeh 1999).

The Reader-Root wetland complex, located 30 km northwest of The Pas, Manitoba, encompasses 49,000 ha of shallow lakes, channels, and wetlands of the Saskatchewan River Delta (SRD) (Figure 1). The Reader-Root wetland complex is part of the Saskeram Wildlife Management Area (SWMA) which was established as a partial mitigation to offset habitat losses in the SRD caused by hydroelectric development (Ould et al. 1979). Two water control structures, one on Rocky Creek and the other at the South Reader outlet, regulate water levels at the upstream and downstream ends of the system, respectively. The Rocky Creek control structure has a vertical slot fish ladder (hereafter referred to as the fishway) incorporated into its design. Fish are known to travel downstream through the fishway in spring to gain access to the wetlands downstream of the control structure. The SWMA is a significant breeding and staging ground for waterbirds, and historically, the Reader-Root wetland complex has been managed for breeding and staging waterfowl as well as muskrat production (Ould et al. 1979).

In mid-December, 2001, a significant winterkill of juvenile northern pike was discovered immediately downstream of the Rocky Creek water control structure. Northern pike are an important species for the recreational fishery of Rocky Lake, located approximately nine kilometres upstream of the Rocky Creek control structure. The winterkill was the result of insufficient dissolved oxygen in the water of Rocky Creek (Lysack 2004). This type of mortality is not uncommon in shallow water wetlands that are typically ice-covered for part of the year (Barica et al. 1983). Derksen and Gillies (1985) reported similar winterkill occurrences in the nearby Saskeram marshes. The occurrence of a winterkill near a water control structure equipped with a fishway presented a unique opportunity to examine water management strategies that may mitigate winterkill occurrences in the immediate area of the structure.

Although the Root-Reader wetland complex was developed primarily as a management project for waterfowl and muskrats, the importance of these wetlands to local fisheries has been recognized. Recent fish winterkills in the Reader-Root wetland complex and other areas of the SRD have increased the awareness of fish resources in these wetlands, resulting in recent water management decisions that address fisheries concerns. Currently, there is insufficient information available on fish community composition, relative abundance, and movements within the wetland system to ensure informed management of fish resources.

1.2 Fishway Function and Design

Dams fragment watersheds and isolate fish from critical spawning and feeding habitats, causing changes in fish community structure, range reductions, and extirpation (Cada and Francfort 1995, Odeh 1999, Ovidio and Philippart 2002). To mitigate the impacts of dams and other barriers, fish passage devices such as ladders (fishways), mechanical lifts, and by-pass channels have been installed at some barriers. Fish passage structures have been used on large hydro-electric dams and for anadromous species, particularly in the Pacific Northwest United States (Odeh 1999). Only 9.5% of federally regulated hydroelectric dams in the United States have effective upstream fish passage facilities (Odeh 1999). Small dams and weirs used to create reservoirs for recreation, floodwater storage, or off-stream agricultural uses can be as detrimental to fish stocks as large mainstem dams (Ovidio and Phillippart 2002). Many potamodromous fish also make significant spawning or feeding migrations (Schwalme et al. 1985, Hladik and Kubecka 2003), however, little information on fishway utilization by non-salmonid species exists in North America (Schwalme et al. 1985). In particular, the efficacy of upstream fish passage devices has been difficult to quantify in relation to fish communities (Ovidio and Phillippart 2002).

The objective of fishways, in general, is to provide an alternate route for fish to swim past an obstacle. This is accomplished by reducing water velocity to a level that fish can move upstream under their own power. Most fishway designs have sections of faster velocity followed by sections of low velocity where fish can recover from the exertion of moving in the faster velocity water. Other designs are intended to reduce velocity so that fish may pass under a continuous, but not overly taxing swimming effort. Both hydraulic and biological information are necessary parameters in fishway design. Katapodis (1981 [cited in Nelson 1983]) described an effective fishway as one that:

1) "attracts and allows them [fish] to enter, pass through and exit the fishway without delay;
2) maintains hydraulic conditions within the fishway channel in harmony with physiological limitations and behaviour of the species involved;
3) permits fish to exit the structure without the danger of them being swept back downstream; and

4) accomplishes the above at a minimum cost."

In addition to the above requirements, fish that successfully navigate a fishway should not be fatigued to the point of becoming susceptible to secondary mortality factors, such as predation or stress-related injury. Mechanical lift systems that transport fish moving in an upstream direction over an obstacle are an alternative to fishways and are usually installed for obstacles that are high and/or have other engineering-related issues that make the selection of fishways unfeasible. There are three main fishway designs described in the following sections.

1.2.1 Step and Pool

Step and pool fishways can be constructed of local materials or made of steel and concrete to form a series of weirs. Fish rest in pools created behind the weirs before jumping over the next weir. Step and pool fishways require adjustments to weir height with corresponding water levels (Schwalme et al. 1985). Weirs may be notched to allow for fish passage at lower flow conditions, alleviating some of the need for frequent adjustments. Pool dimensions depend on the amount of water energy that must be dissipated and which fish species are targeted and/or likely to utilize the fishway.

1.2.2 Denil

The Denil fishway is an artificial channel with a series of closely spaced baffles. The baffles are intended to reduce flow velocity and allow fish passage by continuous movement through the fishway. Baffle placement is important in the proper functioning of the Denil fishway and trash racks should be installed as debris can greatly affect the nature of flow (Nelson 1983).

1.2.3 Vertical Slot

Vertical slot fishways have similar construction to step and pool fishways, with the exception of one or two continuous vertical openings in the weir. Instead of water flowing over the weir, water flows through the slot and is directed against the back wall of the next downstream weir. Deflectors at the slot create a circular flow pattern in each chamber. Vertical slot fishways are frequently installed where large variations in water levels occur (Schwalme et al. 1985). The vertical slot fishway has been used in many applications where salmonid passage is the primary concern. The "Hell's Gate" fishway, on the Fraser River in British Columbia, is an example of a vertical slot fishway.

1.3 Fish Swimming Performance

Fishway design is related directly to the species of concern and their corresponding swimming capacities. Swimming performance of a fish species is difficult to quantify, particularly when trying to distinguish poor swimming capability from a lack of motivation that can occur in unnatural experimental environments. This is particularly relevant considering most fish passage structures are used for spawning migrations, which are highly motivated activities. Swimming performance has been described using a three-part classification: cruising speed (greater than 200 minutes), sustained speed (between 15 seconds and 200 minutes), and burst speed (less than 15 seconds) (Webb 1975) with fast-start swimming as the initial second of effort during burst swimming (Domenici and Blake

1997). Burst speed is most difficult to quantify because of the inconsistent response of test subjects (Nelson 1983) and extremely small time periods of measurement. However, burst speed is extremely important for navigation of vertical slot fishways as water velocities peak over short distances. A general relationship of 10 body lengths per second has been established for burst speed capacity using a large number of fish species with a wide range of lengths (Beamish 1978). The burst speed of northern pike has been measured as 1.5 m/s to 13.7 m/s depending on the technique used (summarized in Nelson 1983). Northern pike are consistently among the fastest fish species in initial acceleration (Domenici and Blake 1997) with rates up to 121 m/s^2 (Table 1 in Domenici and Blake 1997). However, northern pike have been classified as weak swimmers by federal regulators in Canada because of their relatively poor performances in cruising and sustained speed tests (Peake 2004). However, this classification is based largely on a single experiment by Jones et al. (1974).

Bell (1973) reports burst speeds of 3.0 m/s for white sucker (*Catostomus commersonii*) 300 mm to 400 mm long. The swimming performance of cyprinid species has rarely been investigated, although Jones et al. (1974) reported the swimming speed of emerald shiner (*Notropis atherinoides*) as 0.59 m/s. Nelson (1983) reported the burst speed of northern pike 300 mm to 450 mm in length as 3.3 m/s over 2.4 m. White sucker 350 mm to 470 mm in length, were able to overcome water velocities of 2.2 m/s over 2.4 m. Schwalme et al. (1985) reported northern pike (mean fork length = 441 mm), white sucker (mean fork length = 426 mm), and spottail shiner (*Notropis hudsonius*) (mean fork length = 69 mm) utilized a vertical slot fishway at maximal velocities of 0.68 m/s. They also reported that northern pike were twice as likely to swim over the weir, where water velocities ranged from 1.15 m/s to 1.8 m/s, than use the fishway.

1.4 Diel Fish Movement Patterns

Nelson (1983) reported northern pike were more likely to move upstream through a fishway from 18h00 to 03h00, while white sucker displayed short but concentrated movements with little change in usage rate throughout the day. Schwalme et al. (1985) reported higher northern pike, white sucker, and spottail shiner usage of vertical slot fishways from 12h00 to 24h00 than from 0h00 to 12h00. Derksen and Gillies (1985) reported that northern pike and white sucker moved upstream through a fishway more frequently during daylight hours than during the hours of darkness. If one examines their data on a monthly basis, this generalization held during April, but upstream movements of both northern pike and white sucker were greater at night during May, June, and July, 1984. In 1983, no distinct pattern was evident; nearly equal catches occurred in both daylight and night hours for both northern pike and white sucker.

In addition to fishway investigations, Diana (1980) reported that northern pike implanted with ultrasonic transmitters in Lac Ste. Anne, Alberta, were equally active at dawn, mid-day, and dusk, but were almost completely inactive at night. Concurrent summer gill net catch rates supported these findings. Crepuscular activity patterns were reported from telemetry studies conducted by Malinin [(1969, 1971), Podobnyi (1970) (cited in Diana 1980)], and Casselman (1978).

1.5 Wetland Fish Communities

Wetlands are highly productive ecosystems supporting abundant populations of organisms and/or high species diversity (Environment Canada 1993, Mitsch and Gosselink 2000). Terrestrial and avian species have been the subject of the majority of scientific wetland investigations. Comparatively little research has been conducted on fish assemblages and their role in wetland ecosystems (Batzer et al. 2000). Fish inhabiting wetlands typically are inconspicuous due to small size or short duration of wetland use, making study more challenging. There are relatively few species of fish capable of surviving the harsh environment of ephemeral marshes, due to the severity and duration of conditions that influence the fish community (Peterka 1989, Danylchuck and Tonn 2003). However, when conditions are favourable, wetland fish species may reach high abundance and communities may have high species richness (Batzer et al. 2000).

Loss of natural wetlands and anthropogenic influences on remaining wetlands have altered or diminished the functional roles of the communities residing in them. Attempts at wetland restoration or regulation have often been focused on indices of mammalian and/or avian abundance and diversity. This has often led to wetland management strategies that do not include provisions for the management of fish communities. Furthermore, limited fish research in wetlands has been focused on invasive species and degradation of fish habitat (Lougheed et al. 1998). For example, common carp (*Cyprinus carpio*) have negatively influenced wetland ecosystems by reducing fish species diversity through increasing suspended sediment and reduced primary production (King and Hunt 1967). Many native fish species rely on wetland habitat to fulfill all or a portion of their lifecycle. Fish assemblages are limited by biotic, physical, and chemical influences of the local environment as well as its connectivity to the broader watershed factors (Marean 1976, Snodgrass and Burger 2001). The annual fluctuations of water levels in wetlands dictate pattern of habitats and utilization by fish species.

A wide range of environmental conditions are present within wetlands and pose significant challenges to the development of fish assemblages. High summer temperatures, low dissolved oxygen concentrations (summer and/or winter), periodic drying, and complete freezing of the water column in northern latitudes all seem incompatible with most fish. However, many species have adaptations to these conditions (Peterka 1989, Snodgrass and Burger 2001), allowing them to exploit wetlands for spawning and feeding, or as refuge from predators. In Lake Ontario, 89% of fish species use wetlands for at least a portion of their life cycle (Stephenson 1990). In permanent and well connected wetlands, the fish community composition varies seasonally because of environment and life-cycle factors (e.g., spawning, feeding, etc.) (Jude and Pappas 1992). For example, spring spawning fish may be drawn to the warmer water temperatures found in shallow water environments (Bond 1996). Also, fish move downstream out of shallow water areas after a corresponding reduction in stream discharge (Katapodis 1992). Wetland fish communities differ with specific habitat. However, commonalities exist among communities at broader geographic scales, such as the watershed. Adaptations of species to environmental conditions and life history requirements determine the habitat use in wetlands for any species.

1.6 Fish Communities in the Saskatchewan River Delta

The SRD is an important area for furbearing mammals, migrating waterfowl, and is internationally recognized as an important bird area (IBA). Fisheries investigations in SRD wetlands have largely been in response to winterkills of game fish or fish of economic importance. Derksen and Gillies (1985) examined fish use of the Saskeram wetlands (approximately 30 km south of the Root-Reader wetland complex) in 1983 and 1984. They found a total of eight species (not including minnows), with northern pike being the most abundant species. Other species identified in connected portions of the SRD adjacent to the Saskeram wetlands included: carp, walleye (*Sander vitreus*), burbot (*Lota lota*), goldeye (*Hiodon alosoides*), white sucker, shorthead redhorse (*Moxostoma macrolepidotum*) and longnose sucker (*Catostomus catostomus*) (Derksen and Gillies 1985). Large fish species present in Rocky Lake that could potentially move downstream into the Reader-Root wetland complex include: northern pike, walleye, smallmouth bass (*Micropterus dolomieu*), cisco (*Coregonus artedii*), lake whitefish (*C. clupeaformis*), white sucker, yellow perch (*Perca flavescens*), and burbot (Leroux 1984).

Water temperature and dissolved oxygen are correlated in the Reader-Root wetland complex, with low dissolved oxygen reading coinciding with high water temperatures in summer (Lysack 2004). Anoxic conditions may prevent some fish species from inhabiting wetlands such as the Reader-Root wetland complex in winter (Magnuson et al. 1985). The purpose of this study was to look at all species in the Reader-Root wetland complex. However, because northern pike constituted the vast majority of fish captured in this study, fish utilization of the wetland complex was focused on the northern pike population.

1.7 Northern Pike Biology

1.7.1 Distribution and Habitat Requirements

The genus *Esox* consists of five species and is widely distributed in the northern hemisphere (Crossman 1996). The amur pike (*Esox reicherti*) of Eastern Europe and western Asia is considered the largest of this genus in that region, while the muskellunge (*Esox masquinongy*) is the largest of this genus in North America (Scott and Crossman 1973). Other species in the genus *Esox* in North America include the chain pickerel (*Esox niger*), grass pickerel (*Esox americanus vermiculatus*), and redfin pickerel (*Esox americanus americanus*). All three of these species prefer warmer climates and are typically found in more southerly latitudes. Northern pike is closest in geographic range to the muskellunge, and can be visually distinguished by having 5 sub-mandibular pores on each side and partially scaled cheek, while the muskellunge has 6 sub-mandibular pores on each side or more and lacks cheek scales (Stewart and Watkinson 2004). Northern pike fry are a significant predator, where they co-occur, on the later hatching muskellunge fry (Scott and Crossman 1973). Natural hybridization is known to occur between northern pike and muskellunge, but is not common (Crossman 1978).

Northern pike are widely distributed across the northern hemisphere in cool and temperate waters (Raat 1988), reaching as far south in Europe as Italy (Lorenzoni et al. 2002), and Missouri in North America (Crossman 1978). In Canada, northern pike range from the eastern Labrador coast to the eastern slopes of the Rocky Mountains in the west, and to the mouth of the Mackenzie River in the north (Scott and Crossman 1973). Northern pike are absent in the Maritime Provinces and Newfoundland. In Manitoba, northern pike are found in nearly all water bodies where suitable habitat exists in lakes and large rivers. Three colour variants occur in Manitoba (Stewart and Watkinson 2004) with a silver form occurring in areas in west-central Manitoba (Nelson and Paetz 1992).

Northern pike require aquatic vegetation for most of their life cycle including spawning and foraging habitat (Bry 1996, Grimm and Klinge 1996). Habitat suitability index (HSI) models have been developed by Inskip (1982) for different life stages of northern pike and these indicate that vegetation is a key habitat requirement. Manitoba's generally flat topography and abundance of shallow interconnected waterways provide excellent habitat for all life stages of the northern pike.

Northern pike spawn at water temperatures between 4.4°C and 11.1°C (Scott and Crossman 1973) but may move into flooded marshes at water temperatures as low as 1.0°C (Carlander 1969). The upper lethal temperature is reported to be 29.4°C in the laboratory and lower lethal oxygen concentration ranges from 2.0 mg/l to 0.5 mg/l (Casselman 1996). However, live northern pike have been captured in passive sampling gear at oxygen concentrations as low as 0.04 mg/l (Casselman 1978).

1.7.2 Age and Growth

Northern pike growth is directly related to the surrounding environment, with water temperature and forage species being crucial to growth (Casselman 1978, 1996). Growth is highly variable both within and between northern pike populations (Inskip 1982). Generally, longevity and age at maturity are inversely related to growth rate (Carlander

1969, Inskip 1982). Time of annulus formation in pike (in Alberta) is late May to early June (Mackay et al. 1990). Natural mortality is variable, but Raat (1988) suggests a 50% adult annual natural mortality rate for most North American lakes. Northern pike are easily exploited by commercial and recreational fishing, which may increase total annual mortality rates (Mann 1996). With some exceptions, northern pike in the far north generally live longer than northern pike in the south. The largest individual northern pike captured by angling in Manitoba is 150 cm total length (Stewart and Watkinson 2004).

Longevity of northern pike is variable, but has been reported to be up to 25 years (Raat 1988). In central Manitoba, populations reveal that northern pike generally do not live longer than ten years (Gaboury 1982, Leroux, 1984). Derksen and Gillies (1985) reported a maximum age of nine years for northern pike captured in the Saskeram wetlands adjacent to the Root-Reader complex in 1983 and 1984. Lysack (2004) reported a maximum age of ten years from northern pike collected in index gill nets in 1981, 1991, and 1999 in Rocky Lake.

1.7.3 Diet

Although primarily piscivores, juvenile and adult northern pike feed opportunistically, and diets often include a wide variety of insects, crustaceans, birds, and small mammals (Inskip 1982). Cannibalism occurs infrequently in some populations, but it accounts for the majority of the diet in others, and has the ability to influence year class strength (Craig 1996). Abundance of prey items is a key factor determining northern pike diet. Northern pike have been implicated as a factor in poor waterfowl recruitment on shallow lakes and marshes where northern pike and breeding ducks co-exist (Lagler 1956 [cited in Scott and Crossman 1973], Ould et al. 1979). However, the majority of the diet of northern pike consists of fishes (Carlander 1969, Inskip 1982, Beaudoin et al.1999).

1.7.4 Movement

Northern pike are not known for long spawning migrations, as exhibited by some fish species (e.g., salmonids). However, Moen and Henegar (1971) reported a maximum distance travelled of 322 km from a spawning location by a mature individual. Koshinsky (1979) determined that most northern pike in Lac la Ronge, Saskatchewan, dispersed from the streams where they spawned downstream to the main lake where they remained near the mouth of the creek. Spawning site fidelity is supported by Mann (1996) and Miller et al. (2001), but rejected by Billard (1996) and Franklin and Smith (1963 [cited in Inskip 1982]). Derksen and Gillies (1985) determined that most northern pike remained near their spawning marshes, however, some recaptured individuals were found up to 90 km from points of marking. Northern pike tagged with T-bar anchor tags are known to lose tags at a rate of and 1.2% to1.8% per year (Pierce and Tomcko 1993). These tag loss rates are considerably lower than other T-bar anchor tag loss studies for other fish species; 11% for lake whitefish (Ebner and Copes 1982), and 25% for white bass (*Morone chrysops*) (Muoneke 1992).

1.8 Objectives

The primary purpose of this study was to provide baseline information about the fish resources in the Reader-Root wetland complex. A secondary purpose was to investigate the nature of fishway usage including species presence, abundance, and timing of peak movements. Specific objectives were to:

1. determine species composition and relative abundance of fish utilizing the Rocky Creek fishway and Root Lake,
2. describe changes in the fish community using the fishway and Root Lake during the open water period,
3. determine if flow velocities in the Rocky Creek fishway were compatible with swimming capacity of the fish species that were present,
4. record environmental conditions and determine any correlation to fish movements,
5. describe growth, age structure, food selection, and other ecological characteristics of northern pike in the Reader-Root wetland complex, and
6. develop management recommendations and recommend future research for the fishery resources in the Reader-Root wetland complex and surrounding areas.

1.9 Scope

This study was restricted to the fish community in the Reader-Root wetland complex. In particular, most of the sampling occurred in Rocky Creek at the fishway, and in Root Lake. While this research was intended to describe the fish community in this region, it became clear that small fish, and the early life stages of larger fish, were not readily accessible with the sampling gear and techniques that were available. Northern pike comprised the majority of the catch, and because of their importance in the Rocky Lake recreational fishery, a more detailed analysis of their population was conducted. Sampling was conducted in Rocky Creek, Root Lake, Red Rock Creek, and in a deepwater area of North Reader Lake between mid-April, and late October, 2003. In 2004, sampling occurred in Rocky Creek and Root Lake between early April and mid-June.

1.10 Organization

This thesis consists of five sections. Sections 1, 2, and 3, provide the introduction, study area, and methodology, respectively. Section 4 provides the results and discussion of fish utilization of the fishway at Rocky Creek, as well as the results and discussion of the fish community in the Reader-Root wetland complex, with special consideration to the biology of northern pike. Recommendations for management of fish resources in the Reader-Root wetland complex are presented in Section 5. A brief summary of the major findings of this study are presented in Section 6.

2.0 STUDY AREA

2.1 Description

The Saskatchewan River Delta (SRD) is located in east-central Saskatchewan and west-central Manitoba (Figure 1). A network of shallow lakes, marshes, channels, and wet meadows, the delta extends 200 km east to west and 50 km north to south, encompassing over 800,000 ha. It reaches from Tobin Lake in eastern Saskatchewan to the western margins of Cedar and Moose Lakes in Manitoba. The SRD is an important area for migrating waterfowl and furbearing mammals (Ould et al. 1979). Upstream and downstream impoundments and flow regulation on the Saskatchewan River have caused significant impacts to the ecology of the delta (Uchtmann 1983). The SRD has also been impacted by drainage for agriculture on its southern flank. Wetland mitigation measures have been in place since the 1940s (Ould et al. 1979). Small levees and control structures allow managers to independently control water levels in wetlands adjacent to the river.

One such area is the Reader-Root wetland complex on the north margin of the SRD north-west of The Pas, Manitoba. The Reader-Root wetland complex is bound by Rocky Lake in the northwest and the Saskatchewan River to the south, and stretches approximately 28 km north to south and 15 km east to west (Figure 2). The Pas glacial moraine, which stretches from north of The Pas to Long Point on Lake Winnipeg (Klassen 1983), constrains the Reader-Root wetland complex on its eastern boundary. Elevation is approximately 262 m ASL at Rocky Lake and 260.5 m ASL at the downstream end of the wetland complex. The main elevation change occurs at the Rocky Creek control structure, where the water level changes approximately one meter.

The Reader-Root wetland complex is located approximately 11.5 km downstream of Rocky Lake, and consists of a series of creeks, hemi-marshes, and shallow lakes that have been managed since 1941 (Ould et al. 1979). Rocky Lake has two basins, a turbid south basin 3,155 ha in size with a maximum depth of 3.0 m, and a north basin that is considerably larger (7,813 ha) and deeper with a limestone substrate and clear water. Rocky Creek (also known as Paykatuwan Creek), which exits Rocky Lake at the east margin of the south basin, is the only outflow of Rocky Lake, and supplies the Reader-Root wetland complex with water (Figure 2). The creek is approximately 11.5 km long, and has a control structure approximately 2.5 km upstream from its termination at Root Lake. Water in the creek is noticeably clearer than either the south basin of Rocky Lake or Root Lake. The maximum depth of Rocky Creek is approximately 2.0 m, and much of it is less than 1.0 m as it diverges into two hemi-marshes in the reach between the control structure and Rocky Lake. The Rocky Creek control structure is used to regulate water levels on Rocky Lake (primarily for the benefit of cottage owners), as well as water levels on shallow lakes, marshes, and channels further downstream for breeding and staging waterfowl and muskrat production. Unlike most control structures in the SRD, the Rocky Creek dam had a fish ladder incorporated into its original design in the 1940s. The current control structure was installed in 1992, and contains a vertical slot fishway. Recent water management has been adapted for consideration of fish resources. Recent fish winterkills in the Reader-Root wetland complex and in other areas of the SRD have increased the awareness of fish resources in these wetlands.

Root Lake is turbid, has a maximum depth of 1.4 m, and is 3,953 ha in size (Figure 2). Unlike most other marshes in the area, the eastern shore of Root Lake consists of areas of boulders, gravel, and sand from the nearby moraine (Ould et al. 1979). Red Rock Creek flows out of the southeast end of Root Lake. Red Rock Creek is approximately 1.5 m to 2.0 m deep and is approximately 10 km long. Water in Red Rock creek can be diverted into North Reader Lake approximately 2 km downstream of Root Lake, or diverted into South Reader Lake at the terminus of Red Rock Creek. North Reader Lake has a maximum depth of 0.9 m in its main basin. Sampling was focused on an area locally known as the North Reader cut-off located at the southwest end of the lake. This area is characterized by a river-like shoreline with deep (2.5 m), clear water. In high water years, water can be released from the Reader-Root wetland complex into the Saskatchewan River through the South Reader outlet (Figure 2).

2.2 Climate

The climate of the area is continental sub-humid characterized by warm, short summers, and long, cold winters. The average annual precipitation at The Pas is 492 mm; three-quarters falls as rain during the growing season (Weir 1983). The mean annual January and July temperatures are -22.0°C and 18.3°C, respectively. The area has an average of 100 frost-free days per year.

2.3 Soils

Soils in the low-lying areas of the SRD are Cumulic Regosolic and Humid Gleysolic types (Weir 1983) and are poorly drained (Ould et al. 1979). The area is underlain by dolomites and dolomitic limestone mixtures (Geological Survey of Canada, 1987). The bedrock is overlain by surficial deposits of till, lacustrine sediments, and alluvium (Ould et al. 1979).

2.4 Water Quality

The water pH ranges from 9.0 to 10.0, while conductivity ranges from 225 to 300 μS/cm (Ould et al. 1979). Water clarity is lower in open basins such as Root Lake, than in either of the two creeks sampled or the North Reader cut-off. A more detailed description of water chemistry can be found in Ould et al. (1979).

2.5 Vegetation

The Reader-Root wetland complex vegetation community features both southern prairie marsh and northern bog species. Vegetation along well drained areas of shoreline consists of a variety of upland grasses, sedges and shrubs. Emergent vegetation consists primarily of cattail (*Typha* spp.), bulrush (*Scirpus* spp.), and horsetail (*Equisetum* spp.). A variety of pondweeds (*Potamogeton* spp.), milfoils (*Myriophyllum* spp.), pond-lilies (*Nuphar* spp.), and duckweeds (*Lemna* spp.) were present in a survey of submerged vegetation by Ould et al. (1979). A more detailed account of the floral composition of the SRD can be found in Dirschl and Coupland (1972).

2.6 Human Activity and Current Management

Human activities in the Reader-Root wetland complex are mostly recreational (Ould et al. 1979). Recreational hunting, particularly for waterfowl, is an important activity, as is snowmobiling. Considerable effort is directed toward trapping furbearing mammals in years of high muskrat density, however, this has decreased since the early 1990s (Uchtmann 1998). Subsistence food gathering occurs in the wetland complex. Moose and waterfowl harvesting are the most common activities. There is also one outfitter who guides waterfowl hunters and one commercial baitfisher. The Reader-Root wetland complex is managed jointly by Ducks Unlimited Canada (DUC) and the Province of Manitoba. DUC manages water levels through the operation of control structures.

2.7 Rocky Creek Fishway

The current vertical slot fishway has 10 chambers with the first (upstream), fifth, and tenth chambers larger than the others. Chamber exit (slot) is approximately 27 cm in width. Deflectors have been installed near the exit of each of the chambers to ensure streaming flows (and corresponding higher velocities) do not occur from one chamber to the next. Sill heights decrease with each subsequent chamber from 854.5 feet above sea level (ASL) in exit of the first (upstream) chamber to 852.3 feet ASL in the exit of the tenth (downstream) chamber. Water depths in each chamber were generally between 1.5 m and 1.8 m under most flow conditions. Fishway walls consist of heavy corrugated steel plates with a gravel substrate at the bottom of each chamber. Boulders and rip-rap are present within 10 m of the downstream margin of the control structure.

2.8 Fish Habitat Description of the Reader-Root Wetland Complex

Fish populations have been linked to their habitat quantity and quality (Hayes et al.1996). Suitable northern pike spawning, rearing, and adult foraging habitats were noted during field observations, but were not quantified in this study. Northern pike year class strengths have been correlated more to rearing habitat than spawning habitat (Bry 1996). Suitable spawning habitat for other large fish species found in Rocky Lake was likely not present in the Reader-Root wetland complex, although documentation of walleye spawning in wetland environments does exist (Priegel 1970). Habitat was abundant for common carp, but limited for other species that were less tolerant of low oxygen concentrations, high turbidity, and loosely consolidated substrate.

3.0 METHODS AND STUDY DESIGN

3.1 Environmental Monitoring

Cloud cover, air temperature, wind speed and direction, were recorded daily during sampling activities. Water levels were recorded at control structures in Rocky and Red Rock Creeks. Levels were recorded in feet ASL to the nearest hundredth of a foot from staff gauges mounted on control structures. In spring 2004, the downstream water level gauge on the Rocky Creek control structure was obscured by ice until April 26. Flow velocities at the outlet of the fishway were recorded using a model 2030R A.G.O. Environmental Electronics mechanical flow meter. The meter was lowered into place with a short rope at the exit of the fishway. The flow meter had an approximately 1.5 kg weight secured to it to assist in maintaining position of the meter in the maximum flow. The meter used a propeller to turn a series of numbered dials similar to an automobile odometer. Each "count" or increase in number was created by 0.1 of a revolution of the propeller. Once the number of counts was determined, it was divided by the duration that the flowmeter was in the water. To calculate velocity in meters per second, the number of counts per second was multiplied by 26,873 (flow meter constant) and divided by 999,999 (scaling factor). Flow velocity was recorded at the exit of the fishway, where the highest velocities occurred. Velocities at the exit of each of the 10 chambers were recorded at typical water elevations to confirm this observation. In 2004, water velocity was recorded directly over the stoplogs as it was noted that some fish drifted to the crest of the dam, only to turn and swim upstream under high velocity conditions.

Dissolved oxygen and water temperature were recorded at the Rocky Creek control structure, and at the time of gill net deployment, using a digital multi-meter (YSI 550A – 12, Hoskin Scientific Ltd.) and recorded in mg/l and degrees Celsius, respectively. Water temperature and dissolved oxygen were also measured in Red Rock Creek in December 2003. An elevation of 800 feet ASL was used to calibrate the multi-meter. The multi-meter probe was placed at approximately half of the water depth at the upstream entrance to the fishway and moved in a vertical motion at approximately 0.3 m/s to ensure dissolved oxygen was not depleted at the interface of the probe. Supplementary measurements of dissolved oxygen were recorded in winter of 2003-2004 by Manitoba Department of Natural Resources and DUC staff using the same oxygen meter.

In 2003, water temperature was recorded every six hours using Hobo-Temp® data loggers at seven stations, from the upstream mouth of Rocky Creek at Rocky Lake, to the downstream mouth of Red Rock Creek near South Reader Lake. These data loggers were deployed soon after ice-out in spring and retrieved as ice was forming in the fall. The data loggers were deployed at roughly 60% of water depth at each station. Data loggers were not deployed in 2004.

3.2 Fish Capture

To determine the abundance and species composition of the fish community in the Reader-Root wetland complex, a variety of capture techniques were employed in Root Lake, North Reader Lake, as well as in Rocky and Red Rock Creeks (Figure 2).

3.2.1 Fishway Trapping

Sampling of the fish assemblage in the Rocky Creek fishway was conducted during the open water season in 2003 and 2004. In 2003, a survey of fish use of the fishway was conducted from 19 April to 26 October. Sampling occurred from two to four times per week during the early spring spawning season and late fall, and once per week in the summer months. Samples were collected from 11h00 and 15h00. This sampling frequency was chosen to allow the detection of changes in the fish community utilizing the fishway during the spring and fall, and to monitor the use of the fishway during the summer months. Increased frequency of fall sampling was undertaken as emigration of juvenile northern pike from the wetland, as described for the nearby Saskeram marshes (Derksen and Gillies 1985), was anticipated.

In 2004, a shorter (19 April to 16 June), but more intensive sampling regime was conducted, focusing on the spring spawning period of northern pike and white sucker. During this time, we resided at the study site and sampled the fishway between one to four times daily. Sampling was conducted at regular times during daylight hours, with infrequent sampling at night due to the increased risk to personal safety. This sampling schedule allowed us to detect correlations in fish movement patterns and environmental variables. Sampling was conducted less frequently after the spawning period, from 21 May until the end of the 2004 field season on 16 June.

To determine the abundance of fish and direction of fish movement, the fishway was used as a fish trap by installing metal frame screens at the exit of the either the ninth or first chamber. The dimensions of the three steel frames used were variable, but were approximately 1.2 m tall by 0.4 m wide. The frames had two cross beams to support 9 mm Vexar® plastic mesh which was attached to the frame with wire. A screen was placed on the sill of the exit of the prescribed chamber and wedged into place across the opening. Water pressure held the screens in place, but screens were also secured into position with rope to ensure they would not dislodge (Figure 3). To capture fish moving downstream, a single screen was positioned at the exit of the penultimate (ninth) chamber. To capture fish moving upstream, a screen was placed at the exit of the first chamber. Once the initial screen was in place, a period of time (usually between 0.5 and one hour) was allowed for fish to accumulate in the trap. A second screen was then placed in either the exit of first chamber in a downstream capture, or at the exit of the ninth chamber to close the fishway for an upstream capture. Once the fishway was closed, stop-logs were placed in the entrance of the fishway to stop the flow of water. The water depth in the de-watered fishway (generally between 0.5 m and 1.1 m) was dependant on both stop-log seal, and the elevation of Rocky Creek below the control structure. The fishway was then entered and fishes were removed with landing nets, and transferred to large water-filled tubs. In poor weather conditions, or if many individuals were captured, northern pike were sub-sampled, with the remaining fish enumerated and released into Rocky Creek in the same direction as the fish were traveling. White sucker were enumerated and immediately released.

The decision to trap fish moving upstream or downstream was determined by observing fish behaviour on either side of the control structure, and the amount of debris in the water. High amounts of organic drift (aquatic vegetation and algae) clogged the holes in the screens making them ineffective. Downstream capture was not possible when organic drift was prevalent, as screens would become clogged and water would overtop the screen. Upstream capture events were still possible with moderate amounts of debris in the water because water velocity was much lower at the exit of the first chamber compared with velocity at the exit of the ninth chamber.

The default set in the early spring was to capture downstream moving fishes. When fish were observed congregating above and below the fishway, an equal number of upstream and downstream capture events were conducted. However, this condition lasted only a few days in both 2003 and 2004. When upstream movement of fishes and increased organic debris in the water were observed, capture events were conducted to intercept upstream moving fish. Fishes could have been present in the fishway from the onset of the trapping period, however, because the trapping protocols were consistent, and a consistent likelihood of fish presence in the fishway existed, the trapping results are assumed comparable. To determine whether fish movements through the fishway were correlated with environmental variables such as current velocity, the fish community and environmental conditions were measured concurrently.

3.2.2 Night Observations

A rechargeable 1.5 million candle power spotlight was used to observe fish moving in or near the fishway at night. Night sampling was conducted on several occasions to determine if fishes, walleye in particular, were using the fishway at night. Although walleye normally spawn on gravel and/or sand substrates in lakes and medium velocity streams in Manitoba, they also spawn in marshes over flooded terrestrial vegetation, similar to that used by northern pike (Priegel 1970).

3.2.3 Stop-log Observations

In spring of 2004, fishes were observed using the open stoplog bay to pass over the control structure. To determine the degree of stop-log bay use during downstream movement, individuals were counted (by species) as they moved over the submerged stoplogs (Figure 4). Between 21 April and 1 May, 2004, sixty 0.5 hour observations were made of fish passing over the stoplogs. On 13 occasions between 23 April and 9 May, 2004, stoplog fish passage was monitored while the downstream fish trap was in operation, allowing comparison of use between the fishway and stoplog bay. Sampling periods were comparable in time of day and duration. For comparison with the fishway catch, stoplog catch rates were standardized to fish per hour. Fish passage over the stoplog bay was not apparent in 2003.

3.2.4 Gill Netting

Fish were captured in the Root-Reader wetland complex using a standard gang of gill nets consisting of four 22.9 m long by 0.9 m deep panels in 51 mm, 76 mm, 95 mm, and 108 mm (stretch measure) twisted nylon mesh. Nets had a continuous lead line and float line, with additional floats attached at each end. Gangs were set in the late afternoon and removed the next morning. The duration of time the nets were in the water was recorded. Four sites in Root Lake (northwest, northeast, mid-lake, and southeast) were chosen for gill netting. These locations were chosen to determine if changes in fish catch composition or rate occurs in different locations of Root Lake. A GPS receiver was used to record the locations of each of the gill netting sites. At these sites, gill nets were deployed approximately every four weeks in the open water period in 2003, and were set twice in June 2004. In 2003, gill netting was also conducted once at Red Rock Creek (near the inlet to South Reader Lake), and once in North Reader Lake (deep area known as the North Reader cut-off) as a means of determining presence of fish and potential refuge areas from anoxic conditions. Nets were set parallel with the prevailing winds, as this was the only practical method of setting gill nets from an airboat. Nets were generally set in areas of moderate to light macrophyte density. A gill net was also set in Red Rock Creek on 17 December, 2003 to determine if fish were over-wintering in the creek. Gill net catches were tabulated by fish species and sampling location. Because each net was fished for approximately the same time period, standardizing the catch units was not necessary.

3.2.5 Trap Netting

Trap netting occurred near gill netting sites where proper conditions permitted the deployment of the net. Optimal sites required the water depth to be between 0.8 m and 1.2 m, and have no more than moderate macrophytes growth. A modified fyke net with 10 mm mesh on the leads and main body of the trap net was used (Beamish 1972). Two wings, each 15m long, directed fishes into the trap. Fishes were directed into the heart of the net, with a funnel system designed to capture individuals in the collection chamber or "pot". The pot was 1 m x 1 m x 1 m in size, and had an access door on top with a Velcro® closure. The net was weighted with lead weights and the top was floated with plastic floats. Floats were attached to the ends of the wings and one in the middle of the pot. The back of the pot was stretched using a heavy steel pipe at the bottom and a piece of 2x4 inch lumber at the top, each approximately 1 meter in length.

In June and July, 2003, trap netting was done concurrently with gill net sets on a four week rotation. The trap net was also set in other portions of Root Lake and Rocky Creek, and Red Rock Creek during the spring and summer of 2003. Deployment and retrieval of the trap net was difficult, because there were few locations with suitable water depth and a substrate composition that permitted wading. Setting the trap net from the airboat was difficult and retrieving it in moderate to high winds was not possible. The trap net was not used in 2004.

3.2.6 Test Angling

Test angling was used to determine presence of larger fishes (e.g., northern pike, walleye, white sucker) in locations where gill netting or trap netting were not feasible. Test angling was conducted using standard angling tackle, with either metal "spoons" or 3/8 ounce jigs baited with commercially available salted minnows. On 26 May, 2003, one hour was spent fishing at the outlet of Rocky Creek at Root Lake. On 19 June, 2003, two hours were spent fishing at the outlet of Red Rock Creek near South Reader Lake. On 14 July, 2003, two hours were spent fishing in a deep-water portion of North Reader Lake known as the North Reader cut-off. Test angling was not employed in 2004.

3.2.7 Wire Minnow Traps

Wire mesh (6.4 mm) minnow traps were deployed from May to July 2003, in Rocky Creek, Root Lake, and Red Rock Creek. The wire-basket type trap was attached to wooden poles which were secured into the substrate. Traps were positioned in a variety of locations in the water column and in different habitat types (open water, macrophytes beds, near creek mouths etc.). This capture technique did not yield any fish and was discontinued in July 2003.

3.3 Biological Data

Each fish that was captured was identified and enumerated by species, location, and sampling gear in which it was captured. Northern pike, white sucker, and walleye were measured for fork length (± 1 mm) with a measuring board and round weight was determined with an electronic scale (± 10 g). At the fishway, only northern pike were measured and weighed. Northern pike and walleye captured in gill nets were examined internally to determine sex and stomach contents.

Ageing structures were collected from a sub-sample of northern pike and all walleye. Structures removed included pectoral fin rays from walleye and anal fins rays from northern pike. Anal fins were selected as the preferred fin for northern pike as opposed to the pelvic fin as suggested in Zacharias (1987), because anal fin rays are larger in diameter and crowding of annuli is reduced (Walt Lysack Pers. Comm.). Dried ageing structures were prepared and analyzed as described by Mackay et al. (1990). Dried fin rays were coated in epoxy and sectioned with a Isomet® microtome saw. Sections were mounted on glass slides with Cytoseal 280®, and fish ages were determined by examining sections using a dissecting microscope.

3.3.1 Movements

Northern Pike were tagged to determine inter-annual and intra-annual movements in Reader-Root wetland complex and Rocky Lake. Live-captured northern pike (from the fishway trap, trap net and angling) with a fork length exceeding 350 mm were fitted with a numbered yellow T-bar anchor Floy® tag. Tags were inserted on the left side of the fish below the dorsal fin behind the pterygiophores (Guy et al. 1996). Anglers on Rocky Lake were notified with posters, and lodge owners were contacted directly, encouraging anglers to report capture of tagged fish. All northern pike encountered throughout the study were examined for tags and/or evidence of anal fin clipping, as evidence that fish had been previously captured. Mark–recapture population estimates were not calculated due to the low recapture rates, making abundance estimates unreliable.

3.3.2 Stomach Contents

Dead fish were necropsied in the field to determine stomach contents. Only the anterior portion of the stomach was examined. The contents of stomachs from northern pike and walleye were identified and the predominant prey type (by volume) was recorded.

Dietary items in northern pike stomachs were identified to taxonomic group; invertebrates to class and fish to species when possible.

3.4 Data Analysis

Data collected at the fishway were analyzed to determine pattern of use as well as any correlation to water velocity. The number of each fish species captured in a sampling period was recorded as well as the period of time that the trap was in operation. Fish usage was standardized to number of fish per hour. A regression of the log-transformed 2004 northern pike capture data (evening capture events only) versus fishway velocity was performed to determine the correlation between fishway exit velocity and the number of fish entering the downstream chamber of the fishway. A regression of the log-transformed 2004 northern pike fork length data versus fishway velocity was performed to determine the correlation between fishway exit velocity and the average fork length of fish entering the downstream chamber of the fishway.

Data from northern pike captured in all capture techniques were used in analysis of population characteristics. Mean length, weight, and Fulton's condition factor (K) were calculated for northern pike. Length-weight relationships were calculated for using least squares regression analysis on logarithmic transformations of fork lengths and round weights according to the following relationship:

$$\mathrm{Log}_{10}W = a + b\,(\mathrm{Log}_{10}L)$$

Where:

W = round weight (g);

L = fork length (mm);

a = Y-intercept; and

b = slope of the regression line.

Condition factor (K) was calculated for individual northern pike using the following equation (after Fulton 1911, [cited in Ricker 1975]):

$$K = W \times 10^5 / L^3$$

Where:

W = round weight (g); and

L = fork length (mm).

Length-frequency distributions for spring and fall 2003, and spring 2004 were plotted for northern pike. Length intervals of 25 mm were chosen (e.g., 225 – 249 mm). Age-frequency distributions are presented for spring and fall of 2003, and spring 2004. Age-specific mean lengths for spring 2003 and 2004 were calculated and tabulated, and presented with their standard deviations. Average length-at-age was calculated and a von Bertalanffy growth curve was plotted for spring 2003 and 2004, using the following equation:

$$L_t = L_\infty (1\text{-}\exp^{-K(t-t0)})$$

Where:

L_t = length at age t

L_∞ = the asymptote of final maximum size

K = the growth coefficient (rate at which growth curve approaches asymptote)

t_0 = hypothetical length at age 0 (von Bertalanffy 1938 [cited in Mackay et al. 1990])

The L_∞ and K were calculated from a Ford-Walford Plot, while the t_0 was calculated from a plot of the natural log of ($L_\infty - L_t$). The Ford-Walford plots were based on ages two to seven in 2003 and five to nine in 2004.

Abundance and average fork length of northern pike captured in gill nets were graphically presented to depict changes in location and time. Length-frequency of male and female northern pike were presented from the gill net catch. Average fork length and length-frequency distributions of pike consuming different prey items were calculated to determine change in prey selection by size. Comparison of mean length by diet through the use of a *t*-test was inappropriate due to non-normality (Shapiro-Wilk test) of at least one of the data sets in each year (SPSS v11.0, 2001). Therefore, a Mann-Whitney (Rank-Sum) test was used.

The length-weight, condition factor, mean length-at-age, frequency histograms, and stomach contents analysis do not include young-of-the-year (YOY) northern pike captured in the trap net. The length distribution and date of capture are presented for these fish in the trap net section of the results.

Two annual survival estimates (Robson-Chapman and regression) were calculated for northern pike in Rocky and Red Rock Creeks and Root Lake. The Robson-Chapman method has the following assumptions for a survival estimate:

"the survival rate is constant for each age group,

all year classes are recruited at the same abundance,

all ages are sampled equally by the sampling gear" (Krebs 1989).

The regression method has the following assumptions for a survival estimate:

"the mortality rate is uniform with age,

the mortality rate is constant over time,

the sample is taken randomly from the age groups involved,

recruitment is constant for all age groups" (Krebs 1989).

4.0 RESULTS AND DISCUSSION

4.1 Fish Use of the Rocky Creek Fishway

4.1.1 Environmental Conditions

In 2003, water levels at the Rocky Creek control structure varied by more than 30 cm on the downstream side and by 10 cm [converted to metric from imperial units on staff gauge] on the upstream side of the control structure (Figure 5). Water level fluctuations were less pronounced at the North Reader inlet structure (near the outlet of Root Lake), suggesting that water level fluctuations downstream of Rocky Creek control were amplified relative to Root Lake water level.

Water velocity in the fishway increased from chamber to chamber with the highest velocity occurring at the exit (Figure 6), supporting results from previous velocity monitoring (Lysack 2004). In 2003, water velocity at the exit of the fishway ranged from a low of 1.07 m/s recorded in June to a high of 1.88 m/s recorded in September (Figure 7). Water velocity was strongly correlated ($r^2 = 0.88$) to water level downstream of the control structure (Root Lake water level) (Figure 8). During spring 2004, water levels and velocity were less variable; water levels were consistently higher on both sides of the control structure than in 2003 (Figure 9). Velocity in 2004 (1.28 m/s to 1.56 m/s) was within the range observed in 2003. Velocity over the stoplogs was measured at 2.1 m/s in June, 2004.

From late April to mid-May 2004, water temperatures were lower than for the same time period in 2003 (Figure 10). Air temperatures were well below average for the period and The Pas, Manitoba recorded its coldest spring on record. Dissolved oxygen and water temperature at the upstream side of Rocky Creek control were presented from April 2003 to February 2004 (Figure 11), and for spring 2004 (Figure 12). The lowest dissolved oxygen concentrations (3.2 mg/l) were recorded in August 2003 at the fishway and, concurrently, several dead northern pike were encountered in Root Lake, as well as dead white sucker in upstream portions of Rocky Creek.

4.1.2 Fishway Trapping

During the course of this study, five species of fish (northern pike, white sucker, emerald shiner, spottail shiner, and blacknose shiner (*Notropis heterolepis*)) were captured at the Rocky Creek fishway (Table 1). In 2003, 46 northern pike and 162 white sucker were captured moving downstream through the fishway over the course of nine capture events from 23 April to 13 May (Table 2). The highest downstream northern pike passage rate was 22 fish/hour on 6 May (Figure 13). The highest white sucker downstream passage rate was 200 fish/hour on 13 May (Figure 14). Upstream capture events yielded 303 northern pike and 172 suckers from 30 capture events from 9 May to 26 October. The highest upstream fish passage rate occurred on 13 May with 208 northern pike/hour and 172 white sucker/hour. May 20th was the last day that white sucker were encountered in the fishway trap in 2003. Few northern pike were captured after 30 May, with the exception of 30 fish/hour on 9 July.

Between 12 April and 16 June, 2004, an intensive survey of fish movement was conducted at the Rocky Creek control structure. A total of 243 northern pike and 2 white sucker were captured moving downstream in the fishway over the course of 26 capture events from 12 April to 13 May (Table 2). The greatest downstream passage rate by northern pike (86 fish/hour) occurred on April 23 (Figure 15). Upstream capture events yielded 594 northern pike and 362 white sucker from 43 sampling events from 29 April to 16 June (Table 2). The greatest upstream passage rate (140 fish/hour) by northern pike occurred on 19 May (Figure 16). The greatest upstream white sucker passage rate (172 fish/hour) occurred on 20 May (Figure 17), with very few white sucker captured in the fishway after this date.

Northern pike and white sucker were observed entering the fishway without apparent difficulty throughout the study. There was no significant correlation ($r^2 = 0.0143$) of fishway exit velocities and the abundance of northern pike moving upstream into the fishway in the spring of 2004 (Figure 18). There was poor correlation ($r^2 = 0.1953$) of fishway exit velocities and the average length of northern pike entering the fishway in spring 2004 (Figure 19). In summer and fall of 2003, fish were not captured in many of the sampling events coincident with both low and high fishway velocity. Therefore, a comparison of catch rate and fishway exit velocity in 2003 was not calculated, however, a capture rate of 53 northern pike/hour was recorded coincident with a fishway exit velocity of 1.52 m/s on 23 May. In both 2003 and 2004, the average length of northern pike using the fishway decreased during each of the study years (Figures 20 and 21).

Night observations were conducted on several occasions during the spring 2004. Only northern pike were observed in or near the fishway and control structure. Northern pike used the fishway at night at an estimated lower number than late afternoon or evening.

A diel movement pattern was detected for northern pike moving downstream. The number of northern pike in the fishway was higher in the late afternoon and evening than in the morning hours (Figure 22). The pattern was less apparent when northern pike were moving upstream (Figures 23 and 24). Weather conditions appeared to have an effect on northern pike movements both on a daily and hourly basis. Field observations suggested that northern pike were more likely to move through the fishway when the sky was clear, particularly if the previous day had been cloudy. This relationship could not be quantitatively described. White sucker did not exhibit a diel pattern of fishway use.

4.1.3 Stoplog Observations

Fish passage over the stoplog bay was not observed in 2003. Water depth passing over the stoplogs (~ 20 cm) was approximately twice as deep in 2004 as in 2003. Northern pike passage through the stoplog bay twice eclipsed 200 fish/hour, on 21 April and 26 April (Figure 25). White sucker movement peaked on 26 April at 82 fish/hour. Paired sampling events of downstream fish capture and fish observed passing over the stoplog bay revealed that an equal number of fish used the fishway as used the stoplog bay (Figure 26). More northern pike used the stoplog bay in the evening than in the morning and afternoon hours (Figures 25 and 26).

4.2 Discussion

Fish swimming performance and fishway water velocity are critical factors in successful passage through a control structure. Environmental conditions directly affect the Rocky Creek fishway exit velocity and potentially impact fish passage. The exit velocity was highest when the water level on the downstream side of the control structure was low. There was a difference between the water level at the downstream side of the Rocky Creek control structure (Root Lake water level) and a control structure on Red Rock Creek (outlet of Root Lake) (Figure 5). Water may have been retained in the lower portions of Rocky Creek during the summer months due to high macrophyte density. The short term (day-to-day) variability can be attributed to wind set-up during strong wind events. When water levels downstream of the fishway were low, approximately 30% of the water column exiting the fishway was above the water level in lower Rocky Creek. This increased the fishway exit velocity due to the influence of gravity. In late fall 2003, a large congregation of minnows (emerald and spottail shiners) was observed to have difficulty entering the fishway due to water cascading over the sill of the last chamber of the fishway. The near vertical orientation of approximately 30% of the outflow into lower Rocky Creek may have impeded cyprinids entering the fishway due to high water velocity. Northern pike were observed feeding on minnows at this time. The obstruction of forage fish movement could have extended the period of time northern pike fed in the area and delayed their movement out of marsh. This scenario and may have played a role in the 2001 winterkill.

Other instances which limited upstream fish passage included beaver dams in late summer and fall, and occasional pelican (*Pelecanus erythrorhynchos*), double-crested cormorant (*Phalacrocorax auritus*) and river otter (*Lutra canadensis*) predation near the fishway exit.

Burst swimming performance is required for fish to navigate vertical slot fishways, such as the fishway at Rocky Creek, because maximum velocity at the exit of each fishway chamber extends over approximately one metre. Burst swimming speed is proportional to the length of the fish and has been conservatively estimated at 10 times fish length per second for most species, but may be as high as 20 times fish length per second for a few species (Beamish 1978). Using the conservative estimate (10 times length per second), and the maximum observed velocity of 1.88 m/s, fish greater than 188 mm should be able to enter the Rocky Creek fishway. Both regressions, numbers of northern pike and average northern pike fork length in upstream capture, were poorly correlated with fishway exit velocity. This is not surprising because fish smaller than 245 mm were not captured in the fishway, and using the 10 times body length burst speed estimate, a fish of this length would have been able to overcome velocities approximately 75% greater than the maximum velocity (1.88 m/s) recorded at the Rocky Creek control structure.

Maximum water velocity within the fishway was recorded at the fishway exit. Once an upstream-moving fish navigates the fishway exit, it should be able to overcome the water velocities within the upstream chambers. Outflow of the fishway was turbulent and it is likely that velocities lower than the maximum recorded velocity existed on the margins of the fishway entrance. This was supported by observations that cyprinids less than 10 cm in length entered the fishway.

Water temperature and swimming capacity of large fishes are positively correlated; lower water temperatures decrease sustained swimming performance of many large fishes (Jones et al. 1974). However, it is unlikely that low water temperatures were a contributing factor in the winterkill observed near the fishway in 2001, because burst swimming performance does not appear to be related to water temperature (Beamish 1978). Dissolved oxygen and swimming performance are also positively correlated, but only for cruising and sustained swimming performance. Burst swimming is dependant on anaerobic and not aerobic respiration. Therefore, low dissolved oxygen levels would not affect performance because oxygen is not required during glycolysis (Webb 1975). However, low oxygen concentrations may delay recovery after burst swimming, and could be a factor in unsuccessful passage through the control structure.

Northern pike and white sucker were observed entering the fishway without difficulty throughout the study. Results from this study corroborate data reported by Nelson (1983) and Schwalme et al. (1985) for similar situations. Scwhalme et al. (1985) reported that northern pike were more likely to use a Denil fishway than a vertical slot fishway, even though the Denil fishway had higher median and upper limit velocities than the vertical slot fishway. Both Nelson (1983) and Scwhalme et al. (1985) conducted research during the spawning period of northern pike and white sucker, thereby assessing passage of mature fish that were highly motivated to move. While results of this study indicate that northern pike over 300 mm and mature white sucker were able to use the fishway under observed conditions, smaller northern pike and cyprinids may have had some difficulty in entering the fishway. Upstream passage of juvenile white sucker and northern pike has not been studied in vertical slot fishways. Due to the increased number of juvenile northern pike in late summer and fall 2003 (Figure 20), and the high velocities recorded at the fishway in fall, it remains unclear if juvenile northern pike are able to navigate the fishway at all velocities. Low numbers of cyprinids captured in the fishway and the high number observed just below the fishway in fall 2003, indicate that they may have had difficulty ascending into the fishway. Although large numbers of northern pike were observed below the control structure feeding on these cyprinids, few northern pike were captured during upstream trapping events in late fall when emigration seemed imminent.

It is difficult to determine the effect fatigue may have from consecutive passage into the remaining nine chambers of the fishway on the overall passage success. However, Schwalme et al. (1985) reported moderate stress in northern pike after successfully ascending a Denil fishway with a median water velocity of 2.25 m/s. I observed that some fish (particularly larger fish) moved quickly from chamber to chamber of the fishway and had successfully reached the upstream exit within one to two minutes after entering the fishway. Other fish lingered in the slack water areas of the chambers, particularly the fifth chamber, which is twice as large as the others. Some fish seemed to be using the fishway as a foraging site, as it was often densely populated with minnows in the summer of 2003. Also, larger northern pike, presumed to be female, were often accompanied by a group of smaller northern pike, presumed to be males, when passing downstream through the fishway or over the stoplogs in early spring.

In 2003, white sucker were abundant in the fishway. In 2004, they were rarely encountered in the downstream trap. Only 60 white suckers were counted going over the stoplogs vs. 640 northern pike during the same observation periods. Over 88% of the white sucker moved downstream over the stoplogs on the evening of 26 April, 2004. White suckers usually spawn over a gravel or sand substrate (Stewart and Watkinson 2004) in energetic environments (flowing water or wave prone shores) (Becker 1983). There was little, if any, suitable spawning habitat in Rocky Creek or Root Lake, and it is unclear whether white sucker were moving to spawning areas further downstream, or if the fishway and adjacent rocky habitat were the spawning sites. In spring 2004, 60 white sucker were observed moving downstream over the stoplogs and only two were observed moving downstream in the fishway. This may indicate a preference for using the stoplog bay instead of the fishway when water levels are suitable.

It is possible that the peak of the 2003 northern pike and white sucker spawning runs were missed or the spawning run was significantly smaller than in 2004. The selection of sampling times in 2003 may have impacted the number of fish that were observed. As observed in 2004, more northern pike used the fishway in late afternoon and early evening than in the morning or early afternoon. Sampling in 2003 generally occurred in the late morning and early afternoon. Spawning northern pike were observed upstream of the control structure and in some years a greater proportion of northern pike that use Rocky Creek may spawn upstream of the Rocky Creek control structure.

The decrease in average size of northern pike that used the fishway from spring to fall indicated that areas below the Rocky Creek control (Root Lake and Red Rock Creek) were temporarily used by spawning fish. The smaller fish that used the fishway during summer and fall likely were juvenile fish that used this area for foraging on the abundant macroinvertebrate and minnow populations. The decrease in body size suggested that the fishway was used by large mature fish in the spring and by juvenile fish in the fall. In 2004, the study period lasted until mid-June and encompassed the spawning run and the return of spawning northern pike from Root Lake to Rocky Lake. The decrease in average length of northern pike suggested that larger individuals in the population moved earlier than smaller spawning fish; a trend documented in other northern pike populations (Billard 1996).

Walleye have been present at the control structure in the past. Anglers reported consistent catches of walleye in spring (Chris Smith, Pers. Com., Robin Reader, Pers. Com.), therefore, determining if walleye use Rocky Creek and the fishway was of particular interest. Walleye are easily detectable at night using flashlights, due to the reflection of light from their eyes. Based on my observations and the absence of walleye in the fishway catch, it is unlikely that walleye used the fishway during the study period. Walleye spawning typically occurs at 6.7 to 8.9°C with pre-spawning movements occurring as low as 1.1°C, similar to northern pike (Scott and Crossman 1973). As walleye were not captured in the fishway, it is unclear if a walleye spawning run continues to exist in this wetland complex. Although no evidence of walleye use of the Rocky Creek fishway was found, it is also possible that the walleye spawning run occurs under different environmental conditions than northern pike and white sucker, and were missed during this study. It is also possible that walleye spawn exclusively in Rocky Lake.

Based on samples collected in the spring 2004 field season, it became apparent that northern pike abundance in the fishway increased rapidly in late afternoon and early evening. If a similar diel trend occurred in fall 2003, then the presence of staged fish below the fishway in early afternoon and their absence the next day could be explained by a diel emigration through the control structure. Although Derksen and Gillies (1985) reported no difference in day versus night catches of northern pike using the Bracken Dam fishway, their own data showed higher catches during daylight hours in April and during the hours of darkness in May – July of 1984. In addition, Nelson (1983) reported that northern pike were more likely to move between 18h00 and 03h00. Nelson (1983) reported that white sucker had no diel movement pattern, however, their utilization pattern was similar to that of the Rocky Creek fishway in being short and intensive. Schwalme et al. (1985) reported higher use of vertical slot fishways between 12h00 and 24h00 than 0h00 and 12h00 for northern pike, white sucker, and spottail shiner. During the daily multi-capture events during spring 2004 sampling, it was apparent that northern pike had a distinct diel pattern for both upstream and downstream movement in the fishway as well as downstream movement at the stoplog bay. Northern pike moved at the same time of day through the fishway and over the stoplogs. Paired sampling events at the fishway and the stoplog bay indicated approximately equal use of both structures. Based on my observations, stoplog bay use was more likely when water depth increased over the stoplogs. In 2003, fish were not observed moving downstream over the stoplogs. However, because observations were not made during peak movement hours, there may have been movement over the stoplogs that were not observed.

Finally, it should be noted that water levels and flow in Rocky Creek were low in 2003 and high in 2004. It is possible that under more extreme high and low water conditions, fishway use could be substantially different from that reported here. Increased movement of northern pike through the fishway (and over the stoplogs) in 2004 compared to 2003 may simply be the result of higher water levels that year. In very high water years, it is possible that other fish species present in Rocky Lake may use the fishway to access the Reader-Root wetland complex. Fish diversity increases after flood events (Theiling et al. 1999). Young-of-the-year fish are most susceptible to downstream drift (Harvey 1987), and subsequently, may colonize downstream habitats. Flooding events may subsequently change the fish species composition in areas downstream of the Rocky Creek control structure. The ability of these fish species to move upstream through the fishway would need to be assessed.

4.3 Fish use of the Reader-Root Wetland Complex with Special Consideration for Northern Pike

4.3.1 Environmental Conditions

In 2003, maximum water temperatures and minimum dissolved oxygen levels in Root Lake, Red Rock Creek, and Rocky Creek varied among water bodies. The highest water temperature recorded from the temperature data logger located in the middle of Root Lake was 24.8°C on 14 August (Figure 27). The maximum temperature recorded from the YSI meter at the same location was 23.0°C on 24 July. The minimum dissolved oxygen was 6.6 mg/l recorded on August 20 (Figure 28). In Red Rock Creek, a maximum temperature of 25.4°C recorded with the YSI meter was reached on 17 August, similar to the temperature recorded in Root Lake. A low summer oxygen level of 1.8 mg/l was recorded on 18 August (Figure 29), substantially lower than the oxygen level in Root Lake during the same time period. On 17 December, water temperature was 0.3°C and the dissolved oxygen was 0.5 mg/l (Figure 29), the lowest temperature and dissolved oxygen recording during this study. In Rocky Creek, the highest water temperature recorded at the control structure from the YSI meter was 24.6°C on July 23 (Figure 11). The lowest summer oxygen concentration recorded at the control structure from the YSI meter was 3.2 mg/l on 20 August. The lowest spring dissolved oxygen levels were 2.9 mg/l recorded on 23 April, 2003 (Figure 11) and1.7 mg/l recorded in 8 April, 2004 (Figure 12).

4.3.2 Species composition

Six species (northern pike, walleye, white sucker, emerald shiner, spottail shiner, and blacknose shiner) were captured in the Reader-Root wetland complex and an additional two species (fathead minnow (*Pimphales promelas*), and brook stickleback (*Culaea inconstans*)) were observed (Table 3). The fishway trap yielded the most species (n = 5) of the four capture techniques, while angling yielded the least (n = 1). Results are presented for each capture method, followed by results of northern pike population analysis.

4.3.2.1 Fishway Capture

Fish sampling at the Rocky Creek fishway yielded a greater diversity of species than other sampling techniques employed in this survey (Table 4). The technique also proved to be most efficient at capturing northern pike and white sucker. Cyprinids, when present, were not fully contained by the screens and not quantified. In 2003, cyprinids included emerald shiner, spottail shiner, and blacknose shiner. Schools of cyprinids were present in the fishway for the majority of sampling events in the summer of 2003, and often did not move upstream or downstream past the control structure during sampling activities. Only a few small schools of emerald shiner were observed in the fishway in mid-June 2004.

4.3.2.2 Gill Net

Three species were captured in gill nets within the Reader-Root wetland complex (Table 4). Northern pike comprised the highest proportion of the catch (n = 366, 98.4%), followed by white sucker (n = 4, 1.0%), and walleye (n = 2, 0.5%). In 2004, only northern pike (n = 115, 95.8 %) and white sucker (n = 5, 4.2%) were captured in gill nets (Table 4).

One walleye was captured on 29 May and one on18 August in 2003, both in the north-west margin of Root Lake. Both were mature males with fork lengths of 480 mm and 500 mm, and aged 8 and 10 years old, respectively. Fork lengths of white sucker captured in gill nets ranged from 410 mm to 590 mm in 2003, and 405 mm to 465 mm in 2004.

Gill net catches of northern pike differed between sites on Root Lake. In each of the sampling periods from May to October, 2003, the north-west sampling site yielded more northern pike than any other sampling location (Figure 30). This trend was repeated in June 2004, with the exception of the north-east sampling site catching more northern pike on the second occasion (Figure 31). The average fork length of northern pike varied by location and time in 2003; smaller individuals were captured in September (Figure 32). In June 2004, there was an increase in average fork length of northern pike from the first gill netting occasions to the second occasion (Figure 33). The standard deviations for the average northern pike fork lengths are presented in Appendix 2. Twelve northern pike ranging in size from 335 mm to 425 mm were netted from Red Rock Creek, near the South Reader Lake inlet. Gill net sets in the deep water portion of North Reader Lake did not yield any fish. The gill net set in December 2003 in Red Rock Creek did not yield any fish.

4.3.2.3 Trap Net

Northern pike, spottail shiner, and emerald shiner were captured from 12 trap net sets in Red Rock Creek and Root Lake between 27 May and 23 July 2003 (Table 5). Ten YOY northern pike were captured from sets in the northwest and southeast sections of Root Lake, as well the downstream portion of Red Rock Creek. The lengths of northern pike captured in the trap net along with date and location of capture are presented in Table 5.

4.3.2.4 Test Angling

Eleven northern pike, ranging in size from 330 mm to 700 mm, were captured in Red Rock Creek and Rocky Creek by test angling (Table 4). No fish were captured in the deep-water portion of North Reader Lake.

4.3.3 Northern Pike Population

In this study, a total of 1,696 northern pike were captured in the Reader-Root wetland complex. Between 25 April and 26 October, 2003, 744 northern pike were captured using four capture methods (Table 4). Most were captured in Root Lake (n = 366, 49.2%) and at the Rocky Creek fishway (n = 349, 46.9%). Between 19 April and 16 June, 2004, 952 northern pike were captured; 837 at the Rocky Creek fishway and the remaining 115 in Root Lake. The average fork length decreased from spring to fall 2003: 508.9 mm (n = 236) and 385.9 mm (n = 110), respectively (Table 6). The average fork length was 547.7 mm (n = 336) for spring 2004. A summary of length-weight relationships, mean lengths, and length ranges are presented in Table 6. Length-frequency distributions are presented in Figures 34 to 36 for spring 2003, fall 2003, and spring 2004, respectively.

The average age of northern pike decreased from the spring sampling period to the fall in 2003. The average age of northern pike in spring and fall 2003 was 4.9 yr (n = 236), and 1.6 yr (n = 110), respectively. The average age in spring 2004 was 5.5 yr (n = 405). The age-frequency histograms of northern pike captured in spring of 2003, fall 2003, and spring 2004 are presented in Figures 37 to 39. The age-specific growth rate of northern pike in the Reader-Root wetland complex showed a consistent growth rate from year three to seven and an increased growth rate after seven years. The age-specific mean length with standard deviations for spring 2003 and spring 2004 are presented in Figure 40. The age-specific mean length with standard deviations for fall 2003 is presented in Figure 41. Plotting the average growth of northern pike between 2003 and 2004 seasons confirmed the increased growth rate of fish in the older age classes (Figure 42). The von Bertalanffy growth curve (VBGC) for northern pike captured in spring 2003 (Figure 43) showed a higher growth rate in earlier ages, and a shorter expected maximum length than northern pike captured in spring 2004 (Figure 44). The VBGC for northern pike captured in spring 2004 (Figure 44) showed a lower growth rate in earlier ages, a faster growth rate in later years, and a larger expected maximum length, compared to northern pike captured in spring 2003 (Figure 43). The VBGC equations were:

$L_t = 924.1605(1\text{-exp}^{-0.130223(t+2.2437)})$ for spring 2003, and

$L_t = 1478.149(1\text{-exp}^{-0.80993(t-0.017953)})$ for spring 2004.

Survival estimates varied between years within the same method and between methods in the same year (Table 7). The Robson – Chapman annual survival estimate for age ranges used in both 2003 and 2004 varied between 47% and 57%. The survival estimates from the regression method range from 56% to 65% for spring 2003 and 61% to 84% in spring 2004 depending on the number of years included in the analysis (Table 7). The spring 2003, and 2004 catch curves used to calculate survival are presented in Figure 45.

The contents of 366 northern pike stomachs were examined from fish captured in gill nets in Root Lake. In 2003, of the northern pike which had identifiable stomach contents, 62.5 % had invertebrates, while 33.7% had consumed other northern pike. In 2004, of northern pike which had identifiable stomach contents, 57.3% had invertebrates, while 41.2% had consumed other northern pike (Table 8). Invertebrates were primarily amphipods (freshwater shrimp), but included species from orders Hemiptera and Hirudinea. Prey selection changed with increased length of northern pike (Figure 46). Length-frequency histograms of spring 2003 and spring 2004 pike with invertebrates and northern pike as main components of stomach contents are presented in Figures 47 and 48. In 2003, the mean length of cannibalistic northern pike was 418 mm (n = 35), while the mean length of northern pike that were feeding on invertebrates was 339 mm (n = 65). In 2004, the mean length of cannibalistic northern pike was 593 mm (n = 28), while the mean for northern pike feeding on invertebrates was 415 mm (n = 39). In 2003, the mean length of northern pike feeding on other northern pike was significantly greater (rank-sum test, U = 431.0, $p < 0.001$) than those feeding on invertebrates. In 2004, the mean length of northern pike feeding on other northern pike was significantly greater (rank-sum test, U = 121.0, $p < 0.001$) than those feeding on invertebrates.

More female than male northern pike were captured in gill nets set in Root Lake in both years of this study. The female to male ratio was 1:0.63 (61.6% to 38.6%) in 2003, and 1:0.82 (55.5 % female 45.5% male) in 2004. The length-frequency histograms of male and female northern pike are presented in Figure 49 for spring 2003, and Figure 50 for 2004.

4.3.3.1 Movement

A total of 463 northern pike were tagged at the Rocky Creek fishway during this study. Of the 188 northern pike tagged in 2003, 46 were tagged moving in a downstream direction, and 142 were tagged moving upstream. None of the fish tagged moving downstream were re-captured in the fishway in 2003. Anglers re-captured three northern pike in the north basin of Rocky Lake in 2003 (Table 9). In 2004, 274 northern pike were tagged, 95 of which were deployed on fish moving downstream, and 179 moving upstream. Four fish tagged when moving downstream were re-captured moving upstream. The length of time these fish remained downstream of the Rocky creek control structure ranged from 10 to 22 days. One northern pike tagged moving upstream through the fishway in spring 2003, was re-captured moving upstream through the fishway in spring 2004. In 2004, two tagged northern pike were re-captured by anglers in the north basin of Rocky Lake. One fish swam the approximately 25 km distance from the Rocky Creek fishway, to the north basin of Rocky Lake, in 14 days.

4.4 Discussion

Environmental conditions in the Reader-Root wetland complex in 2003 and 2004 were generally compatible with the physical requirements of northern pike. However, high summer temperatures and low dissolved oxygen levels in summer and in winter (particularly in Red Rock Creek) were likely near the tolerances of northern pike. Some summer kill may have occurred in August of 2003, when several dead northern pike were observed in Root Lake. On the same date, several dead white sucker were observed in the upper portions of Rocky Creek. The lowest oxygen recording came from Red Rock Creek in December 2003. No fish were captured in gill nets set in the creek at that time. I have hypothesized that fish may be able to seek refuge from low oxygen concentrations in deep water areas of the marsh such as the North Reader Lake cut-off. Fish were not captured in likely refuge areas during the summer of 2003, despite gill net and angling efforts. Fish sampling in the winter of 2003 was not conducted in the relatively deep North Reader Lake cut-off.

The number of fish species in the Reader-Root wetland complex (eight) is less than that reported for the Saskeram wetlands (eight large species documented; small species composition was not assessed) (Derksen and Gillies 1985) and the Netley-Libau Marsh (25 species) (Janusz and O'Connor 1985). This may be due to the connectivity of those wetlands to rivers that have large species assemblages. Both the Saskatchewan and Red Rivers have a larger proportion of riverine fish species than Rocky Lake. The results of this study are similar to those of Derksen and Gillies (1985); the fish population in Saskeram wetlands was also dominated by northern pike. This differs from Janusz and O'Connor (1985), who reported that the summer fish community of the Netley-Libau Marsh was dominated by goldeye, bullhead (*Ameiurus* spp.), common carp, sauger (*Sander canadensis*), yellow perch, freshwater drum (*Aplodinotus grunniens*), and shiner minnow species.

The abundance of northern pike in each of the four sampling locations in Root Lake generally declined from June to October, 2003. The exception to this trend was the high number recorded in October 2003 at the north-west margin of the lake. This may be due to its proximity to the outlet of Rocky Creek. The increased abundance at this location may be a result of staging to emigrate from Root Lake. A second explanation may be that the higher northern pike abundance was in response to a food source. Large numbers of cyprinids had congregated below the Rocky Creek control structure and in the lower reach of Rocky Creek.

Fish used the Reader-Root wetland complex primarily for spawning and rearing, however, based on analysis of stomach contents, mature and juvenile northern pike also used the area for foraging. Based on average fish length, the majority of northern pike and white sucker moving downstream through the fishway were mature. Northern pike were observed spawning upstream of the Rocky Creek control structure in spring 2003, and under the ice in the lower reach of Rocky Creek in spring 2004. Young-of-the-year northern pike were observed in Rocky Creek, Root Lake, and Red Rock Creek. Young-of-the-year northern pike were also found in the diet of juvenile and adult northern pike in Root Lake. Large pike were present throughout the open water period in Root Lake and Rocky Creek in 2003. However, the number of large northern pike in the fishway trap decreased from spring to fall (Figures 20, 21). The decreasing average length of northern pike was not clearly evident from the gill net catch in Root Lake, and may have been obscured by the rapid growth of individual northern pike over the course of the summer.

Many white sucker moved over short time periods in Rocky Creek. Most of these fish were in spawning condition, so these fish were probably moving downstream through the Rocky Creek control to spawn. The short duration of stay (Figure 14) may be due to the lack of suitable spawning habitats (e.g., gravel, sand, or boulders) (Stewart and Watkinson 2004), which are absent or rare in the Reader-Root wetland complex. A second explanation for the movement of white sucker during and shortly after northern pike spawning is that this movement was based on foraging for pike eggs, although the relative importance of fish eggs in the diet of white sucker is controversial (Scott and Crossman 1973).

Common carp have been present in the Saskatchewan River since 1958 (McCrimmon 1968), and are able to enter the Reader-Root wetland complex from the Saskatchewan River in high-water years, when the river backfloods into the marsh. Common carp were not captured in this study, but YOY were captured and adults observed on several occasions near the Rocky Creek control structure by a commercial baitfish operator in previous years (Terry Jaeger, Pers. Comm.). Common carp negatively influence wetland ecosystems by increasing suspended sediment, and by reducing primary production causing a reduction in fish species diversity (King and Hunt 1967).

In the past, the control structure had walleye abundance high enough to attract recreational fishers (Chris Smith, Pers. Comm., Robin Reader, Pers. Comm.) and it was anticipated that walleye would be captured. It is unclear whether the two walleye captured in Root Lake during 2003 indicated walleye were now rare in the system, or opportunistically move into the system when water levels are higher than documented in the present study.

Cyprinids that resided in the fishway were likely attracted by the amount of algae or plankton stirred in the water column by turbulence in the chambers. They did not make significant movements for hours, suggesting drift feeding behaviour. Northern pike, smaller ones in particular, were observed to enter the fishway from the downstream side, to apparently forage on the cyprinids, and then return to the downstream side of the control structure. Observations of brook stickleback and fathead minnow in December 2003 in Red Rock Creek increased the number of species that were present, but it was not possible to quantify their abundance.

This survey was not intended to provide a complete species list for the Reader-Root wetland complex. Sampling methodology was not sufficient to capture all sizes of fish present in all habitats (e.g., small benthic fish). In general, species diversity increases with increasing effort over space, time, and method of sampling (Krebs 1989). This study occurred when water levels and flow in Rocky Creek were relatively low in 2003 and near normal in 2004. It is possible that both lower and higher water levels could result in different species assemblages. In high water years, other fish species present in Rocky Lake and the Saskatchewan River may use the Reader-Root wetland complex.

Differences in the northern pike population parameters of average lengths and condition factors between 2003 and 2004 are not likely biologically significant. Most of the variation can be explained by commencing sampling earlier in the season (i.e. larger fish move earlier) and sampling at the time of day of highest fish movement at the fishway in 2004. The average condition factor of northern pike in the Reader-Root wetland complex (0.72) was similar to that of Rocky Lake northern pike (0.70) (Leroux 1984), but lower than that reported from the Saskeram wetlands (0.77) (Derksen and Gillies 1985).

Northern pike captured in the fishway during the two week period following the spawning run appeared to have a higher rate of abrasions, infections, and injuries than at other capture periods. During the peak of upstream movement (post-spawn) through the fishway, some northern pike attempted to jump over the stoplogs (height of approximately

1.0 m) in the operating stoplog bay, but rarely succeeded. Some of the northern pike that leapt toward the stoplogs collided with the stoplogs and the attached steel pegs. Other northern pike that attempted to jump the stoplogs were caught in the turbulence below the control structure and were washed against the stoplog pegs. Although empirical evidence is lacking, I believe that some of the wounds that I observed originated from collisions with the stoplog pegs. However, viral and bacterial diseases, such as "red sore" and lymphosarcoma, also produce similar skin erosions and sores in northern pike (Scott and Crossman 1973, Stewart and Bernier 1999) and may be responsible for the observed wounds.

The growth rate of northern pike in the Reader-Root wetland complex was similar to that for age 1-3 northern pike at the Netley-Libau Marsh (Janusz and O'Connor 1985), and for age 4-9 fish at the Saskeram Marshes (Derksen and Gillies (1985). The northern pike population of the Reader-Root wetland complex had a greater frequency of individuals age eight and older than compared to the Saskeram Marshes. The growth rate from age seven to ten was higher than most earlier age increments, a trend also observed in the Saskeram (Derksen and Gillies 1985) and Netley-Libau Marshes (Janusz and O'Connor 1985). These patterns made calculating the growth curves difficult, because growth curves are based on the theory that indeterminate growth rates diminish at a predictable rate. The von Bertalanffy growth equation has limitations, and much has been written regarding its use (for example, Roff 1980, Szalai 2003). Based on growth curves for northern pike in the Reader-Root wetland complex, older fish grow to a greater length than most northern pike populations [presented in Figure 4-5 in Casselman (1996)]. The growth of northern pike (mean length at age) for the two years of this study, 1983 and 1984 data for Saskeram Marsh (Derksen and Gillies 1985), and 1981 and 1982 data for the Netley-Libau Marsh (Janusz and O'Connor 1985) is presented in Figure 51. The lengths at age nine and ten, calculated from the spring 2003 and 2004 data, were greater than for the other two data sets (Figure 51). The asymptote calculated for the spring 2004 data (1478 mm) was likely too high. A better asymptote might be 1190 mm (total length), the longest northern pike captured in Rocky Lake of (Government of Manitoba Conservation web site http://www.travelmanitoba.com/huntfish/master_angler_search.html). Casselman et al. (1999) corroborated an asymptote calculated for muskellunge captured in 12 Ontario lakes with the angling record for the corresponding lake.

Northern pike maximal size-at-age and growth curves reported in this study were higher than those previously reported for northern pike caught in experimental index gill nets in Rocky Lake (Leroux 1984, Lysack 2004). This may be due to the capture of spawning fish in this study. Spawning fish may be larger than the average for the population, and therefore may over-represent larger size classes and older age classes. The length data in this report correspond well with the size distribution of northern pike captured by anglers in the 2002 creel census at Rocky Lake (Lysack 2004). Since 2003, seven northern pike from Rocky Lake have exceeded 1040 mm (total length), a size which is considered a "Master Angler" or trophy sized fish in Manitoba.

The diet of northern pike captured in gill nets in Root Lake was primarily amphipods and other northern pike. More large northern pike remained in Root Lake after spawning in 2004 than in 2003, which corresponded to increased cannibalism in 2004

(Figures 47, 48). The cool spring temperatures in 2004 also could have delayed primary production, and fewer invertebrates were present compared to the same time period in 2003. In 2003, the flesh from small northern pike tended to be tainted orange, supposedly from a diet of amphipods (Shahidi et al. 1998).

The annual survival rate of adult northern pike captured in this study ranged from 47% to 84%, depending on year and method of calculation, but were generally near 50% to 60% (Table 7). This is consistent with a low rate of exploitation, if a 50% natural adult mortality is considered a typical annual survival rate for an unexploited population (Raat 1988). A similar northern pike survival rate (59%) has been reported at Lac la Ronge, Saskatchewan (Koshinsky 1979).

The gender ratio of northern pike captured in gill nets during 2003 and 2004 was similar to that reported by Leroux (1984), but different from Derksen and Gillies (1985) who reported a higher proportion of males relative to females. Gender bias toward males is sometimes encountered in spawning aggregations, because males usually mature before females (Raat 1988). In both 2003 and 2004, females out-numbered males in the largest length categories of the length-frequency distribution.

After spawning, some northern pike left Root Lake within 14 to 21 days after entering the lake. This agrees with spawning run durations reported in Scott and Crossman (1973). Derksen and Gillies (1985) reported northern pike leaving the Saskeram Marshes soon after spawning, with a small increase in emigration as marsh water temperatures increased in summer. A mass emigration from Root Lake by YOY northern pike was expected based on observations in Saskeram Lake (Derksen 1989). Northern pike emigration in that study coincided with a drop in temperature below 10°C, and northern pike emigration ended by the time water temperature fell to 4.0°C. Although northern pike were observed congregated below the Rocky Creek control structure on several occasions in September and October 2003, no mass emigration was observed. The last upstream fishway trapping in 2003 was conducted on 20 October (5.2°C), 23 October (5.0°C) and 26 October (1.6°C). No fish were captured on both 20 and 26 October, and two small northern pike were captured on 23 October. Northern pike were feeding on cyprinids below the control structure and were abundant in the lower portion of Rocky Creek. However, these fish were not moving upstream through the fishway.

Tagged northern pike were rarely recaptured in the fishway, either moving downstream to upstream in the same year, or between years of this study. This could be because northern pike spawn in other locations in and around Rocky Lake in different years, depending on water levels. This explanation would contradict the hypothesis that northern pike exhibit spawning site fidelity. A second explanation may be that large pike such as the individuals tagged during the spawning run in Rocky Creek are heavily exploited in Rocky Lake and anglers may not have known about the project or failed to report tag returns. A third explanation is a high rate of tag loss. In 2004, I examined fish for evidence of tag loss (scars) and fin clips, and found no evidence to support this explanation. A fourth explanation is that the northern pike population using Rocky Creek in spring is large. A large population size would decrease the probability of recapturing tagged individuals. Although all four explanations are plausible, it is my opinion that a large number of northern pike use the Reader-Root wetland complex, therefore reducing the probability of recapturing tagged fish..

5.0 MANAGEMENT RECOMMENDATIONS AND FUTURE RESEARCH NEEDS FOR FISHERIES RESOURCES IN THE READER-ROOT WETLAND COMPLEX

5.1 Introduction

Wetlands are among the most diverse ecosystems in North America (Environment Canada 1993). Across western Canada, drainage and land reclamation have drastically reduced both the quantity and quality of these habitats (Mitsch and Gosselink 2000). Large contiguous wetlands, such as the Saskatchewan River Delta, are critical habitats for a number of species dependant on semi-aquatic and shallow-water environments. Results from this research will be used as a basis for developing recommendations to manage wetlands in the Reader-Root wetland complex to benefit fish resources, as well as other wetland species. The successful management of these resources will also benefit the people who use the Reader-Root wetland complex for recreation or commercial purposes.

For the Reader-Root wetland complex to support fish communities and other wetland species, it must be in a healthy state. Wetland health is dependant upon seasonal, annual, and multi-annual cycles of water level variation (Mitsch and Gosselink 2000). Appropriate management of controlled wetlands should be based on ecologically relevant management of water levels as well as periodic inspection of control structures to ensure proper function.

5.2 Operation and Maintenance of the Rocky Creek Fishway

Juvenile and adult northern pike, and adult white sucker were able to use the fishway under observed conditions. However, it remains unclear if small fish (cyprinids and YOY northern pike and white sucker) were able to move upstream through the fishway. In late fall 2003, a large school of cyprinids had congregated below the fishway concurrent to relatively high water velocities (~1.8 m/s) at the exit of the last chamber of the fishway. Some cyprinids were attempting to enter the fishway, but very few were observed in the fishway during sampling periods. Northern pike were observed to be feeding on the school of cyprinids at this time. When water levels downstream of the fishway were low, approximately 30% of the water column exiting the fishway was above the water level in lower Rocky Creek. This increased the fishway exit velocity due to the influence of gravity. It is conceivable that the barrier to cyprinid emigration may have delayed the northern pike movement out of marsh in fall 2001. The combination of high water velocity and partially cascading water column is not conducive to fish passage. A survey of the sill heights in the fishway, as well as other elevations of critical components of the structure should be undertaken to determine if the elevation of the fishway chambers has changed since installation. If water elevations have changed and are determined to cause high velocities that affect fish passage, the water level of the lower reach of Rocky Creek should be elevated to slow water exiting the fishway. This could be accomplished by installing a rock weir adjacent to the fishway exit. Alternatively, the water level of Root Lake could be maintained at a higher level to ensure backwater effects prevent cascading water flow out of the fishway.

The design of the Rocky Creek control structure permits almost maintenance-free operation when water levels are in the normal range. However, the fishway portion of the control structure can become blocked periodically from beaver activity. Beaver activity peaked in late summer and early fall 2003, when on several occasions, the upstream portion of the fishway was blocked to the point of preventing fish passage. Blockages were a combination of mud, wood, and roots masses of emergent vegetation. Fish inhabit Root Lake, Red Rock Creek, and Rocky Creek throughout the open water period. Fish in wetlands are susceptible to summerkill as a result of high water temperatures and low oxygen levels (Barica and Mathias 1979). Because northern pike and other fish species can detect changes in oxygen concentrations, low oxygen levels may trigger an exodus of fish from Root-Reader complex. Although large migrations of fish were not noted in summer and fall 2003, if summerkill conditions were eminent in Root Lake, fish might emigrate from the marsh to upstream areas with higher dissolved oxygen. Periodic inspection and maintenance of the fishway should be undertaken, and scheduled more frequently during long periods of hot, calm weather, to ensure fish can move freely to more suitable habitats. A significant summerkill could result if fish were impeded from leaving Root Lake.

Periodically, islands (some up to 0.25 ha) of floating emergent vegetation (mostly *Typha* spp.) would drift toward the upstream margin of the control structure. A floating wooden barrier prevented the vegetation from drifting up against the structure. However, occasional strong west winds pushed a portion of the vegetation onto the barrier. The barrier would then prevent the vegetation from drifting away from the structure. While it is unclear if the vegetation has an effect on fish passage, it has been implicated as a factor in the winterkill that occurred in 2001 near the control structure (Lysack 2004).

Northern pike captured in the fishway in the two week period following the spawning run had a higher rate of abrasions, infections, and injuries than at other capture periods. During the peak of upstream movement (post-spawn) through the fishway, some northern pike attempted to jump over the stoplogs (height of approximately 1.0 m) in the operating stoplog bay, and collided with the stoplogs and the steel pegs that are used to move them. Some of these injuries may originate from collisions with the stoplog pegs. However, viral and bacterial diseases, such as "red sore" and lymphosarcoma, also produce similar skin erosions and sores in northern pike (Scott and Crossman 1973, Stewart and Bernier 1999) and may also be responsible for the wounds observed. The steel stoplog pegs should be covered to protect fishes from injury. In a preliminary trial, automotive radiator hose was fitted tightly over the pegs, and permitted the logs to be manipulated without further modification of equipment. This preventative measure has not yet been properly tested, but its effectiveness should be assessed at the Rocky Creek fishway. This application, if proven successful, should be employed at other structures where fish come into contact with stoplogs.

5.3 Water Management

The location of the Rocky Creek control structure allows for experimental operation to determine the effect on fish movements, as well as temperature and dissolved oxygen trends in Rocky Creek, Root Lake, and Red Rock Creek. Increasing flows in Rocky Creek in winter may draw water with higher dissolved oxygen from Rocky Lake. Dissolved oxygen in measured in December 2003 decreased from 7.8 mg/l at the control structure to 0.5 mg/l in Red Rock Creek. Experimental releases of water through the control structure, with downstream monitoring of dissolved oxygen, may prove useful in reducing winterkill in some portions of the wetland. Summer releases may also yield information on oxygen-rich water dispersion and may reduce severity of summerkill. Any experimental water releases should be carefully noted, along with other environmental conditions (particularly dissolved oxygen levels in Rocky Creek, Root Lake, and Red Rock Creek), and presence and activity of any fish present at the fishway. Over time, enough data may be gathered to determine some cause-and-effect relationships between environmental variables and fish activity. Adaptive management strategies could be applied to better understand the interaction of variables in the system. Other effects on winter water releases must also be considered. For example, experimental water releases in winter could create hazardous ice conditions, affecting the safety of snowmobile traffic, as well as increasing the risk of moose drowning in the partially frozen creek. The value of experimental winter water releases of water must be weighed against these concerns.

Water level management may be used to influence the spawning success of northern pike in the Reader-Root wetland complex. If the objective is to produce a strong year class of northern pike, water levels should rise to inundate terrestrial sedges and grasses (preferred spawning habitat) by 20 cm to 40 cm prior to spawning (Casselman and Lewis 1996). This water level should be maintained for four to six weeks to allow hatching and dispersal of fry (Casselman and Lewis 1996). Water levels may be lowered earlier if water temperature rises quickly because egg maturation rate is positively correlated to water temperature (Inskip 1982). The four to six week inundation period allows the eggs to hatch and for fry to absorb their yolk sack and become mobile. After they are mobile, northern pike fry require moderately dense stands of aquatic vegetation (Casselman and Lewis 1996). Submergent vegetation is a basic habitat requirement, but a mixture of submergent and emergent vegetation is optimal for foraging and escape from predators. The availability of rearing habitat is the most important factor to year class strength (Bry 1996). After submergent vegetation is established in water of 0.5 m to 1.5 m depths, water levels can be allowed to slowly recede, provided submerged vegetation is available. A gradual reduction of water levels combined with rising water temperatures and falling dissolved oxygen levels may trigger northern pike fry to emigrate from the wetland (Derksen 1989). Derksen and Gillies (1985) reported a mass fall emigration of YOY northern pike from the Saskeram marshes, where water was flowing out of the marsh into a deeper water habitat. It is unknown how YOY northern pike may respond to water fluctuations, when an upstream migration is required to reach the refuge of Rocky Lake. Further research is required to determine if a migration of YOY northern pike occurs from Root Lake through the Rocky Creek fishway. An intensive survey, similar to the sampling of spring 2004, should be undertaken from mid-September to freeze-up. The protocol should include sampling at various time of the day to determine if a deil pattern of movement exists in fall, as was observed in spring.

Long-term objectives of maintaining a healthy wetland (and therefore a healthy northern pike population) require that water levels be managed in ecologically relevant cycles of flooding and drawdown. Ecologically relevant fluctuations in water levels also provide a diversity of habitats for other fish species, as well as other wetland species. Preferred habitats for all species in the ecosystem will not be present every year, however, a diversity of water levels is instrumental in creating a diversity of habitats, and therefore, a diverse species composition. Because northern pike are heavily dependant on aquatic vegetation, water management should foster the development of submergent, emergent, and terrestrial vegetation. In low water years, it is obvious that production of a strong year class of pike may not be possible, because flooded terrestrial vegetation will not be available. However, a healthy pike population is not dependant on strong recruitment every year. In light of the recreational use of fish resources in Rocky Lake, the annual production of large quantities of YOY northern pike may not be desirable (Lysack 2004). The northern pike population in Rocky Lake is dominated by smaller individuals which compete with walleye for food (Lysack 2004). Northern pike populations compensate for weak year classes by increasing growth rate and decreasing age of maturity (Casselman and Lewis 1996). Low water levels are required seasonally and over several years to allow development of vegetation types preferred by northern pike. Northern pike populations respond rapidly to inundation of new habitat by increasing growth and recruitment rates (Bodaly and Lesack 1984).

Northern pike disperse from the Reader-Root wetland complex into Rocky Lake, where they are an important component in the recreational fishery. Therefore, it may be desirable to quantify the importance of this wetland to the northern pike population of Rocky Lake. Although not demonstrated in this study, northern pike have been proven to exhibit spawning site fidelity, as well as natal site fidelity (Miller et al. 2001). This would allow for genetic divergence amongst northern pike that spawn in different tributaries and margins of Rocky Lake. If spawning site and natal site fidelity does occur at Rocky Creek, a study could be done to determine sub-populations of northern pike in Root Lake. DNA samples could be taken from northern pike at the Rocky Creek fishway, as well as other suspected spawning areas, such as Bignell Creek. If the DNA samples from these groups of northern pike were distinct, an index gill netting program in Rocky Lake similar to one conducted in 1962, 1981, 1991, and 1999 could be conducted to gather samples of northern pike DNA. Through analysis of DNA, it may be possible to determine what proportion of northern pike in Rocky Lake originates from each spawning site. This would provide valuable information for the management of the wetlands for fish resources and the northern pike population of Rocky Lake.

A more detailed survey of the forage fish use the Reader-Root wetland complex should be conducted. I did not encounter large quantities of forage, although, in some years, they are abundant (Terry Jaeger, Pers. Com.). The forage fish study should include their distribution in the wetland as well as their diet and their importance as a food source for larger fish, birds, and mammals.

Further research is needed to determine which species enter the Reader-Root wetland complex and what their relative abundance and residency times are when water levels in the Reader-Root wetland complex are high and the South Reader control is opened to the Saskatchewan River. Walleye were once abundant at the Rocky Creek control structure (Chris Smith, Pers. Com., Robin Reader, Pers. Com.) and the fact that they were not encountered at the fishway and very rarely encountered in Root Lake may be related to the connection with the Saskatchewan River during periods of higher water. A subsequent gill net survey in Root Lake, further sampling at the Rocky Creek fishway, and a creel survey on Rocky Lake may indicate the nature of fish use of the Reader-Root wetland complex and Rocky Lake when the system is connected to the Saskatchewan River.

6.0 SUMMARY

The following is a list of the major findings of this study.

- A total of eight fish species were captured or observed in the Reader-Root wetland complex: northern pike, white sucker, walleye, emerald shiner, spottail shiner, blacknose shiner, fathead minnow, and brook stickleback. Five species were captured at the Rocky Creek control structure: northern pike, white sucker, emerald shiner, spottail shiner, and blacknose shiner.
- Northern pike and white sucker were observed to successfully move upstream through the Rocky Creek fishway under observed fishway exit velocities.
- Small fish (minnows) were not found moving upstream through the fishway when velocities were high (1.8 m/s) in fall 2003, despite their apparent attempts to do so.
- Northern pike was the most numerous species captured at the fishway and in gill nets in Root Lake.
- Both northern pike and white sucker used the fishway at rates of up to 200 fish/hour.
- Fish use of the Rocky Creek fishway was highly variable; catch rates of zero northern pike/hour and over 80 northern pike/hour occurred on the same day in April, 2004.
- In spring 2004, northern pike moved more frequently in the late afternoon and early evening than early in the afternoon, morning, or at night.

- In spring 2004, northern pike and white sucker used the stoplog bay for downstream movement over the Rocky Creek control structure at similar rates as downstream passage through the fishway.
- Spawning northern pike remain downstream of the Rocky Creek control structure for two to three weeks.
- Northern pike moving upstream at the Rocky Creek control structure dispersed into the north basin of Rocky Lake in as little as two weeks.
- The northern pike population that used the Reader-Root wetland complex had a wide range of sizes and ages, and individual fish exhibited above average growth rates compared to other populations.
- In Root Lake, cannibalistic northern pike had a significantly longer average fork length than northern pike that were consuming invertebrates.
- Northern pike in the Reader-Root wetland complex had an annual adult survival of 47% to 58% (Robson-Chapman method).
- Low oxygen concentrations were recorded in Red Rock Creek in August and December 2003 and apparent summerkill conditions occurred in August, 2003.

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TABLES AND FIGURES

Table 1. List of common and scientific names of fish captured in the Rocky Creek fishway.

Common Name	Scientific Name
Northern Pike	*Esox lucius*
White Sucker	*Catostomus commersonii*
Emerald Shiner	*Notropis atherinoides*
Spottail Shiner	*Notropis hudsonius*
Blacknose Shiner	*Notropis heterolepis*

Table 2. Total numbers of fish captured at the Rocky Creek control structure.

Year / Species	Fishway		Stoplog bay
	Downstream	Upstream	
2003			
Northern Pike	46	303	NO
White Sucker	162	172	NO
Spottail Shiner	**	**	NO
Emerald Shiner	**	**	NO
Blacknose Shiner	**	**	NO
2004			
Northern Pike	243	594	640
White Sucker	2	362	60
Emerald Shiner	**	**	0

** Observed but not quantified - no direction of movement detected
NO – No observations

Table 3. Species captured in the Reader-Root wetland complex during 2003 and 2004.

Common Name	Scientific Name
Northern Pike	*Esox lucius*
White Sucker	*Catostomus commersonii*
Walleye	*Sander vitreus*
Emerald Shiner	*Notropis atherinoides*
Spottail Shiner	*Notropis hudsonius*
Blacknose Shiner	*Notropis heterolepis*
Fathead Minnow *	*Pimphales promelas*
Brook Stickleback *	*Culaea inconstans*

* Observed in December 2004 in Root Lake and Red Rock Creek

Table 4. Number of fish captured by species and capture technique in the Reader-Root wetland complex in 2003 and 2004.

	Fishway		Gill net	Trap net	Angling	Minnow trap
	Downstream	Upstream				
2003						
Northern pike	46	303	366	18*	11	-
White sucker	162	172	4	-	-	-
Walleye	-	-	2	-	-	-
Spottail shiner	**	**	-	80	-	-
Emerald shiner	**	**	-	6	-	-
Blacknose shiner	**	**	-	-	-	-
2004						
Northern pike	243	594	115	ND	ND	ND
White sucker	2	362	5	ND	ND	ND
Spottail shiner	**	**	-	ND	ND	ND

* 10 were < 100mm (see Table 3-3)
** Observed by not quantified - no direction of movement detected
ND - Capture technique not deployed

Table 5. Results of trap net catch data, 2003.

Date	Location	Species	n	Length (mm)
27-May	Root Lake ~ 1.5Km south of Rocky Creek mouth	No Catch		
28-May	Root Lake ~ 1.5Km south of Rocky Creek mouth	Northern pike		535
		Northern pike		395
29-May	Root Lake ~ 1.5Km south of Rocky Creek mouth	Spottail shiner	20	NR
20-Jun	Red Rock Creek near South Reader Lake	Northern pike		50
		Northern pike		50
		Northern pike		50
		Northern pike		50
		Northern pike		52
		Emerald shiner	1	NR
24-Jun	Root Lake S.E. Corner	Northern pike		85
25-Jun	Root Lake - N.W. corner	Northern pike		75
		Emerald shiner	5	NR
26-Jun	Root Lake - ~1.5km north of Red Rock Creek inlet	Northern pike		605
27-Jun	Root Lake - N.E. corner	Spottail shiner	~ 30	NR
15-Jul	Red Rock Creek near South Reader Lake	Spottail shiner	~ 30	NR
21-Jul	Root Lake S.E. Corner	Northern pike		95
		Northern pike		95
		Northern pike		100
22-Jul	Rocky Creek ~ 200m Downstream of Fishway	Northern pike		700
		Northern pike		285
		Northern pike		260
		Northern pike		260
23-Jul	Rocky Creek ~ 200m Downstream of Fishway	Northern pike		350

NR - Not recorded

Table 6. Length and weight parameters (length – weight equation with R^2, mean condition factor (K), with standard deviation (S.D.), mean length (mm) with standard deviation (S.D.)) of northern pike in the Reader-Root wetland complex, 2003 and 2004.

	25 April - 30 May 2003	10 Sept. - 23 Oct. 2003	19 April - 16 June 2004
	n = 236	n = 110	n = 336
Length - Weight equ.	Y = 11.1+2.87x	Y = 11.9+3.02x	Y = 11.8+2.99x
(R^2)	(R^2 = .98)	(R^2 = 0.98)	(R^2 = 0.98)
Mean K (S.D)	0.70 (0.078)	0.75 (0.071)	0.72 (0.078)
Mean Length (mm) (S.D.)	508.9 (123.9)	385.9 (90.8)	547.7 (132.1)
Max (mm)	898	620	990
Min (mm)	300	245	210
% over 600 mm	20.3	4.6	25.3

NA – Not recorded

Table 7. Survival estimates of northern pike captured in the Reader-Root wetland complex, spring 2003 2004.

Year / Ages Used	Method	Annual Survival	Variance	R^2
2003				
Ages 5 - 8	Robson-Chapman	0.568	0.040	
	Regression	0.842		0.914
Ages 5 - 9	Robson-Chapman	0.583	0.040	
	Regression	0.607		0.697
2004				
Ages 5 - 8	Robson-Chapman	0.474	0.044	
	Regression	0.563		0.971
Ages 5 - 10	Robson-Chapman	0.574	0.023	
	Regression	0.651		0.934

Table 8. Stomach content analysis in relation to length (average fork length (mm) and standard deviation (S.D.)) of northern pike captured in the Reader-Root wetland complex in 2003 and 2004.

	2003				2004			
	n	% of total examined	Avg. F L (mm)	S.D.	*n*	% of total examined	Avg. FL (mm)	S.D.
Empty	113	45.0	415.3	92.7	47	40.9	492.7	130.1
Unidentified	34	13.6	390.7		0	0.00		
		% of identifiable				% of identifiable		
Cyprinid	2	1.9	317.5		0	0.00		
Invertebrate	65[1]	62.5	339.2	62.0	39[2]	57.3	415.0	108.5
Northern pike	35	33.7	418.0	83.6	28	41.2	592.7	61.9
Unidentifiable fish	2	1.9	570.0		1	1.5	660.0	
Total identifiable	104				68			
Total examined	251				115			

[1] Mostly Amphipoda

[2] Mostly Hirudinea and Hemiptera

Table 9. Summary of northern pike movement in the Reader-Root wetland complex and Rocky Lake, 2003 and 2004 based on tagged and recaptured specimens.

Date Captured	Tag No.	Direction of Travel	Date Re-captured	Method and Location of Re-capture	Days Between Capture
28 April 2003	5	Downstream	04 June 2003	Angling - North Basin Rocky Lake	37
09 May 2003	773	Upstream	04 June 2004	Fishway - Upstream	390
09 May 2003	103	Upstream	06 June 2003	Angling - North Basin Rocky Lake	27
09 May 2003	124	Upstream	06 June 2003	Angling - North Basin Rocky Lake	27
21 April 2004	243	Downstream	13 May 2004	Fishway - Upstream	22
23 April 2004	268	Downstream	08 May 2004	Fishway - Upstream	15
23 April 2004	269	Downstream	07 May 2004	Fishway - Upstream	14
27 April 2004	298	Downstream	18 May 2004	Fishway – Direction unknown	21
27 April 2004	303	Downstream	07 May 2004	Fishway - Upstream	10
17 May 2004	399	Upstream	04 June 2004	Angling - North Basin Rocky Lake	18
19 May 2004	514	Upstream	02 June 2004	Angling - North Basin Rocky Lake	14

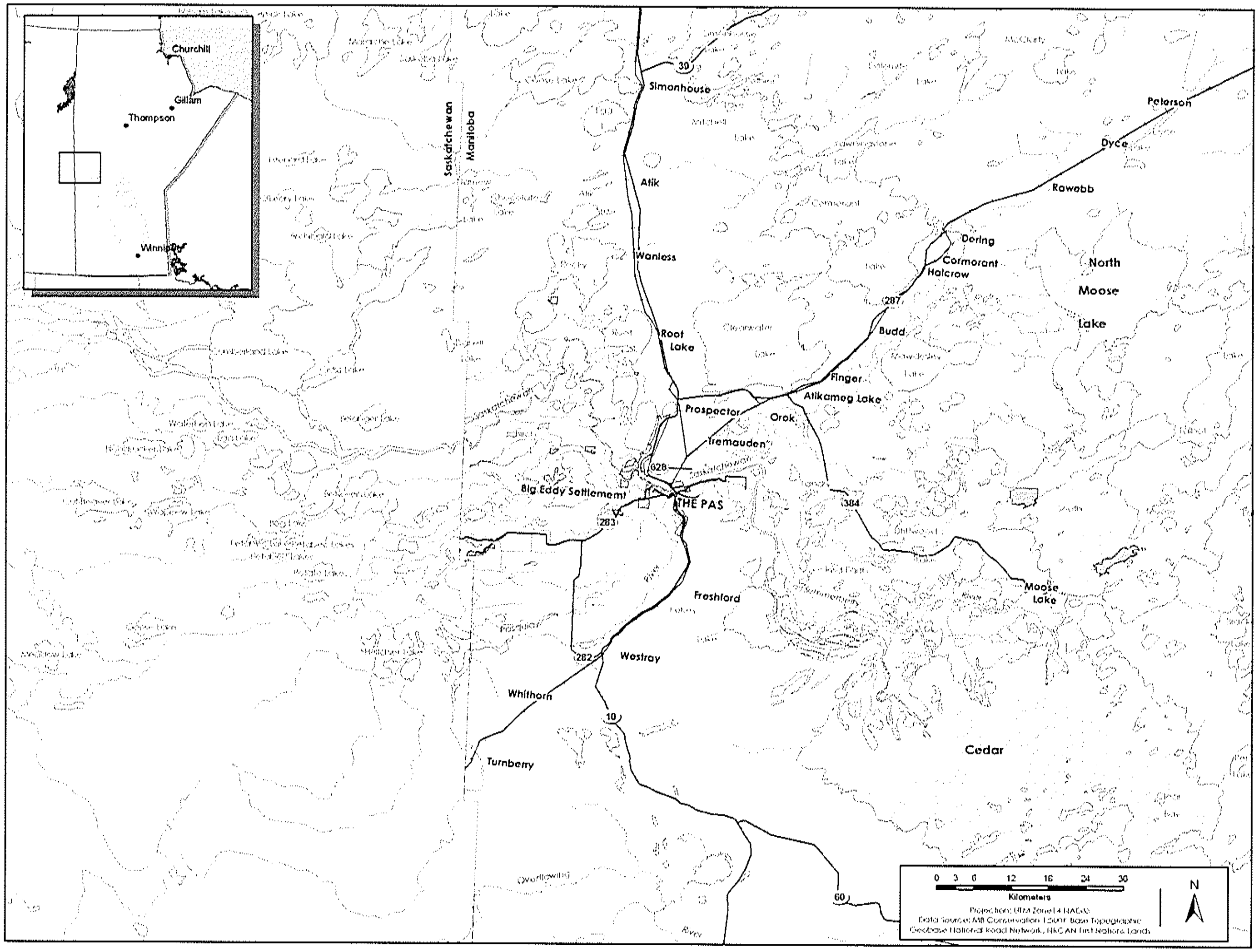

Figure 1. Saskatchewan River Delta.

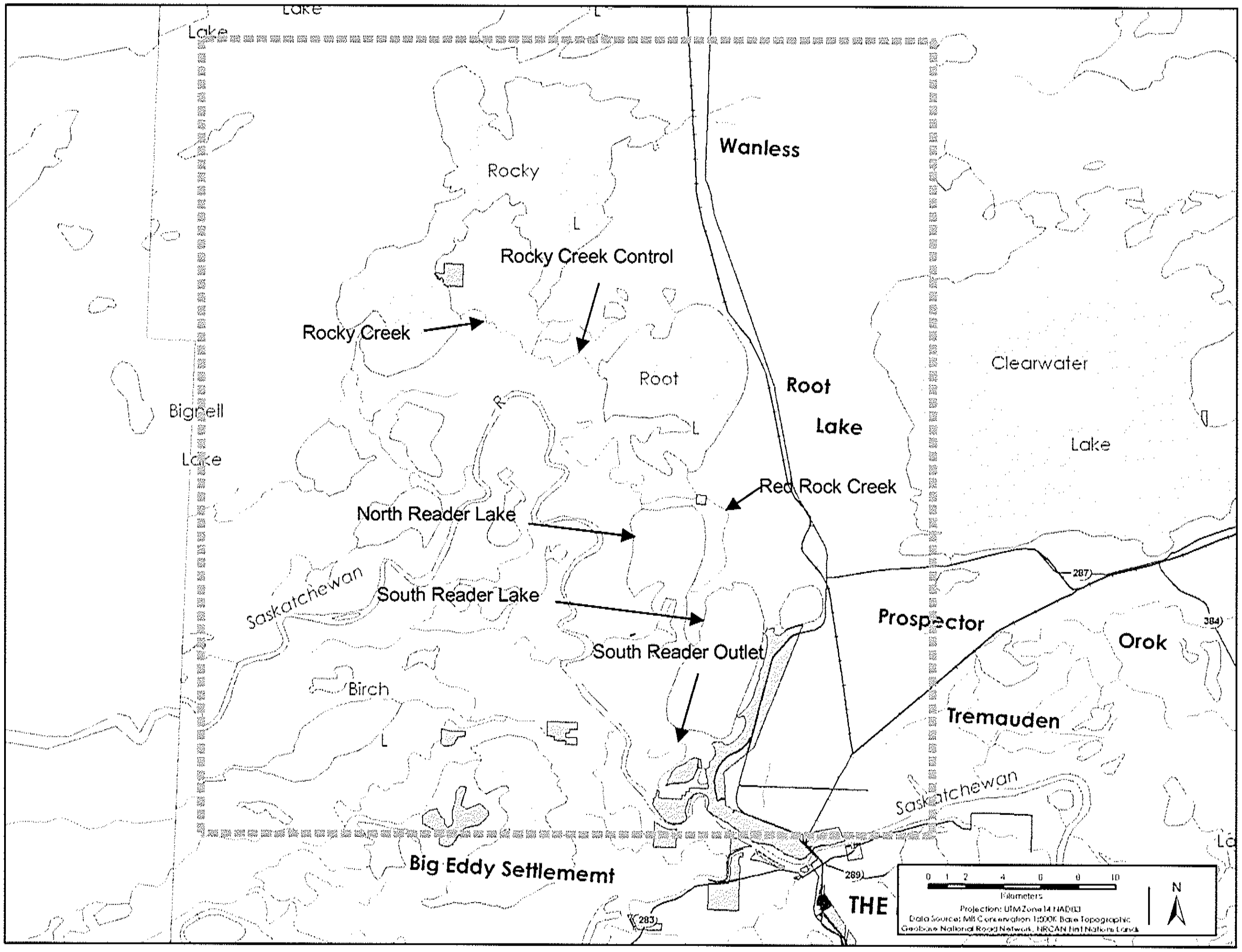

Figure 2. Reader-Root wetland complex and surrounding area.

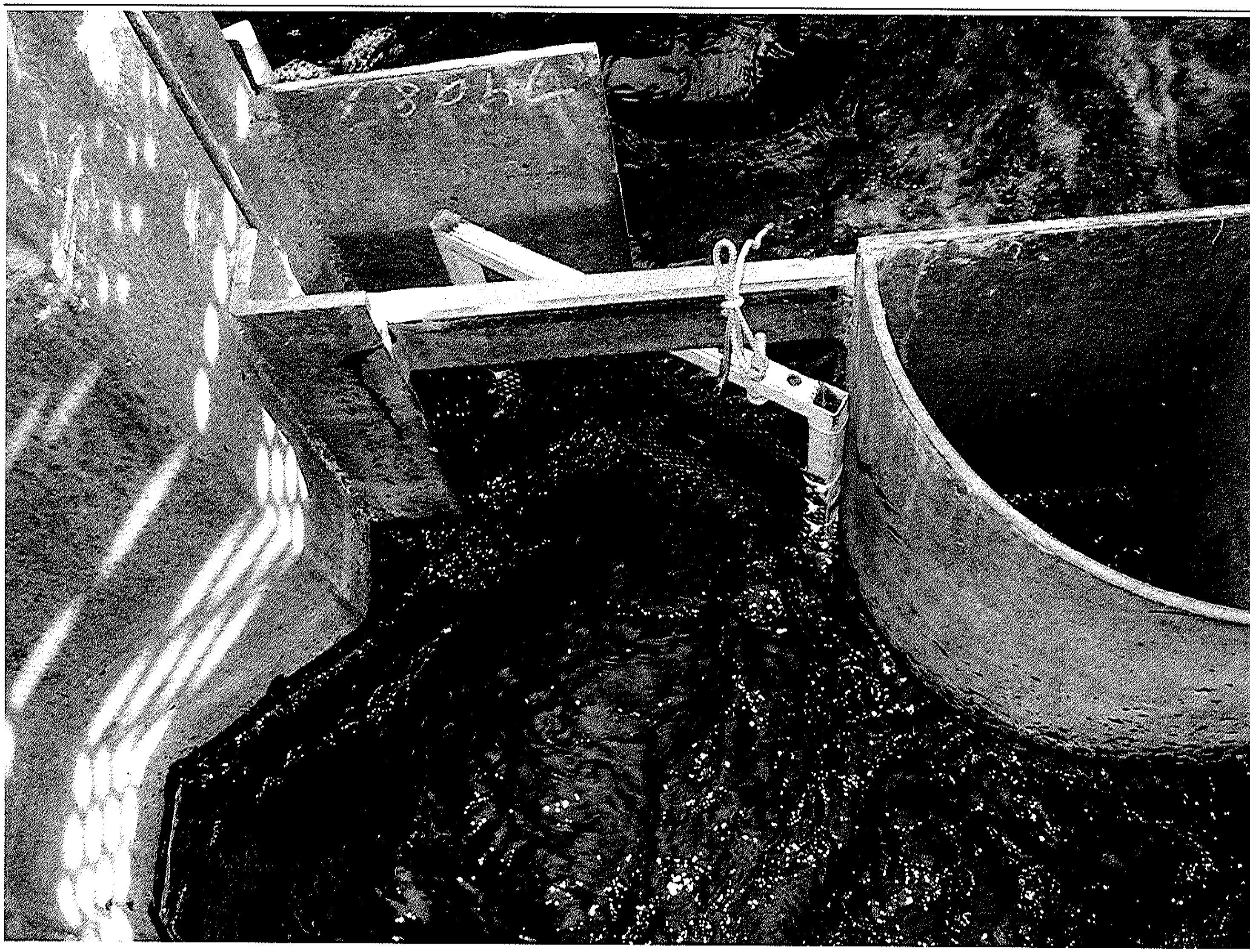

Figure 3. Placement of screen at exit of 9th chamber in the Rocky Creek fishway.

Figure 4. Northern pike passing downstream over stoplog bay at Rocky Creek control structure, April, 2004.

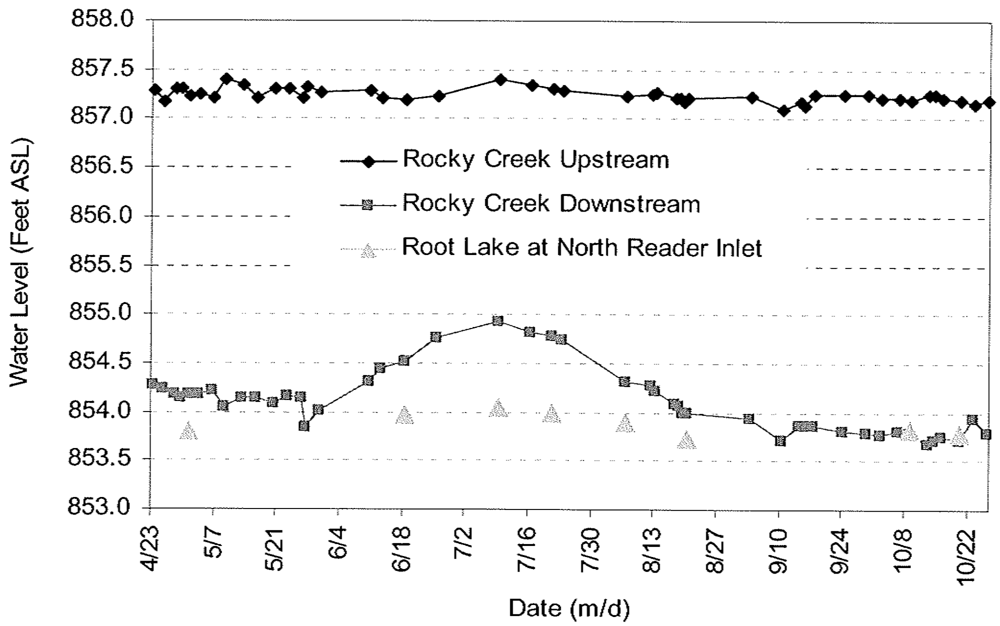

Figure 5. Water levels at the Rocky Creek and North Reader Lake control structures, 2003

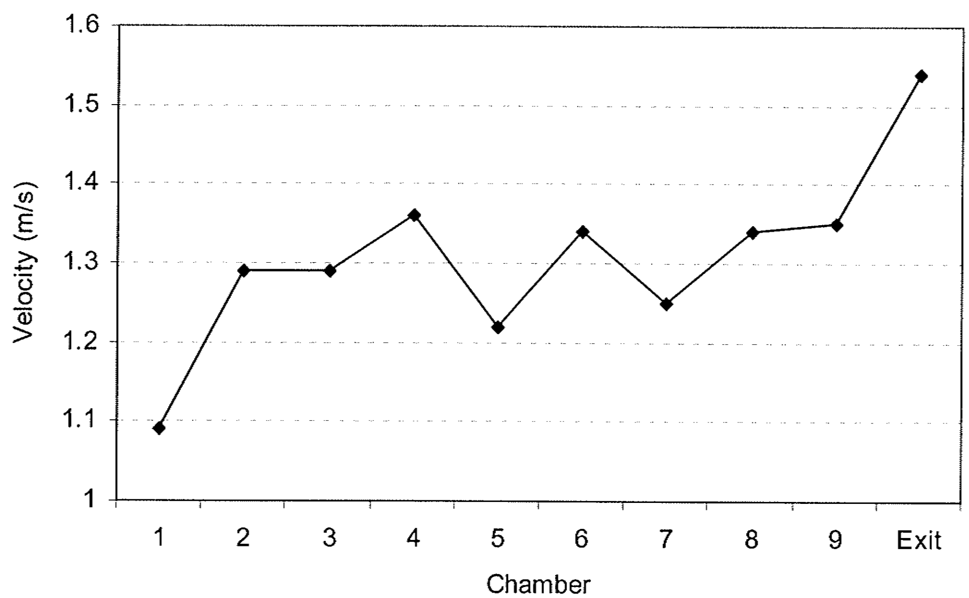

Figure 6. Exit velocities for individual chambers (upstream to downstream) of the Rocky Creek fishway, 10 May, 2004.

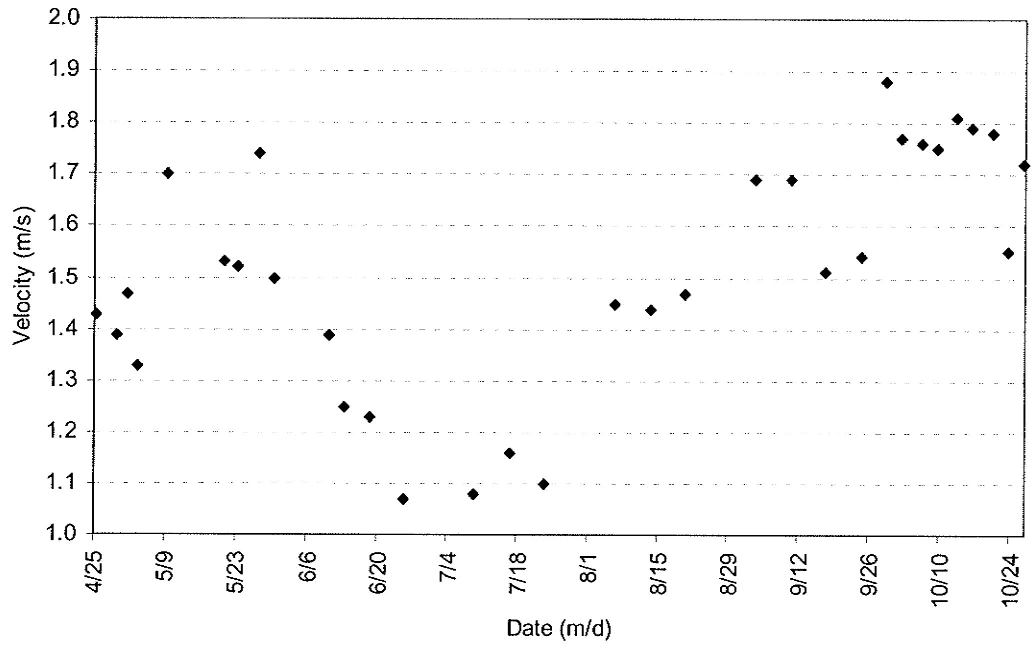

Figure 7. Current velocities at the exit of the Rocky Creek fishway measured during fish sampling events in 2003.

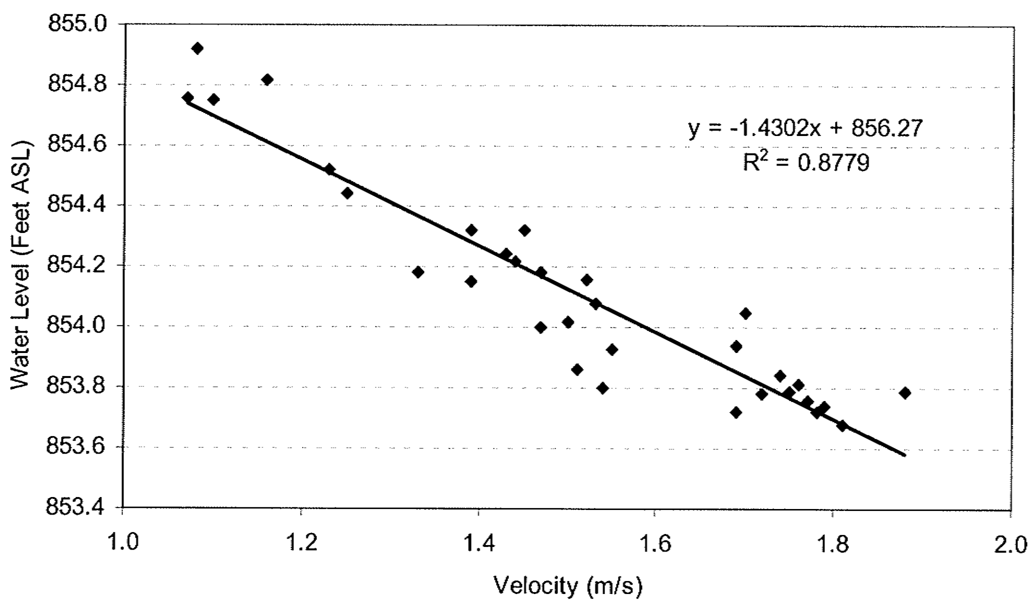

Figure 8. Regression of fishway exit velocity and downstream water level at the Rocky Creek control structure, 2003.

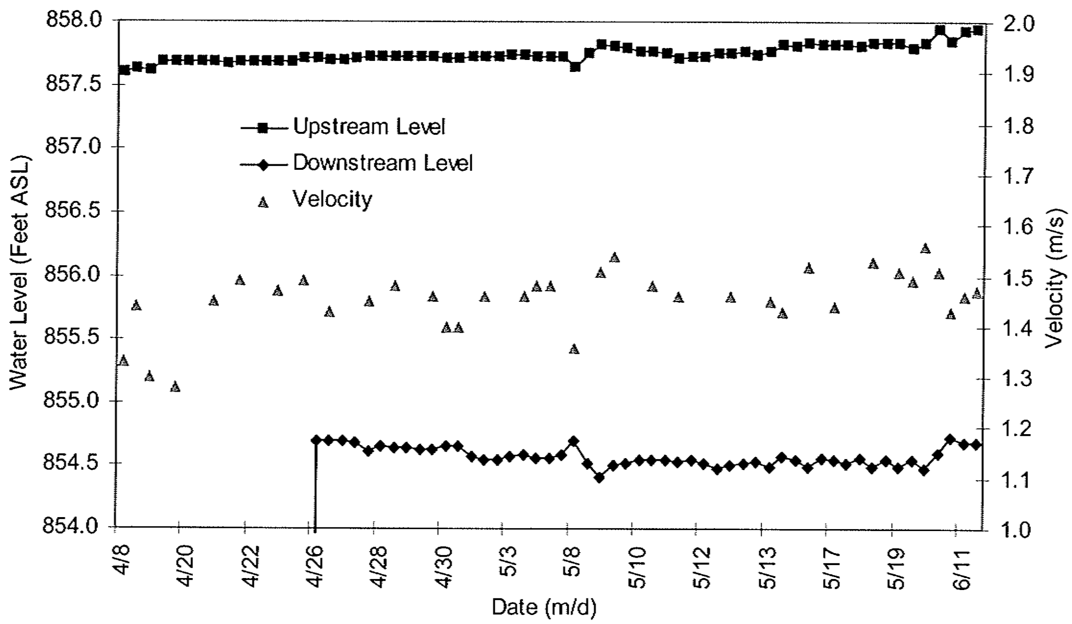

Figure 9. Water level and fishway exit velocity, at the Rocky Creek control structure, spring 2004.

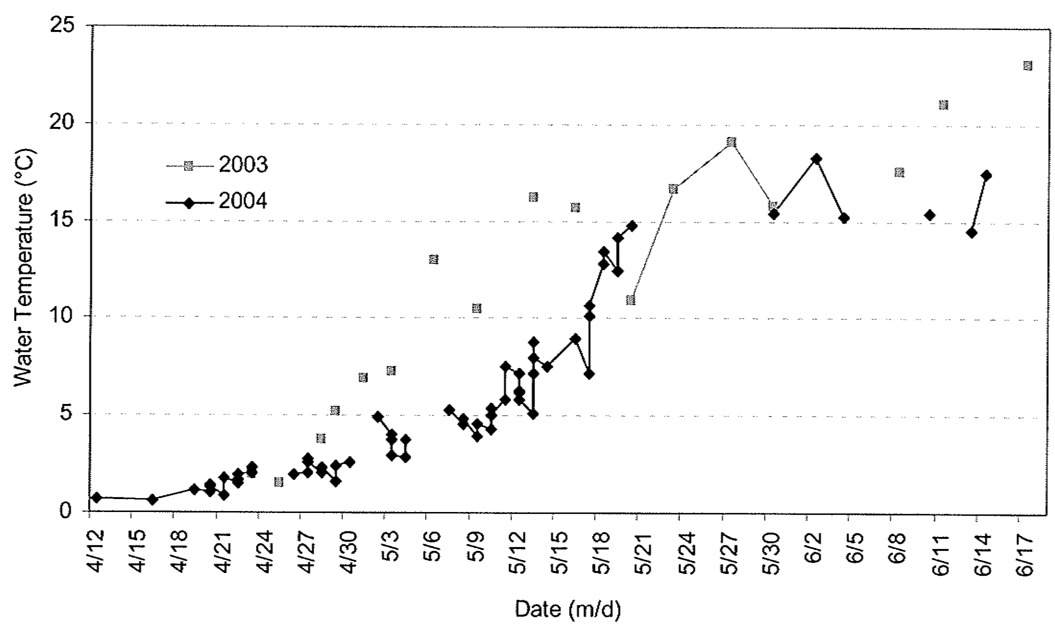

Figure 10. Water temperature at the Rocky Creek control structure, spring 2003 and 2004.

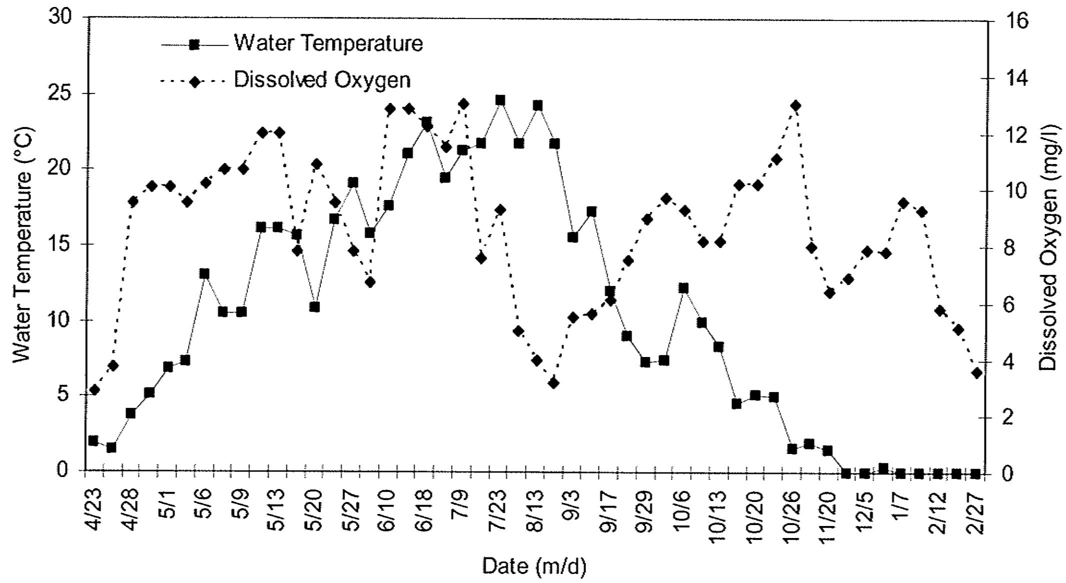

Figure 11. Water temperature and dissolved oxygen at the Rocky Creek control structure, April 2003 – February 2004.

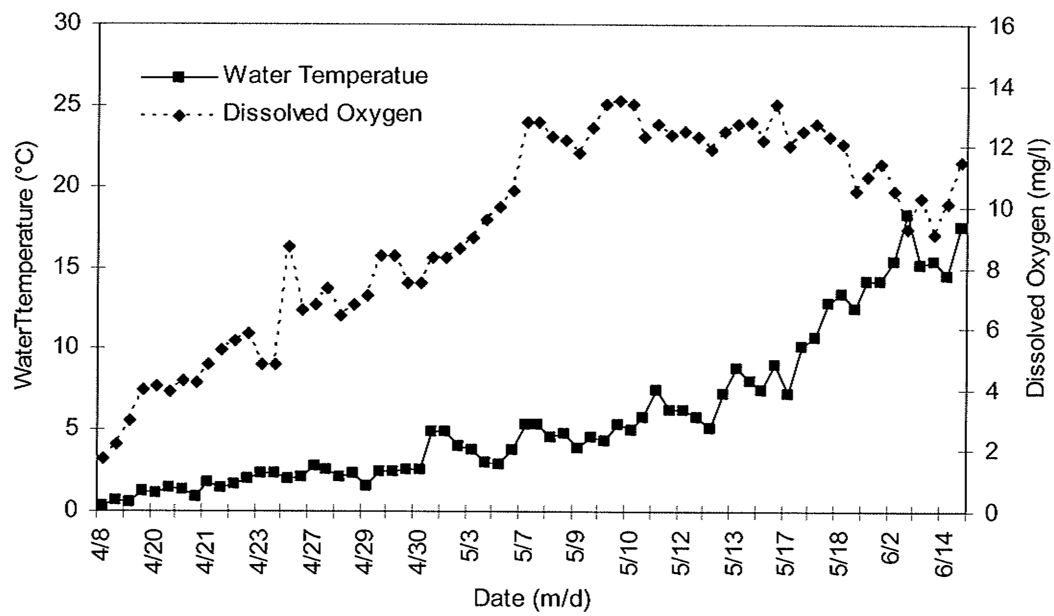

Figure 12. Water temperature and dissolved oxygen at the Rocky Creek control structure, spring 2004.

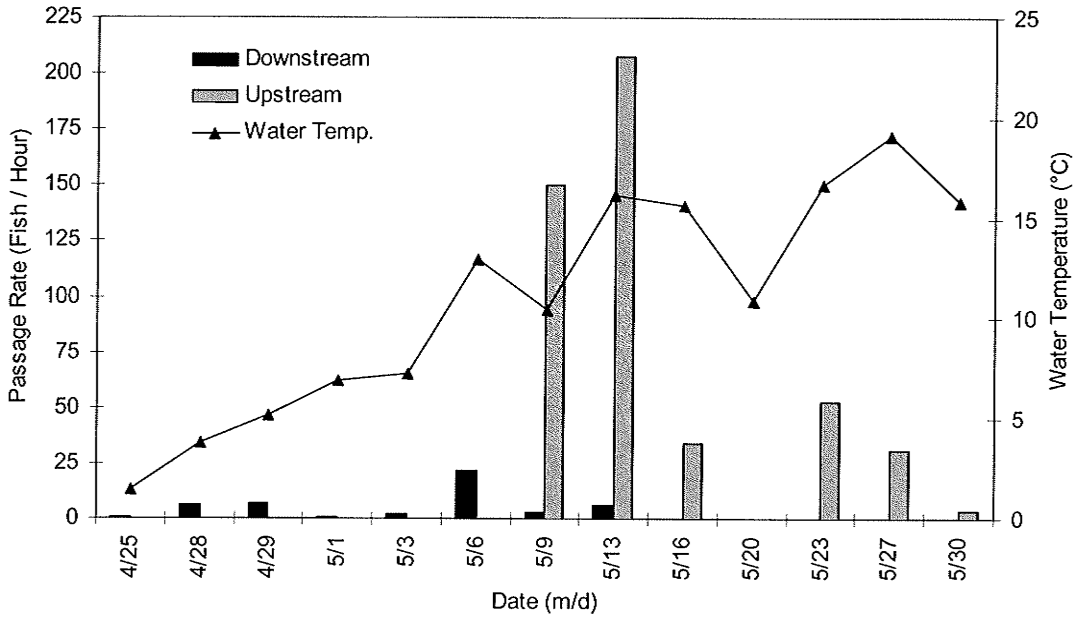

Figure 13. Northern pike passage and water temperature at the Rocky Creek control structure, spring 2003.

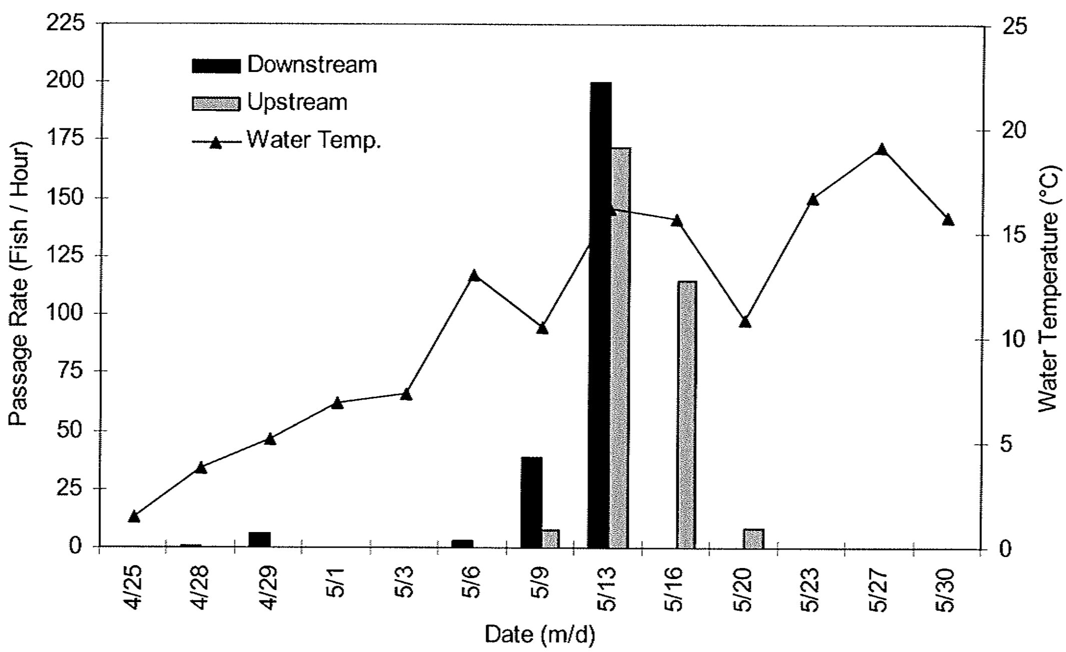

Figure 14. White sucker passage and water temperature at the Rocky Creek control structure, spring 2003.

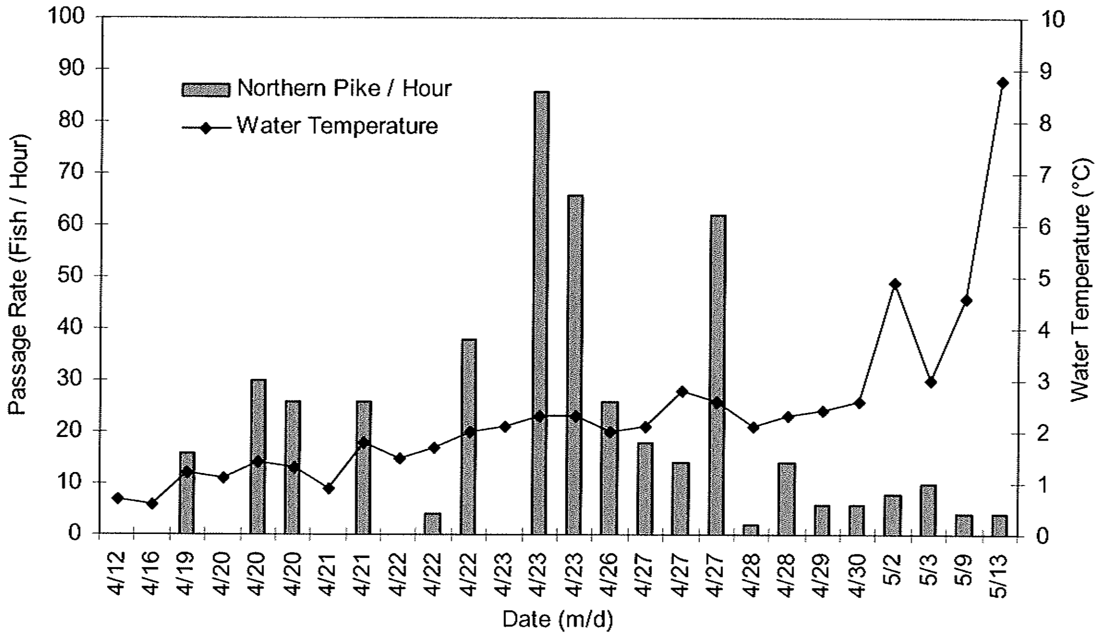

Figure 15. Downstream northern pike passage and water temperature at the Rocky Creek control structure, spring 2004.

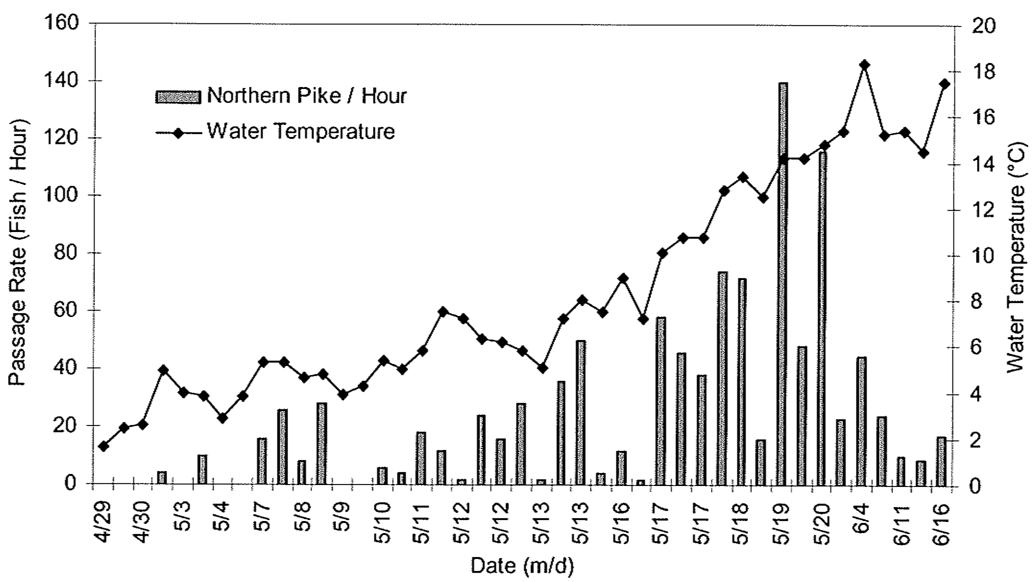

Figure 16. Upstream northern pike passage and water temperature at the Rocky Creek control structure, spring 2004.

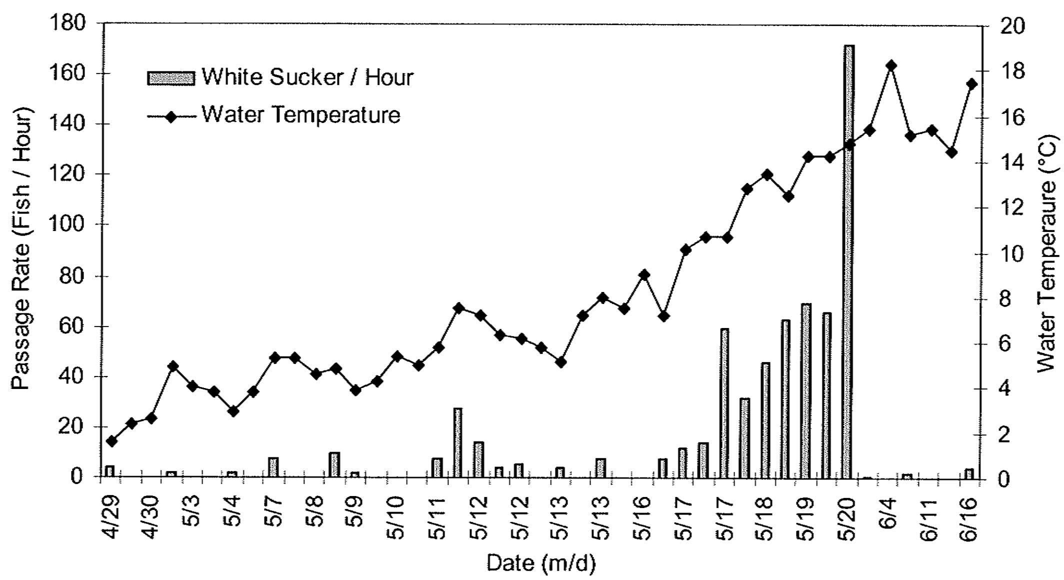

Figure 17. Upstream white sucker passage and water temperature at the Rocky Creek control structure, spring 2004.

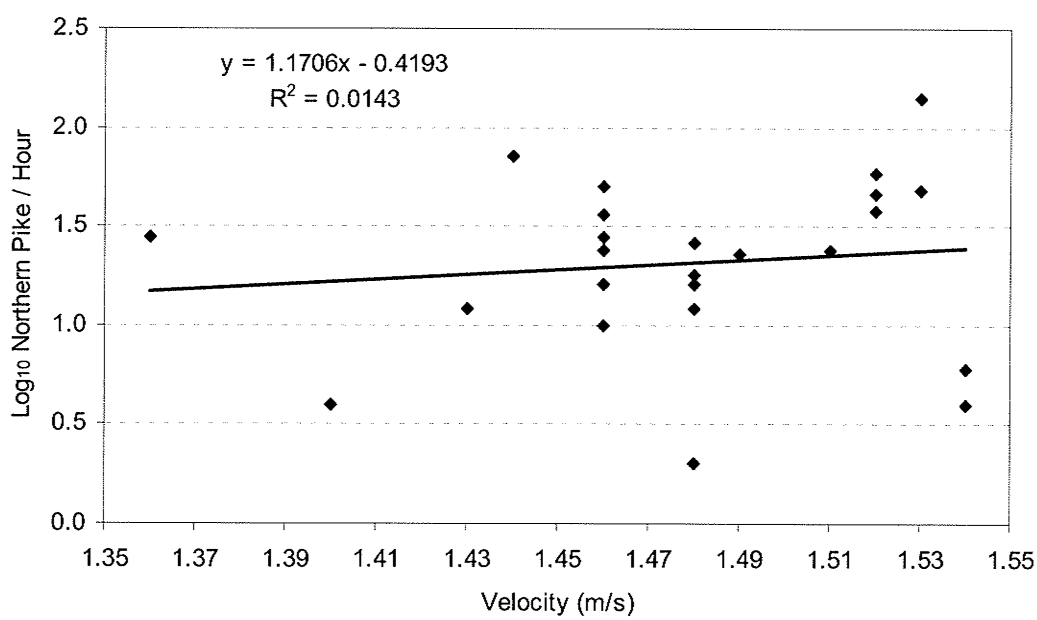

Figure 18. Log_{10} transformed evening upstream northern pike passage and concurrent fishway exit velocity at the Rocky Creek control structure, spring 2004.

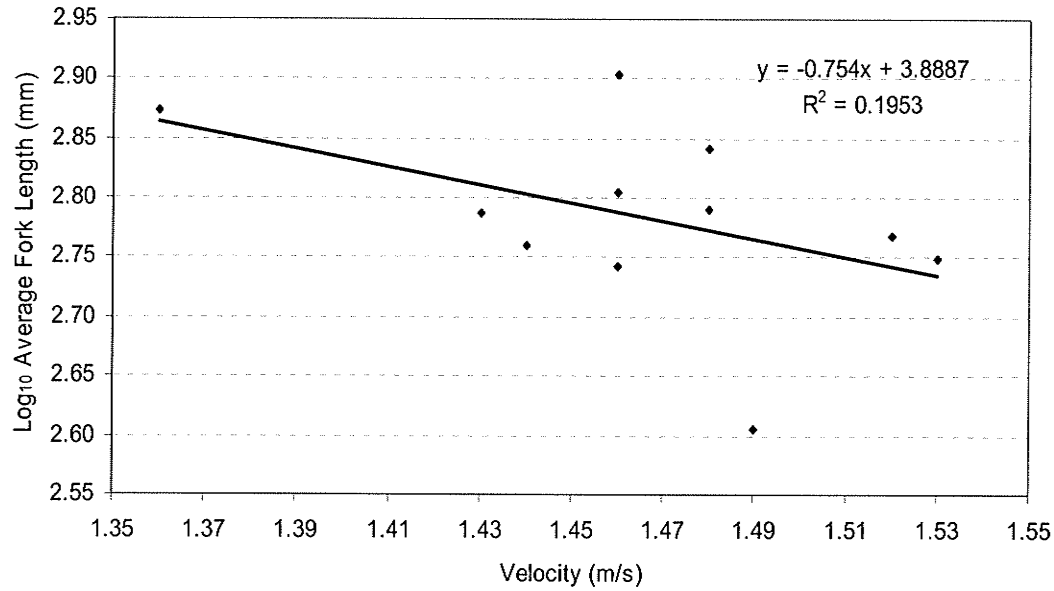

Figure 19. Log_{10} transformed upstream northern pike average fork length and concurrent fishway exit velocity at the Rocky Creek control structure, spring 2004.

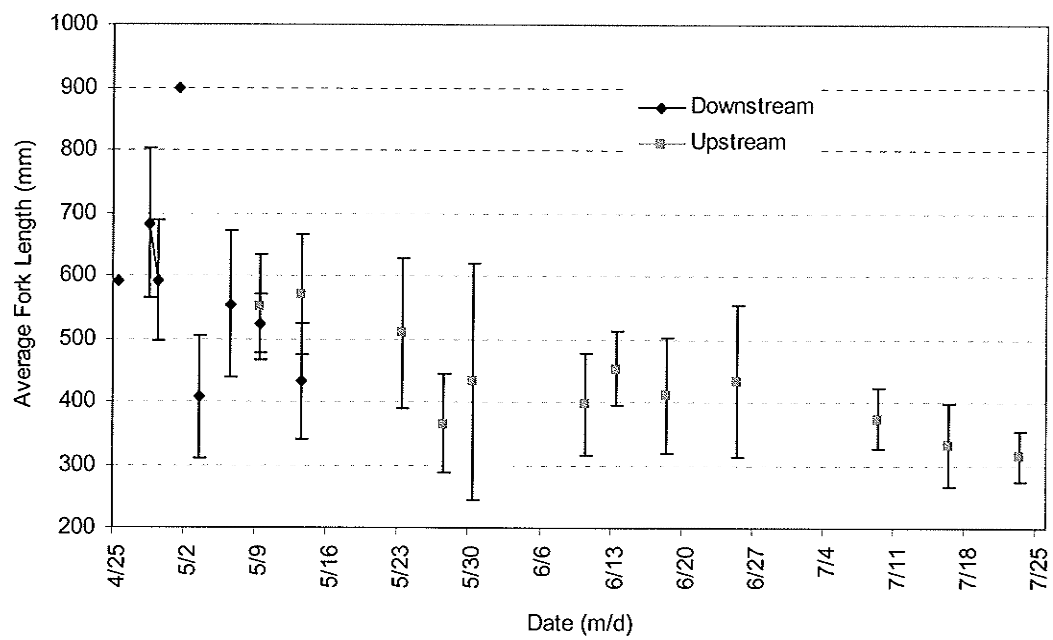

Figure 20. Temporal changes in average fork length (bars = standard deviations) of northern pike using the Rocky Creek fishway, 25 April – 23 July, 2003.

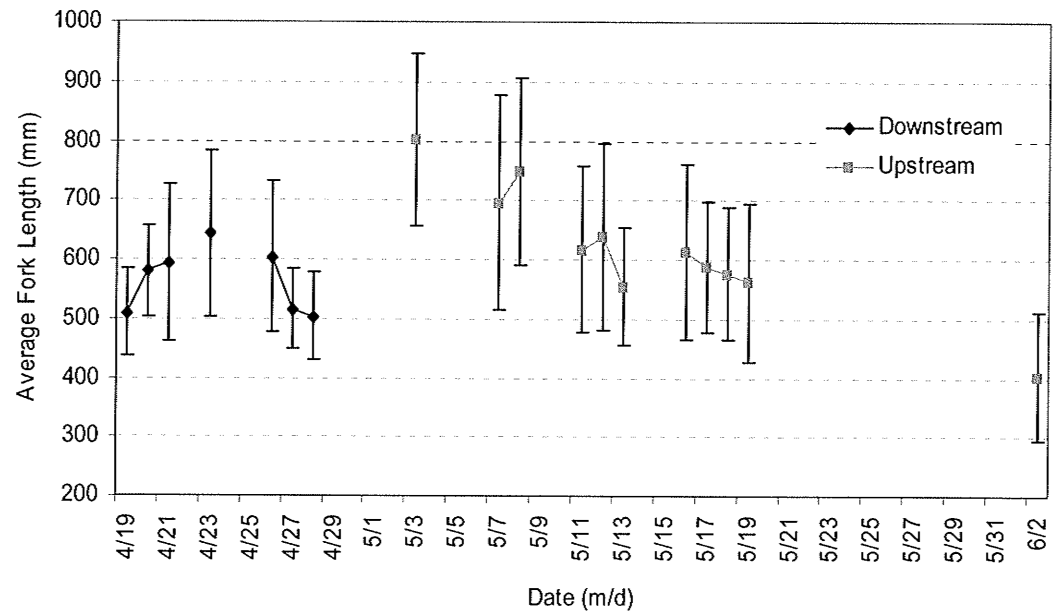

Figure 21. Temporal changes in average fork length (bars = standard deviations) of northern pike using the Rocky Creek fishway, 19 April – 2 June, 2004.

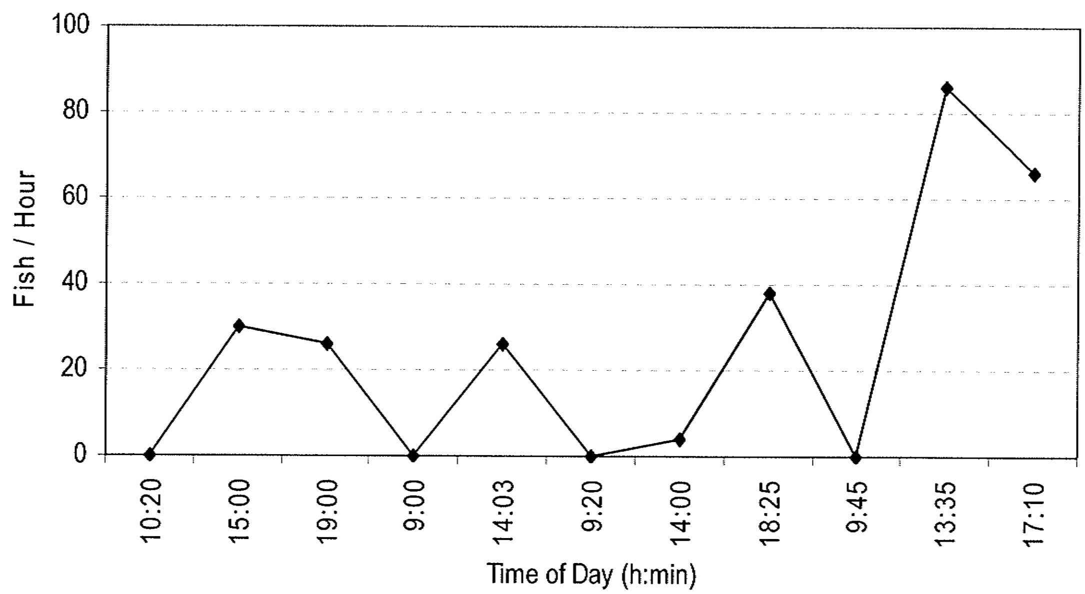

Figure 22. Rate of northern pike downstream movement at various times of day through the Rocky Creek fishway from 20-23 April, 2004.

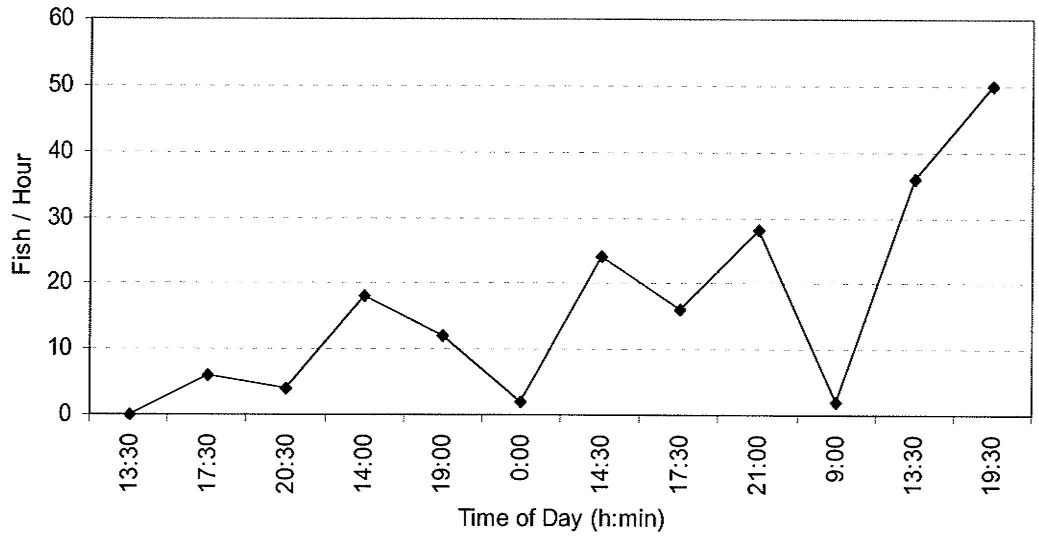

Figure 23. Rate of northern pike upstream movement at various times of day through the Rocky Creek fishway from 10-13 May, 2004.

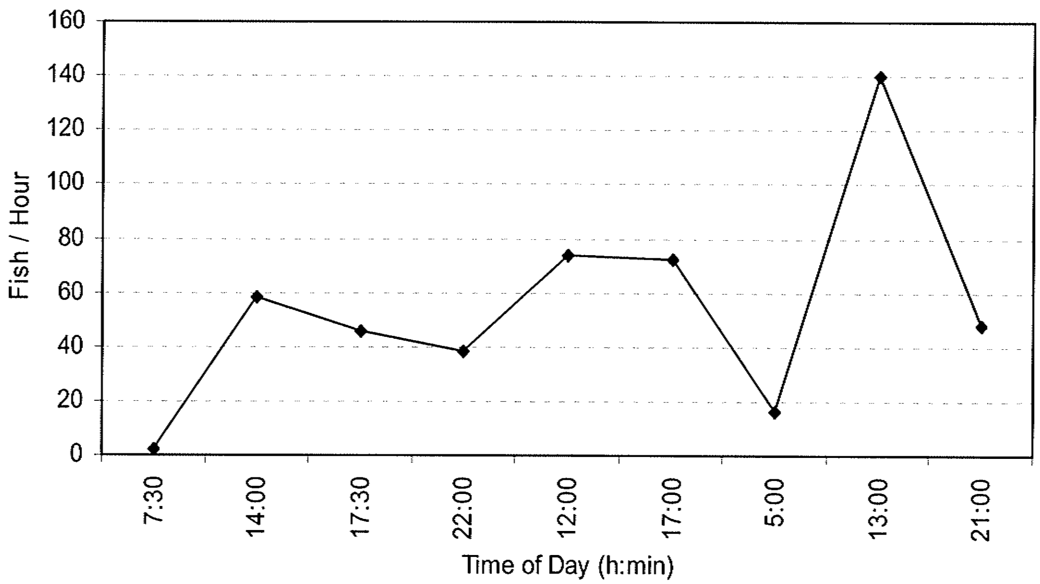

Figure 24. Rate of northern pike upstream movement at various times of day through the Rocky Creek fishway from 17-19 May, 2004.

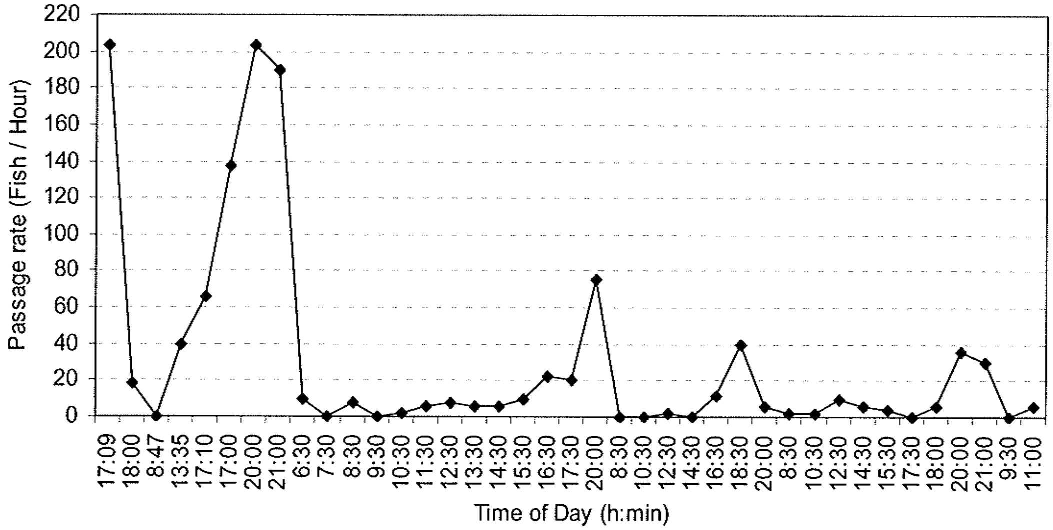

Figure 25. Rate of northern pike downstream movement at various times of day over a stoplog bay at the Rocky Creek control structure from 21-23, and 26-30, April, 2004.

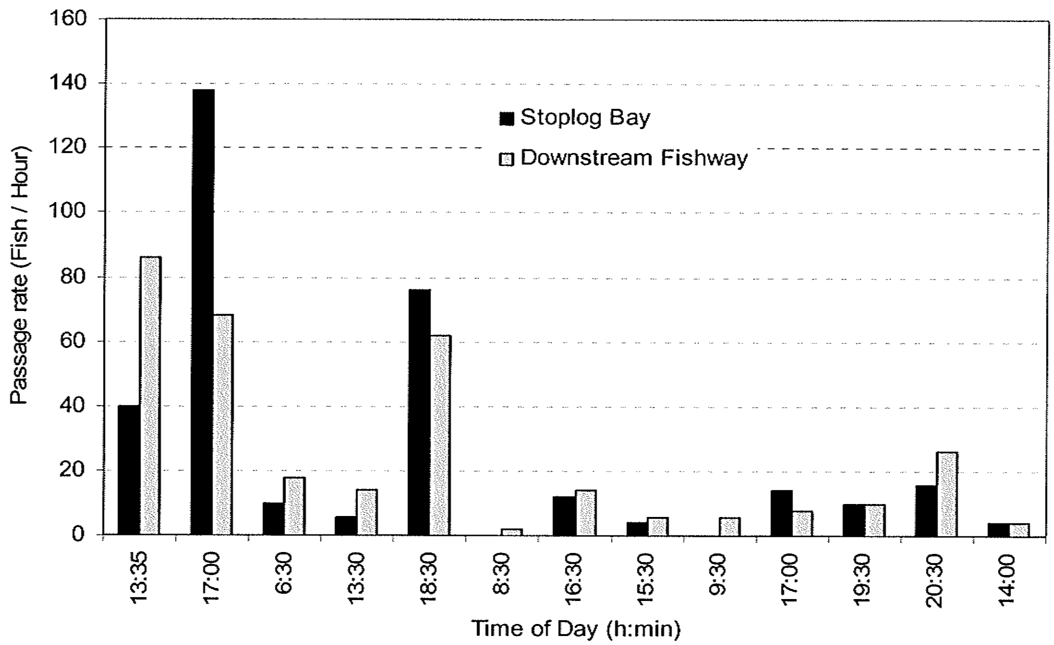

Figure 26. Rate of northern pike downstream movement – paired sampling (stoplog bay fishway) at various times of day at the Rocky Creek control structure, 23, 26-30, April, and 2,3,7,9, May 2004.

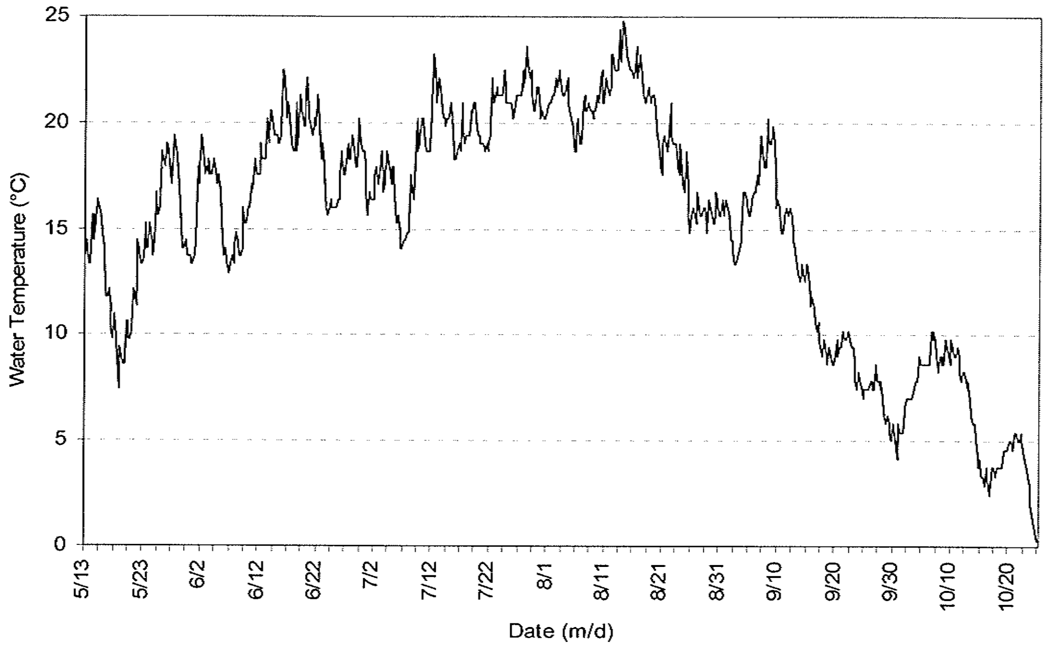

Figure 27. Water temperature recorded in Root Lake by data logger from 13 May to 26 October, 2003

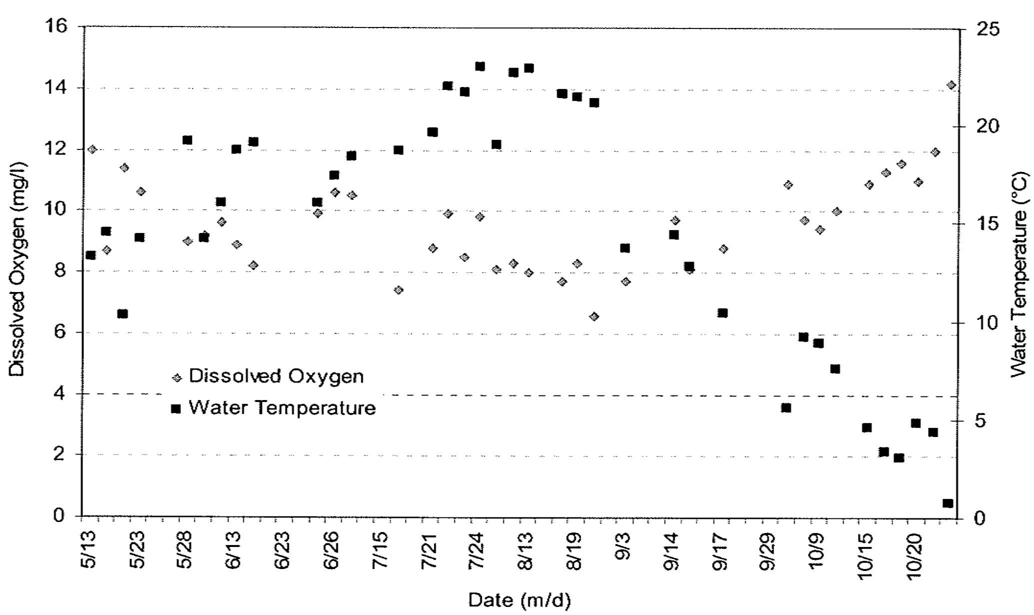

Figure 28. Late-morning water temperature and dissolved oxygen near the middle of Root Lake (recorded with YSI meter), from 13 May to 26 October, 2003.

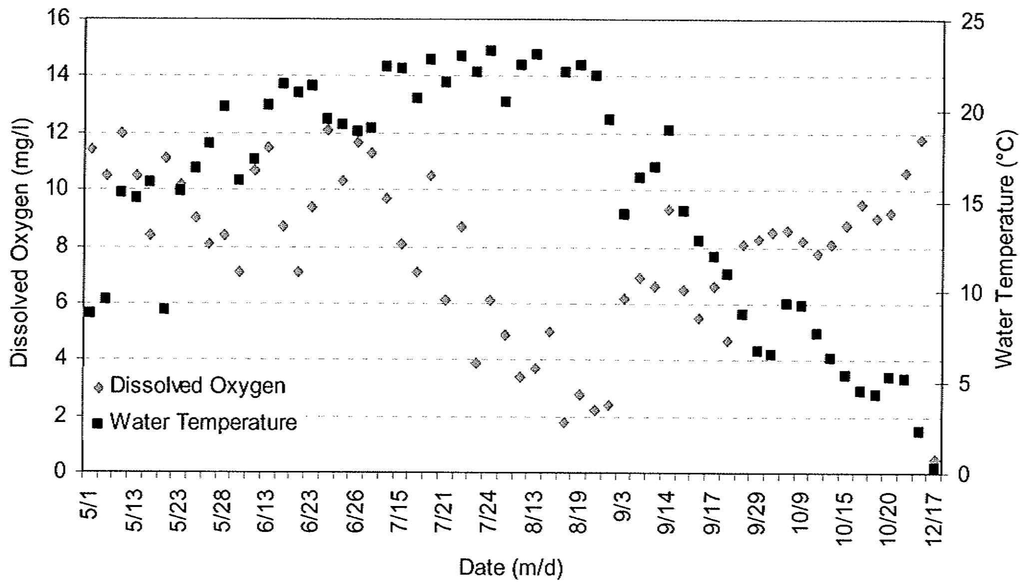

Figure 29. Water temperature and dissolved oxygen recorded in Red Rock Creek with YSI meter from 1 May to 26 October, and on 17 December, 2003.

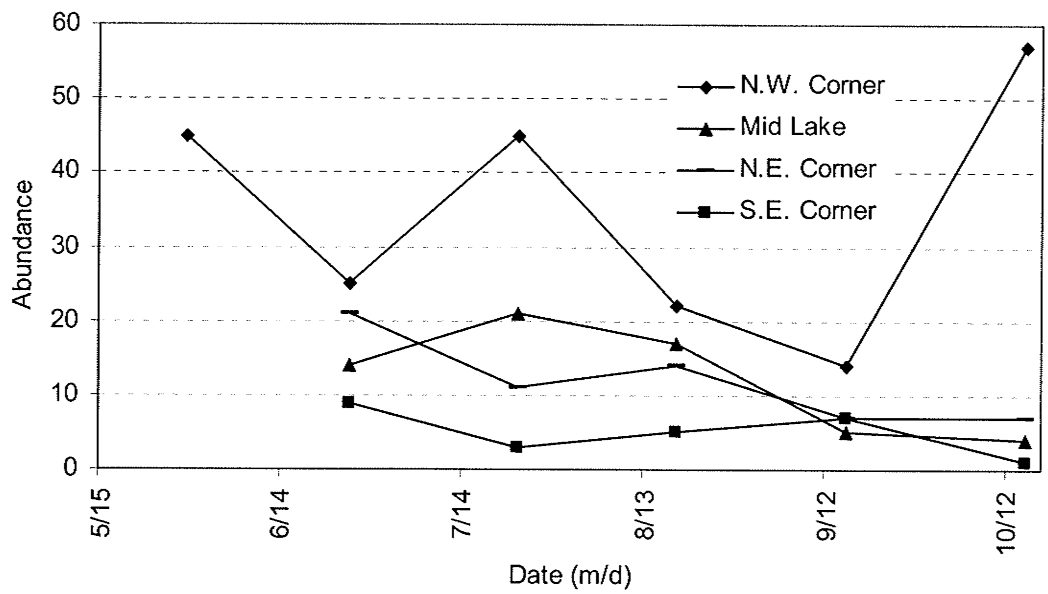

Figure 30. Northern pike abundance per gill net at four locations in Root Lake, 2003.

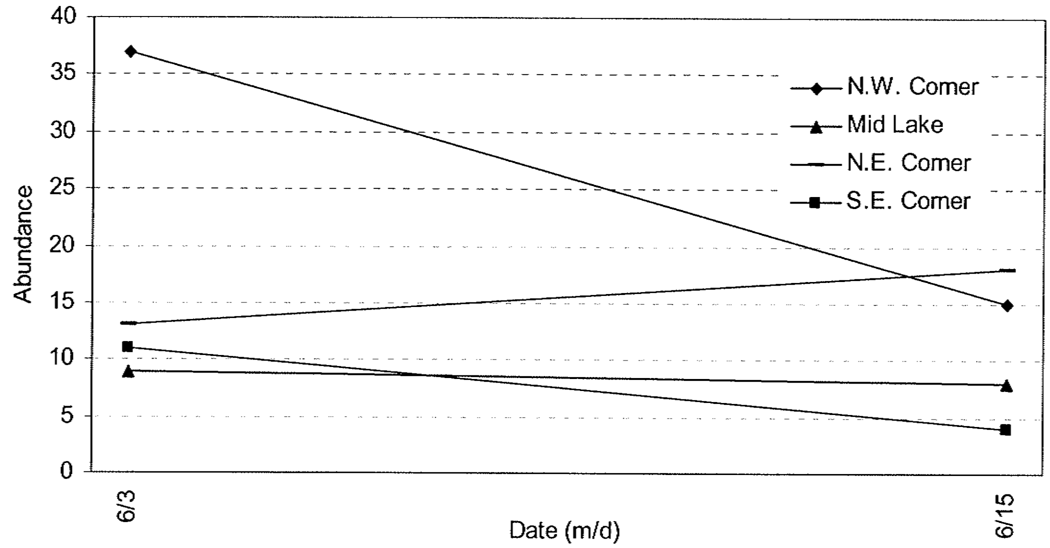

Figure 31. Northern pike abundance per gill net at four locations in Root Lake, June 2004.

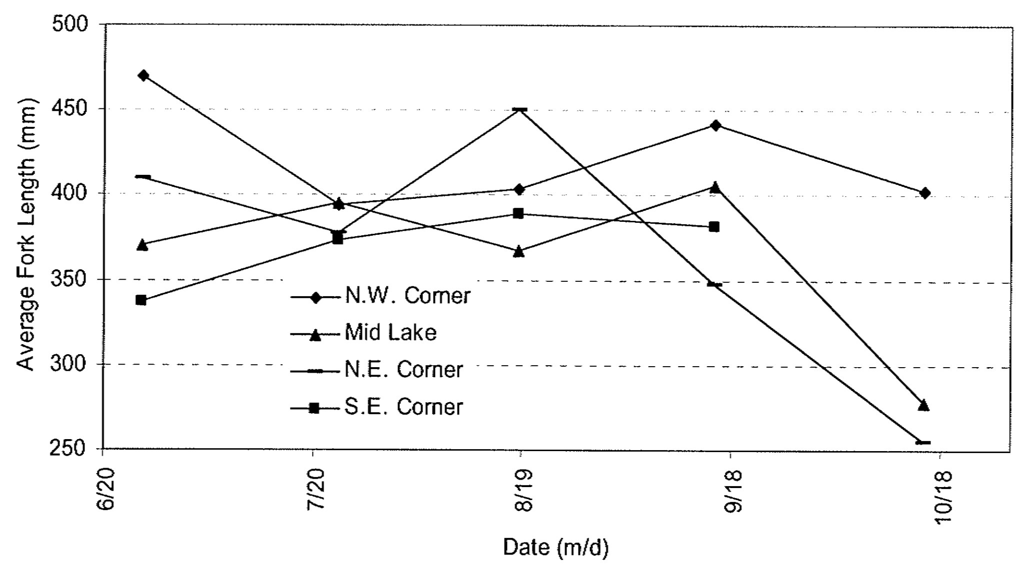

Figure 32. Average fork length of northern pike captured in gill nets set at four locations in Root Lake, 2003.

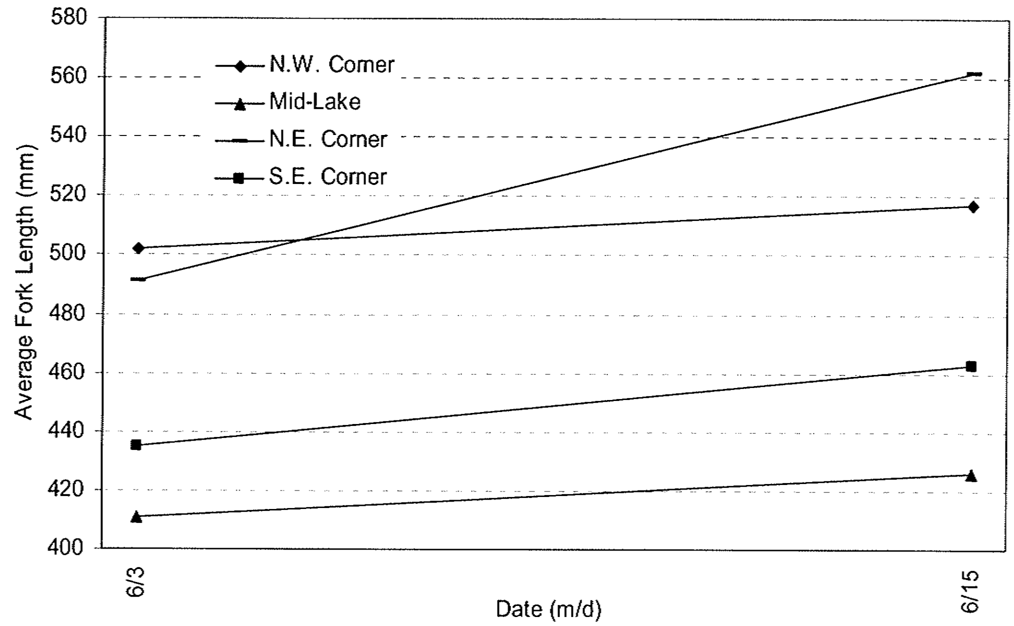

Figure 33. Average fork length of northern pike captured in Root Lake gill net sampling, June 2004.

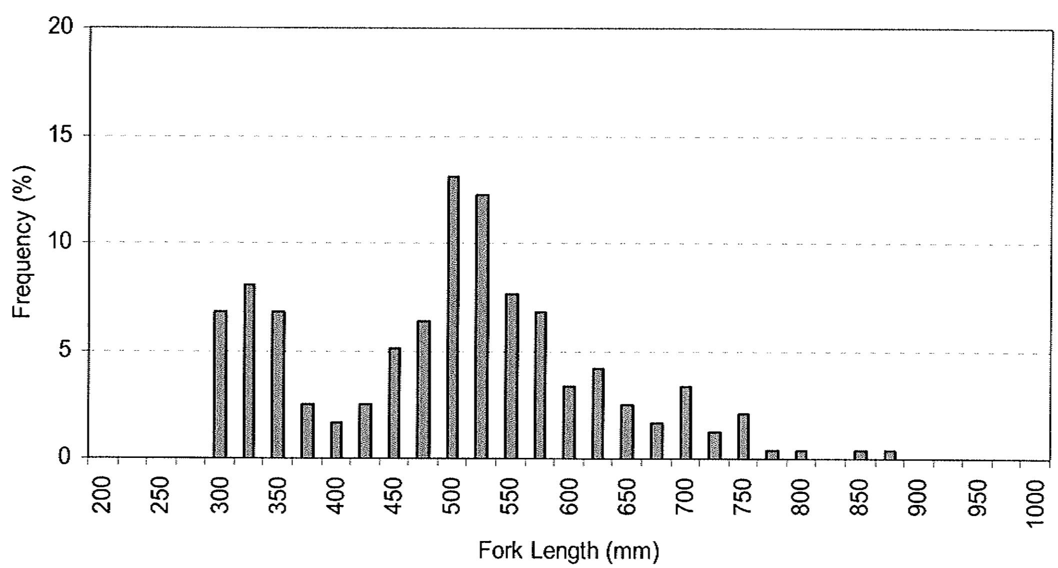

Figure 34. Length frequency of northern pike captured in the Reader-Root wetland complex, 25 April – 30 May, 2003 (n = 236).

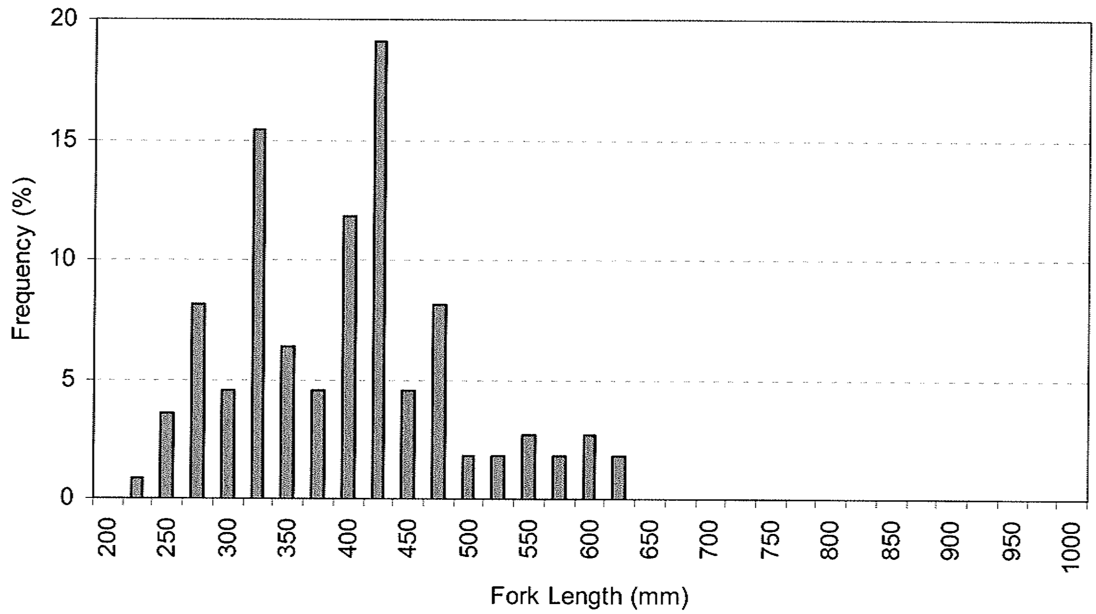

Figure 35. Length frequency of northern pike captured in the Reader-Root wetland complex, September and October, 2003 (n = 110).

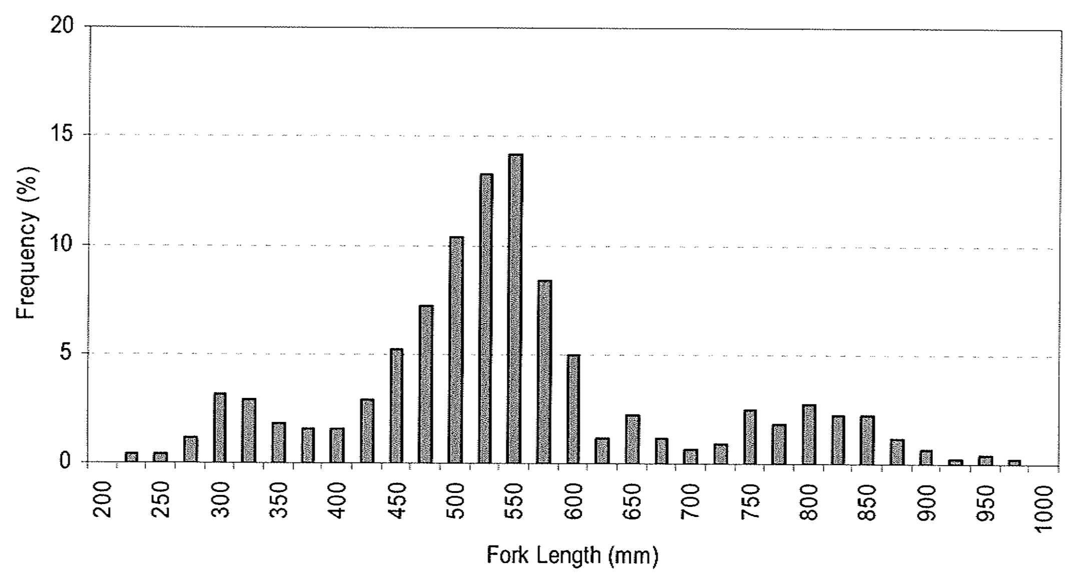

Figure 36. Length frequency of northern pike captured in the Reader-Root wetland complex, 19 April – 16 June, 2004 (n = 443).

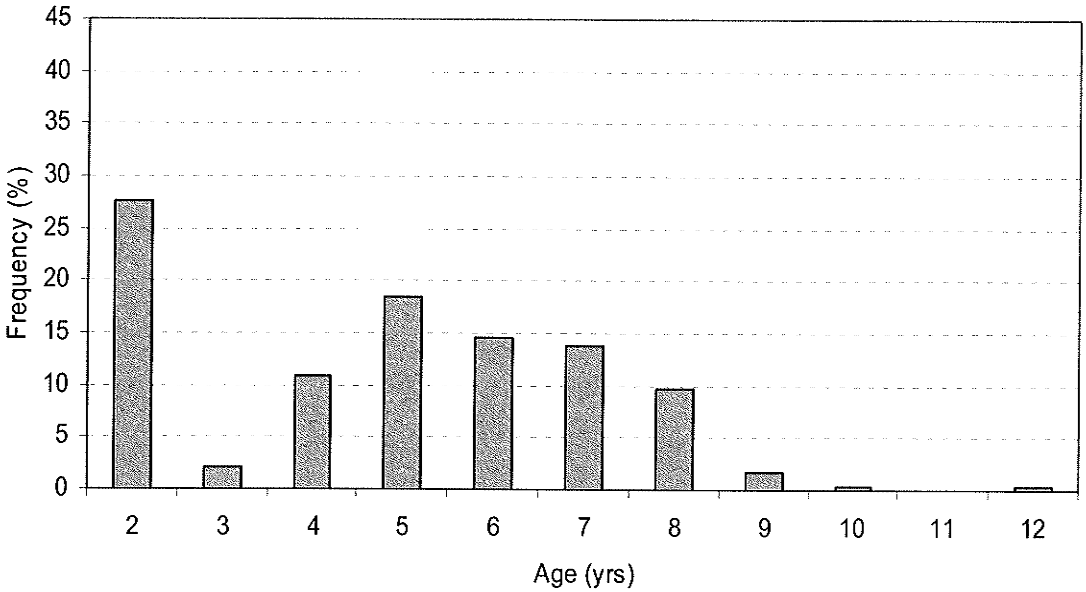

Figure 37. Age frequency of northern pike captured in the Reader-Root wetland complex, 25 April – 30 May, 2003 (n = 236).

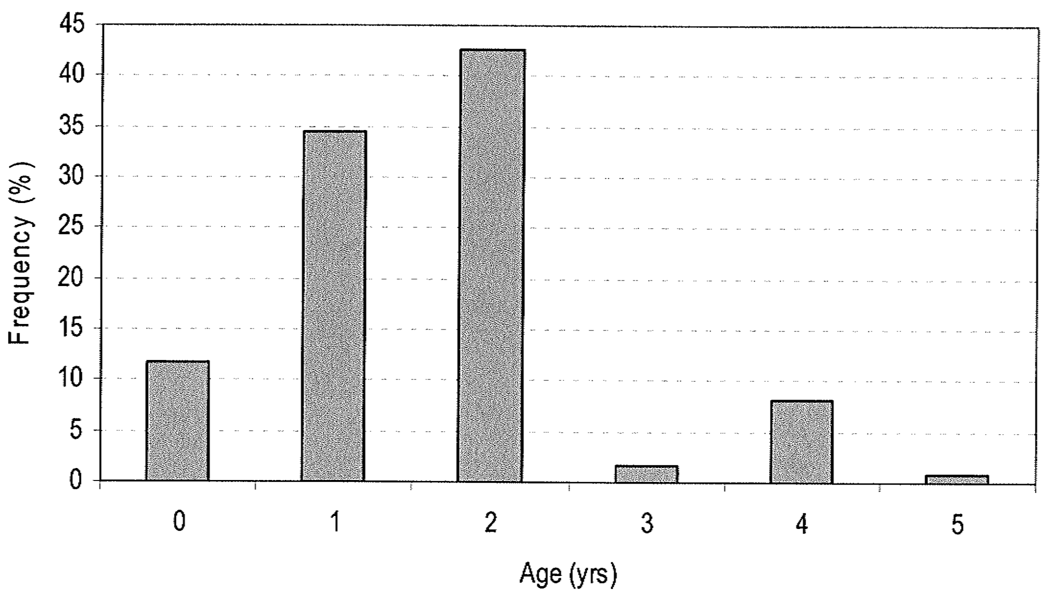

Figure 38. Age frequency of northern pike captured in the Reader-Root wetland complex, September and October, 2003 (n = 100).

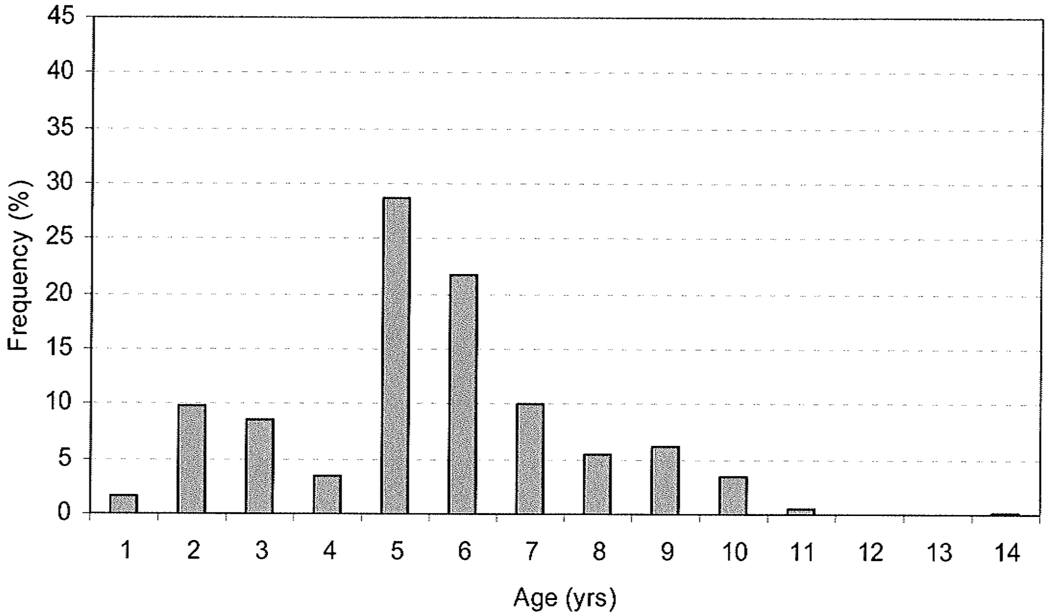

Figure 39. Age frequency of northern pike captured in the Reader-Root wetland complex, 19 April – 16 June, 2004 (n = 405).

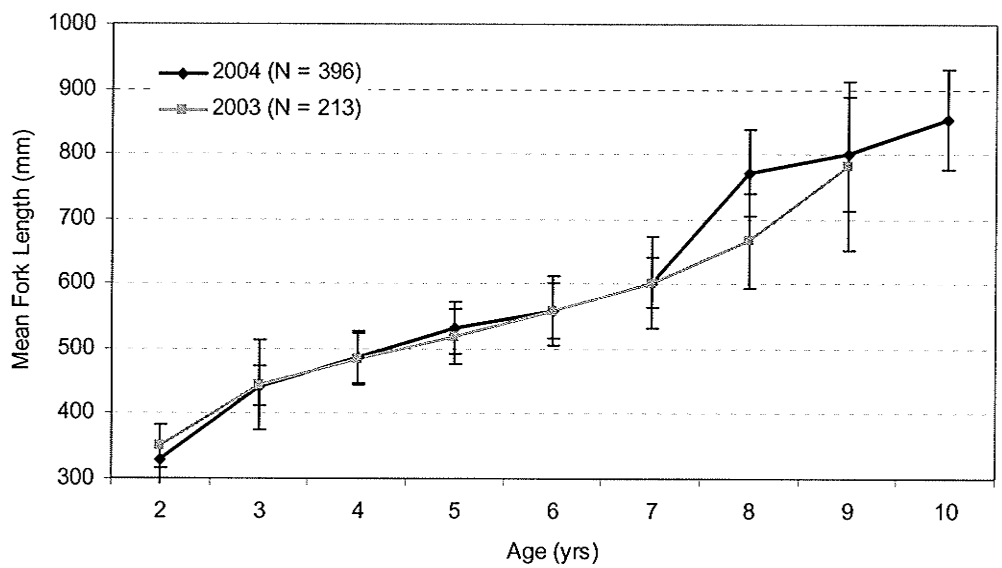

Figure 40. Age specific mean fork length (mm) with standard deviations for spring 2003 and 2004. Data sets only include ages 2 – 9 in 2003, and 2 – 10 in 2004.

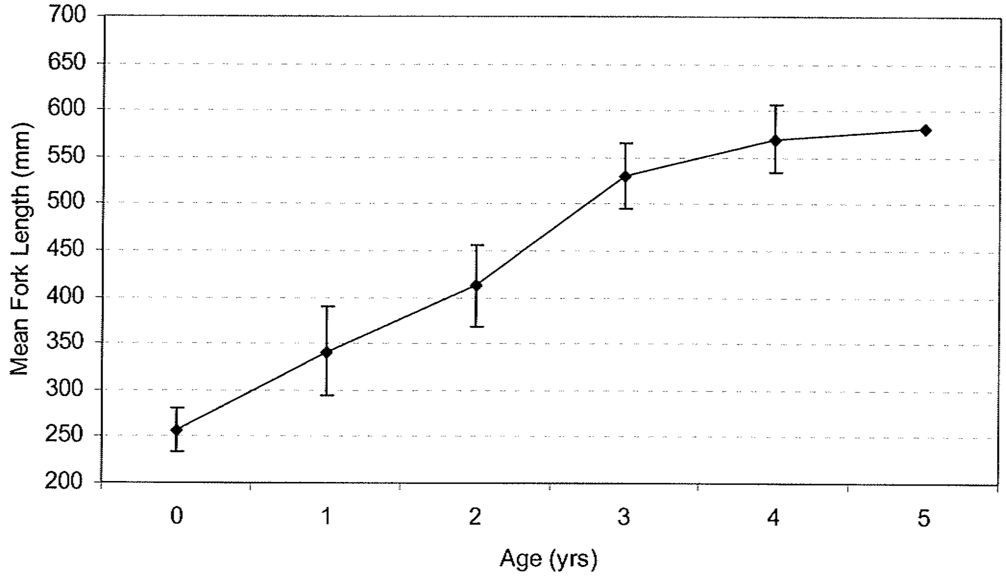

Figure 41. Age specific mean fork length (mm) with standard deviations for September and October, 2003 (n = 100).

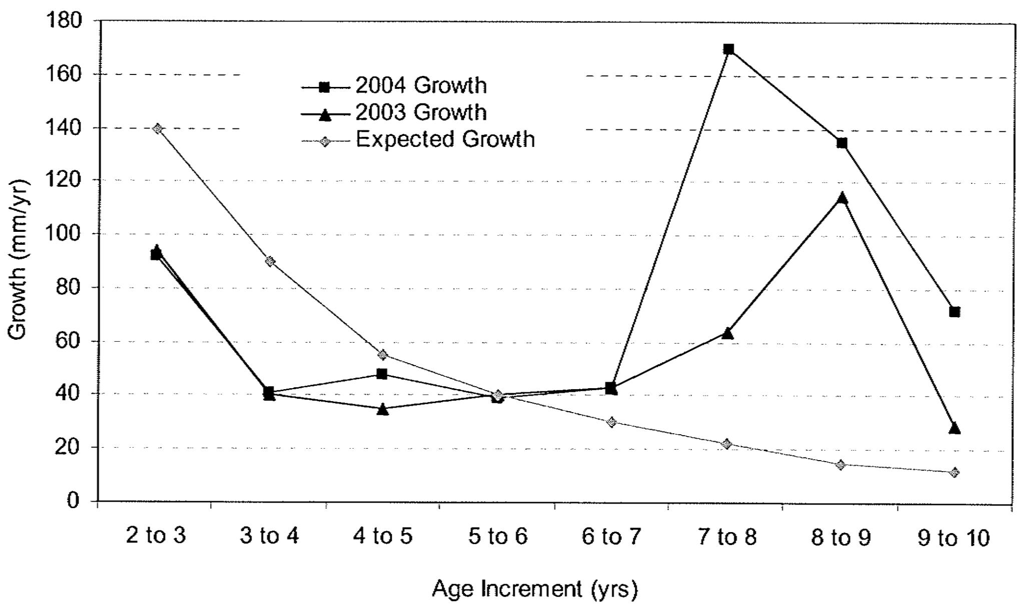

Figure 42. Rate of growth from age specific mean fork lengths between spring 2003 and spring 2004, as well as an example of a decreasing growth rate expected to occur in most fish populations.

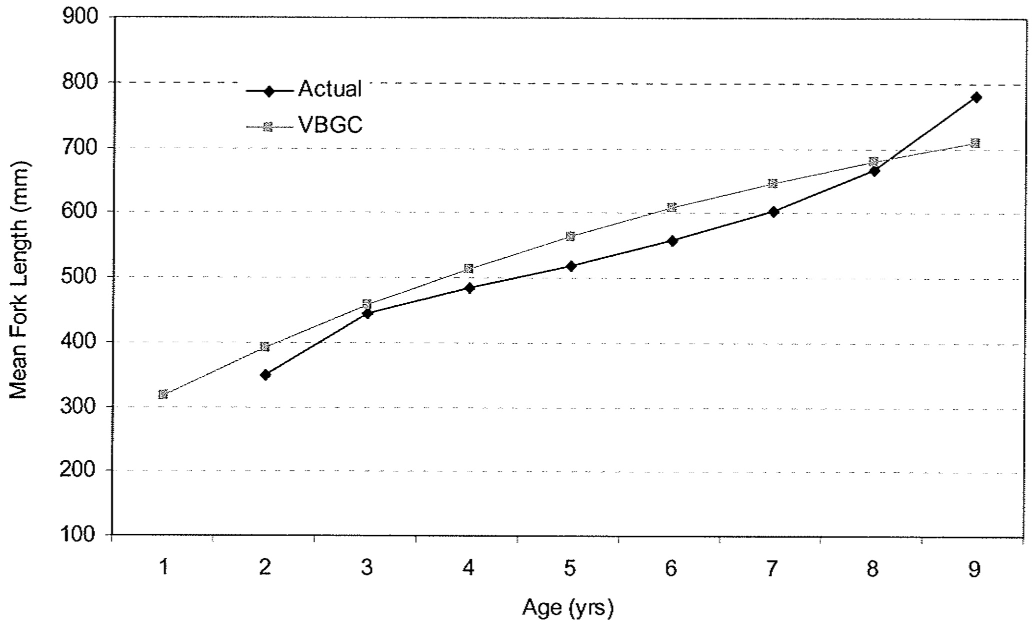

Figure 43. Mean length at age and von Bertalanffy growth curve (VBGC) based on ages 2 – 7 for northern pike sampled in spring 2003.

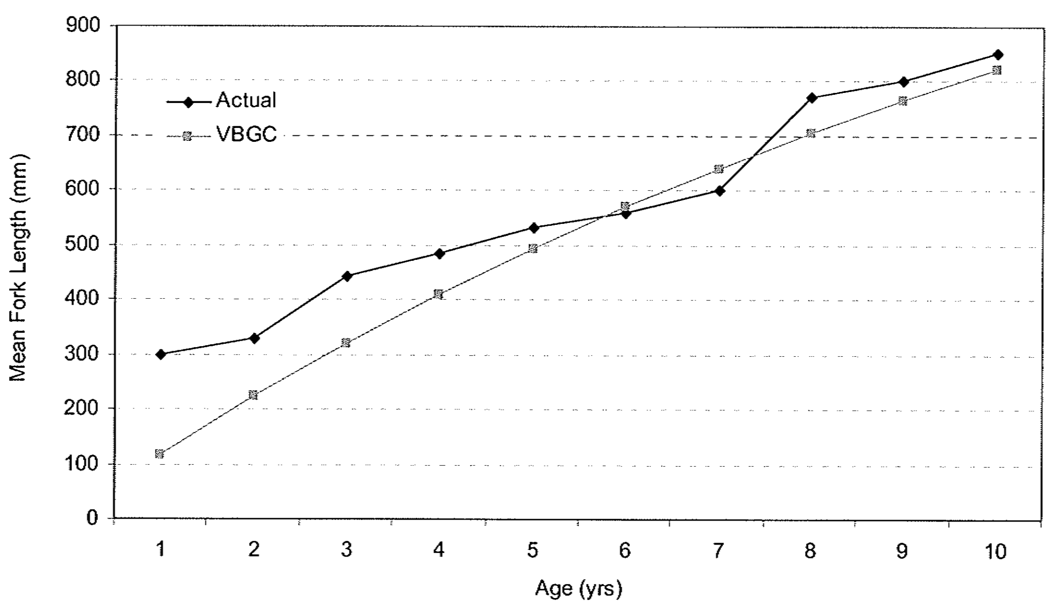

Figure 44. Mean length at age and von Bertalanffy growth curve (VBGC) based on ages 5 – 9 for northern pike sampled in spring, 2004.

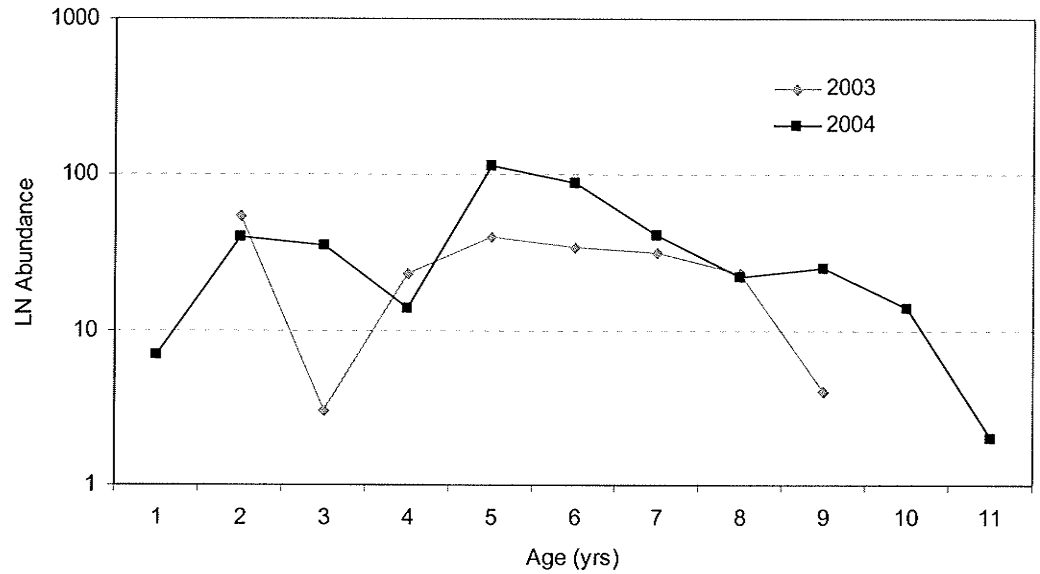

Figure 45. Northern pike catch curve for spring 2003 and 2004.

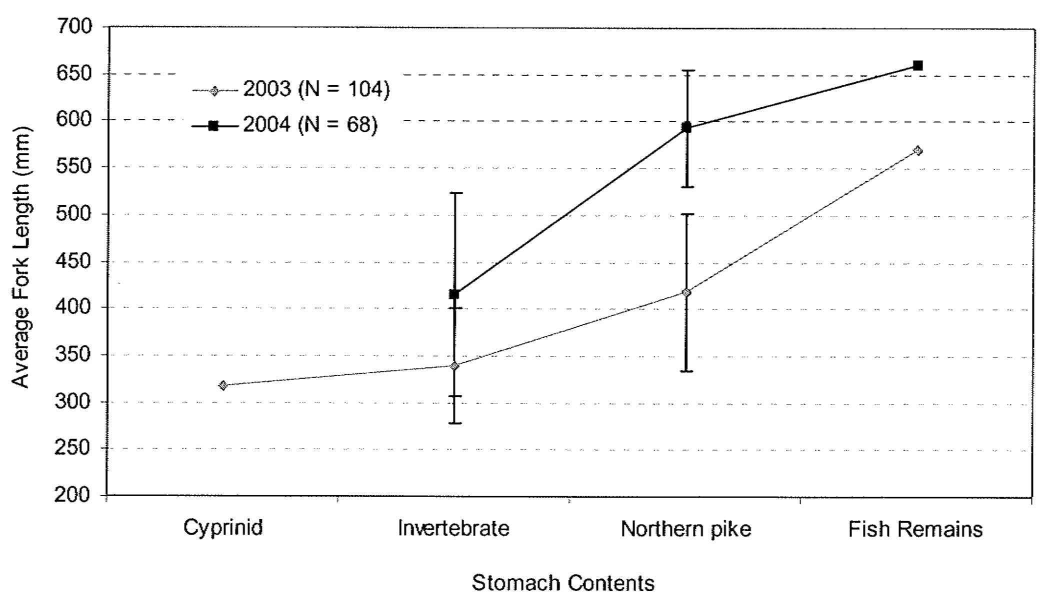

Figure 46. Average fork length (mm) (± standard deviation) of northern pike with identifiable stomach contents from Root Lake in 2003 and 2004.

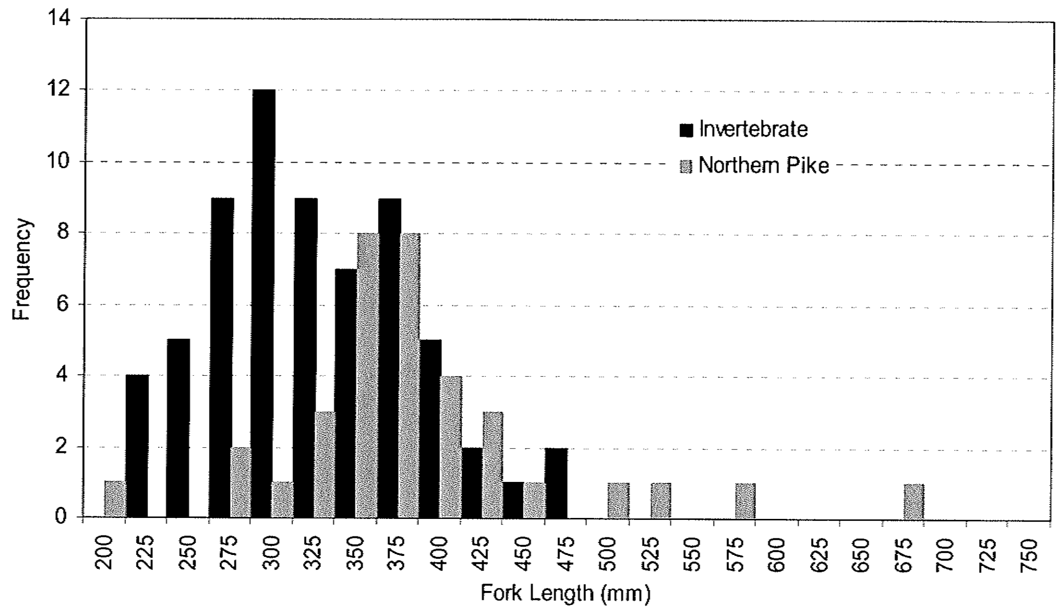

Figure 47. Fork length (mm) frequency distribution of northern pike captured in Root Lake with invertebrates and northern pike as stomach contents, 2003 (n = 100).

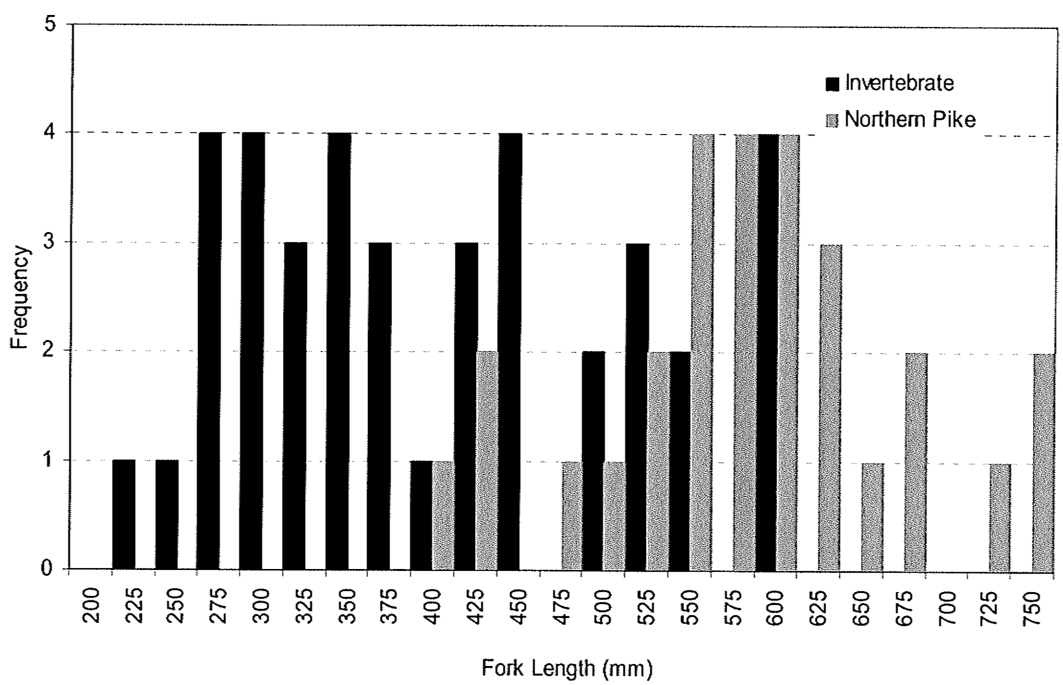

Figure 48. Fork length (mm) frequency distribution of northern pike captured in Root Lake with invertebrates and northern pike as stomach contents, 2004 (n = 67).

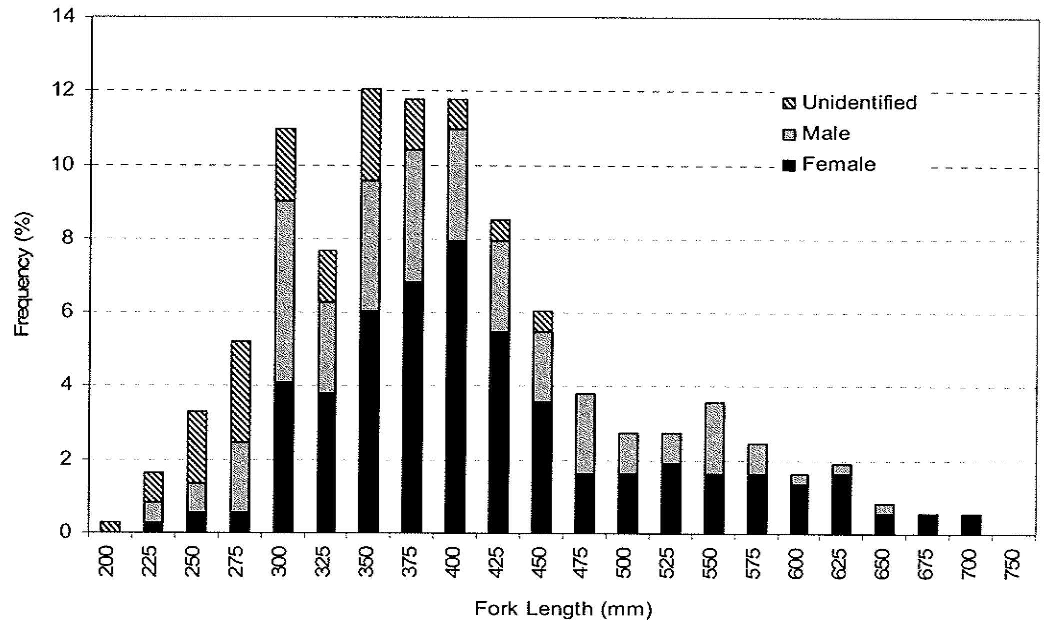

Figure 49. Fork length (mm) frequency distribution of northern pike captured in Root Lake by gender, 2003 (n = 364).

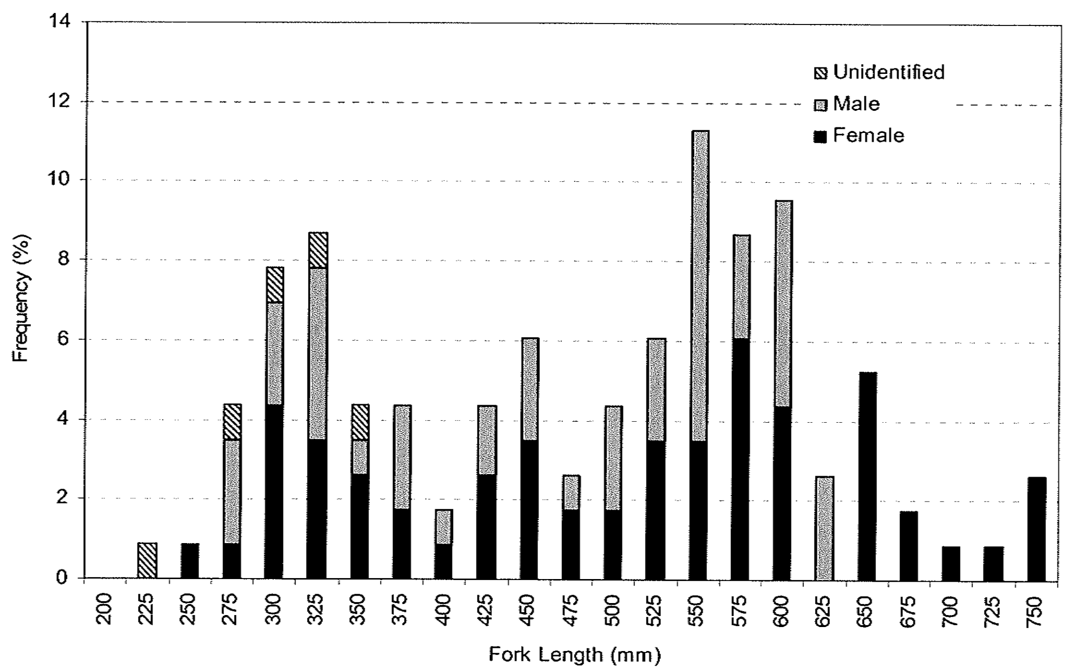

Figure 50. Fork length (mm) frequency distribution of northern pike captured in Root Lake by gender, 2004 (n = 115).

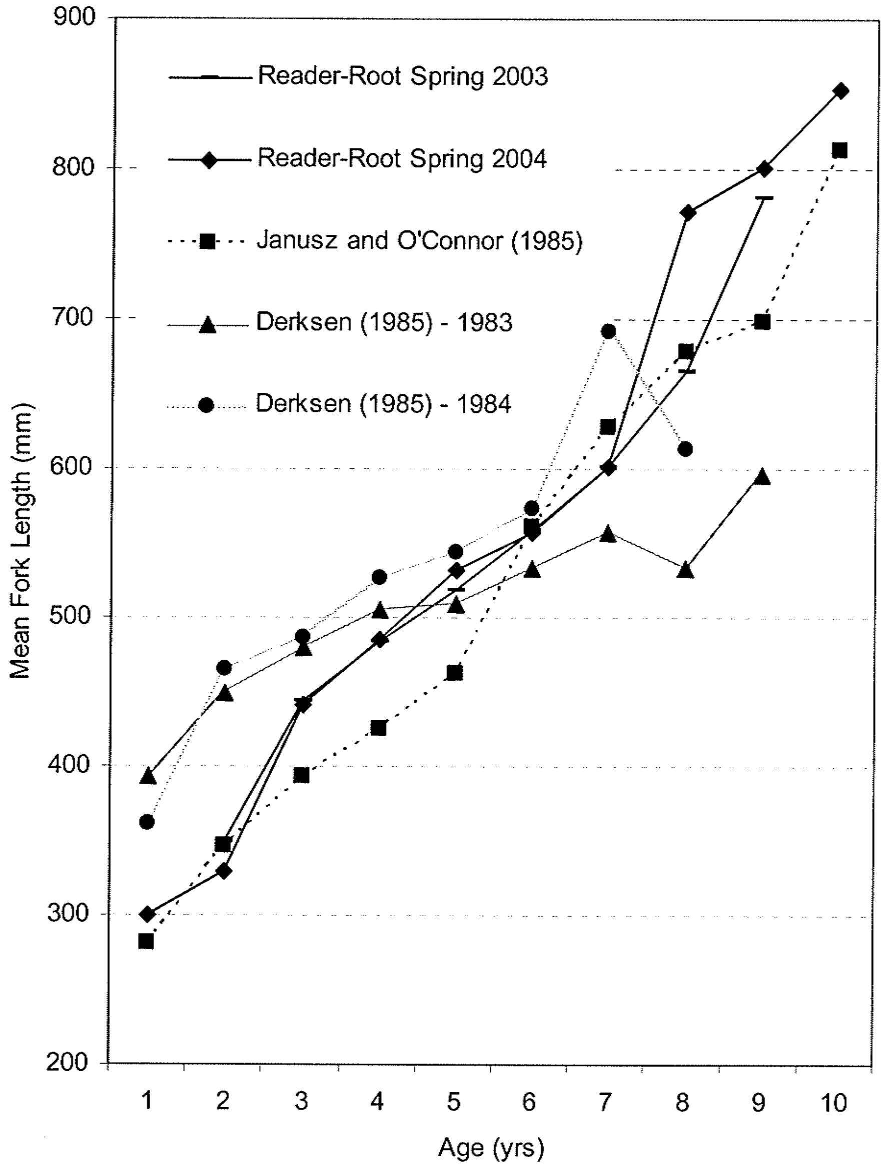

Figure 51. Comparison of mean length at age of northern pike from this study (Reader-Root wetland complex, 2003, and 2004), Saskeram Marsh (Derksen and Gillies 1985), and Netley-Libau Marsh (Janusz and O'Connor 1985).

APPENDIX A: DETAILS OF NORTHERN PIKE ABUNDANCE AND FORK LENGTH FROM GILL NET SAMPLING IN ROOT LAKE, 2003 AND 2004

Table A-1. Abundance, mean length, and standard deviation (S.D.) of northern pike sampled from 4 locations in Root Lake, 2003 and 2004.

	North West				Mid-Lake				North East				South East			
2003	Mean	S.D.	Range	n	Mean	S.D.	Range	n	Mean	S.D.	Range	n	Mean	S.D.	Range	n
29-May	477.4	118.2	310 - 710	45	-	-	-	-	-	-	-	-	-	-	-	-
25-June	470.0	98.7	285 - 685	25	369.7	95.9	255 - 640	14	409.5	83.0	240 - 630	21	336.7	53.6	270 - 420	9
23-July	393.8	91.4	285 - 605	45	394.5	78.7	300 - 700	21	377.7	106.0	280 - 655	11	373.3	20.8	350 - 390	3
18-Aug.	403.6	104.4	290 - 640	22	367.4	39.3	315 - 475	17	450.7	124.1	240 - 700	14	389.0	50.2	305 - 430	5
15-Sep.	442.1	90.3	320 - 620	14	406.0	54.0	315 - 460	5	347.9	56.4	295 - 445	7	382.9	65.3	280 - 455	7
15-Oct.	401.9	91.0	210 - 605	57	255.0	11.6	245 - 265	4	277.9	49.5	245 - 380	7	475.0	-	-	1
2004																
03-June	501.8	148.8	245 - 760	37	411.7	146.9	285 - 680	9	491.2	150.3	310 - 750	13	435.9	76.2	315 - 590	11
15-June	517.3	107.9	285 - 665	15	426.3	139.4	265 - 630	8	562.2	77.6	440 - 760	18	463.8	112.9	375 - 615	4

APPENDIX B: DATA AND ANALYSIS USED FOR CALCULATION OF CATCH CURVES AND VON BERTALANFFY GROWTH EQUATIONS

Table B-1. Age specific mean fork lengths (mm), standard deviations (S.D.) used for calculation of mean age at length curves and catch curves. (Ages over 11 removed from analysis)

	Spring 2003				Spring 2004			
Age	N	Mean FL	S.D.	% of N	N	Mean FL	S.D.	% of N
1	-	-	-	-	7	300	52.3	1.7
2	54	350	32.8	25.4	40	330	31.4	9.9
3	3	444	68.5	1.4	35	442	39.6	8.7
4	23	484	41.2	10.8	14	485	39.7	3.5
5	40	519	42.1	18.7	116	532	42.8	28.7
6	34	559	53.4	16.0	88	558	39.7	21.8
7	32	602	69.4	15.0	42	602	66.4	10.2
8	23	666	72.3	10.8	22	772	88.2	5.5
9	4	781	130.8	1.9	25	801	77.8	6.2
10	-	-	-	-	14	853	75.2	3.5
11	-	-	-	-	2	815	91.9	0.5

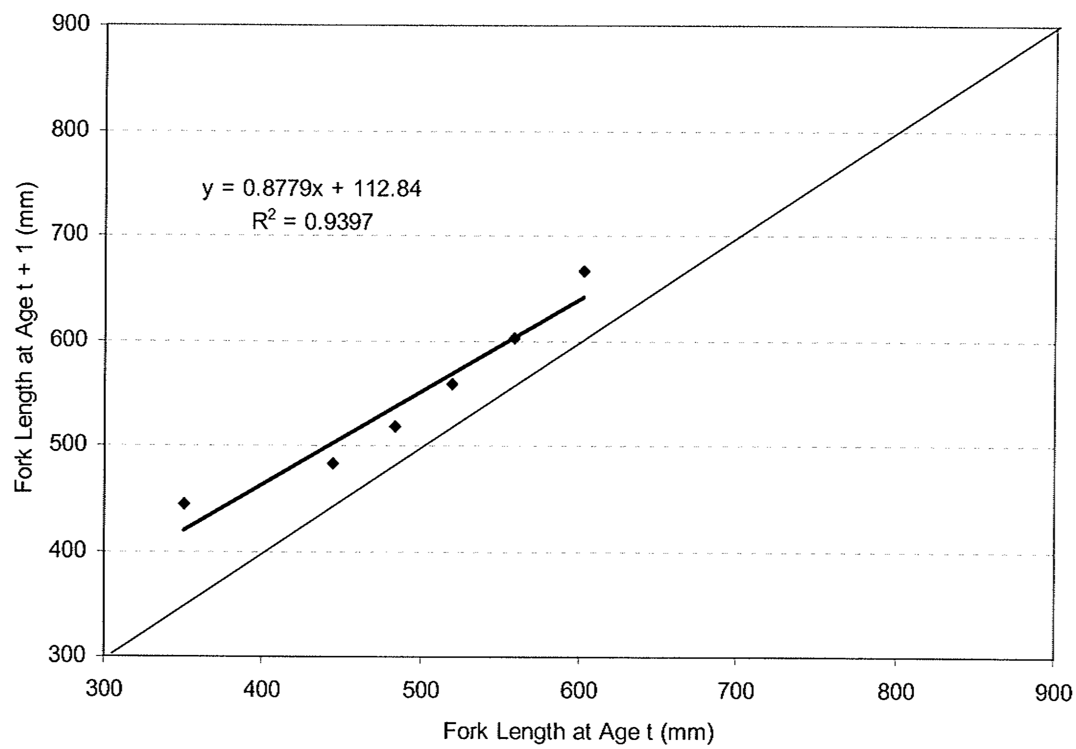

Figure B-1. Ford-Walford plot for northern pike ages 2 - 7 from spring 2003.

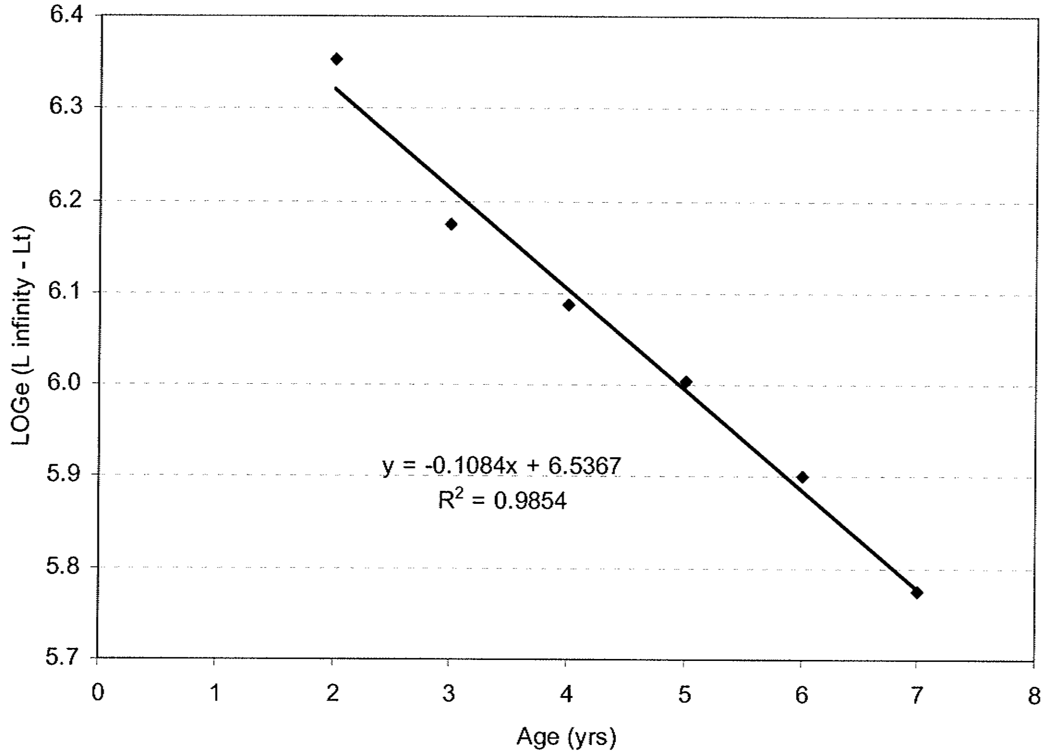

Figure B-2. Brody plot for northern pike ages 2 - 7 from spring 2003.

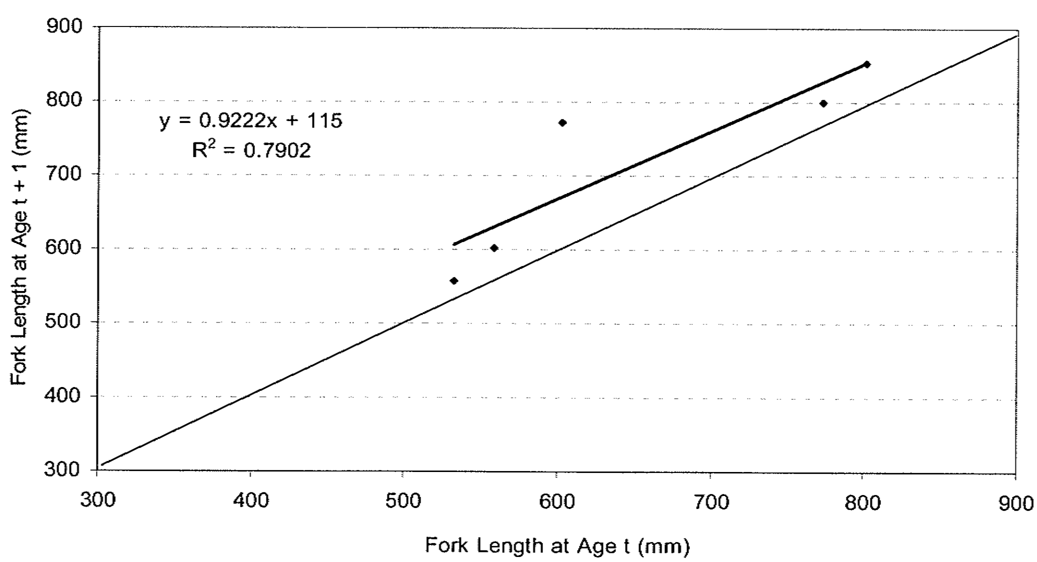

Figure B-3. Ford-Walford plot for northern pike ages 5 - 9 from spring 2004.

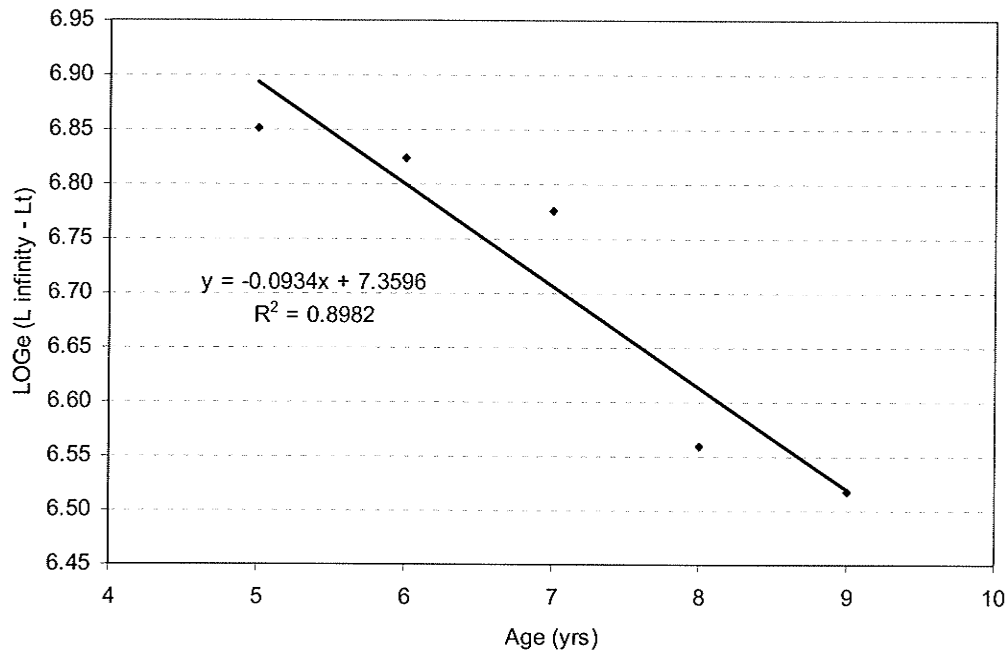

Figure B-4. Brody plot for northern pike ages 5 - 9 from spring 2004.