Environmental factors influencing recruitment of walleye in Iowa's interior rivers

Louise Marie Mauldin

Iowa State University

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Environmental factors influencing recruitment of walleye
in Iowa's interior rivers

by

Louise Marie Mauldin

A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE

Major: Fisheries Biology
Major Professor: Robert C. Summerfelt

Iowa State University
Ames, Iowa
1999
This is to certify that the Master's thesis of

Louise Marie Mauldin

has met the thesis requirements of Iowa State University
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CHAPTER 1. GENERAL INTRODUCTION

Introduction

Iowa has more than 30,400 km of fishable streams (Harlan et al. 1987). A 1994 survey of Iowa anglers indicated that 26% of the 364,246 licensed anglers preferred to fish inland streams (Lutz et al. 1995) and of the several species of gamefish, the walleye (Stizostedion vitreum) was one of the more popular. Because natural recruitment of walleye is limited or non-existent in most Iowa rivers, populations are maintained by stocking. Walleye were stocked in Iowa waters as early as the 1870s by the Iowa Conservation Commission (now the Department of Natural Resources) (Gengerke et al. 1991). In 1951, fry stocking was expanded to include some of the major rivers (Cleary and Mayhew 1961).

Low survival of stocked fry and lack of natural recruitment has been documented in the Cedar, Shell Rock, and Wapsipinicon Rivers (Cleary and Mayhew 1961, Degan 1978, Kingery 1991). However survival of stocked fingerlings in these rivers have made significant contributions to river populations (Kingery 1991, Siegwarth 1996).

The factors contributing to poor survival of stocked larval walleye and limited natural recruitment of walleye in Iowa's interior rivers are not certain. Early mortality of larval walleye in riverine environments has been attributed to lack of food, excessive suspended solid levels, fluctuation in water levels, lack of spawning substrate, fluctuation in water temperature during egg development and first feeding, excessive river discharge in spring, and predation (Cleary and Mayhew 1961, Priegel 1970, Russell 1973, Busch et al. 1975, Koonce et al. 1977, Corbett and Powles 1986, Paragamian 1987, Fielder 1992, Heidinger and
Kohler 1992, Jude 1992, Mion et al. 1998). Mortality attributable to these factors ultimately govern strength of a year class (Colby et al. 1979).

**Goals and objectives**

The walleye is an economically valuable gamefish and an important sportfish sought after by Iowa anglers. The goal is to develop and enhance natural reproduction and recruitment of walleye in Iowa's inland rivers. The strategy to achieve this goal is to develop an understanding of some of the factors limiting recruitment in Iowa’s rivers.

The objectives are 1) to characterize the historical and current distribution of walleye in Iowa’s inland rivers; 2) to assess the opinions of Iowa Department of Natural Resources fisheries management biologists as to factors contributing to the lack of natural recruitment in Iowa's rivers; and 3) to describe environmental conditions occurring in the Cedar and Wapsipinicon rivers associated with walleye spawning and occurrence of walleye eggs and larvae. The latter objective includes description of concentrations of pesticides in water, sediment, and walleye eggs, and an effort to establish a relationship between catch per unit effort of larval walleye and zooplankton and physical and chemical variables of the two rivers.

**Thesis Organization**

This thesis consists of a general introduction, a literature review, two manuscripts, and a general conclusion. Because of the focus on Iowa rivers, the plan is to submit the manuscripts to the Journal of the Iowa Academy of Science. The thesis format follows that prescribed by the ISU Graduate College, but the style follows that of the Journal of the Iowa.
Academy of Science.

**Literature Cited**


CHAPTER 2. LITERATURE REVIEW

Landforms of Iowa

Landscape level characteristics affect watershed and riparian habitat, which are fundamental influences on hydrology and stream habitat. These factors influence the quality of spawning and nursery habitat needed by walleye. Prior (1991) described seven topographic (landform) regions in Iowa. Most river descriptions are taken from Menzel (1987) and Paragamian (1990a).

Paleozoic Plateau

The Paleozoic Plateau is the oldest region in the state (Fig. 2.1). It has a rugged topography with steep valleys lined with forest and bedrock outcroppings. Cool, clear waters are characteristic of rivers in this region. Chief rivers include the Upper Iowa, Yellow, Volga, and Turkey. Upper reaches of streams in this region have high gradients and substrates comprised of limestone bedrock, cobble, gravel, and sand. Lower reaches have lower gradients and consist of silt–rock substrates.

Iowan Surface

This ecoregion has gently rolling terrain with long slopes. In the upper region, sinkholes are evidence of shallow limestone beneath the land surface. The lower part of the region is known for its small ridges or pahas, areas where little soil erosion occurred. The Iowan surface is well drained by rivers and streams. The Cedar, Wapsipinicon, and Maquoketa rivers are the main rivers that flow through this ecoregion. River floodplains are
forested, and scattered marshes and backwaters are present throughout the lengths of these rivers. Substrates of boulder, cobble, and gravel are found in extensive reaches, but shift to sand and silt substrates. The Iowan Surface region is an intensively cultivated region, and its karst terrain makes groundwater vulnerable to contamination.

**Des Moines Lobe**

The Des Moines Lobe forms the southernmost portion of the "prairie pothole" region of central North America. The retreat of the Wisconsin glacier left meandering rivers and streams, shallow lakes, and four deeper lakes called the Iowa Great Lakes. The area has a
series of depressions, knobby moraine ridges, and numerous wetlands. The retreating glacier left many partially closed depressions joining neighboring depressions to form chains of prairie potholes. The potholes act as an extensive system of "natural drainage tiles," joining poorly drained upland areas with surface waters. Major rivers in this region include the Boone, North Raccoon and Middle Raccoon rivers, and the East and West Fork of the Des Moines, all tributaries to the Des Moines River. Other rivers of the region that lie east of the Des Moines River are the South Skunk River and the upper portion of the Iowa River. Stream bottoms in the Des Moines Lobe consist of cobble, gravel, sand, silt, and occasional outcrops of bedrock.

**Northwest Iowa Plains**

This agricultural landscape is gently rolling, and the bedrock is covered by layers of glacial drift and wind-blown silt (loess). Streams in the region have moderate gradients. Row crops and grazing dominate the riparian zones. The loess soils in this region are easily eroded, and unprotected riverbanks are unstable. The Big Sioux and Little Sioux are the dominant rivers here.

**Southern Iowa Drift Plain**

The Southern Iowa Drift Plain has steeply rolling, well-drained terrain with deep loess soil deposits. Rivers have steep banks and substrates composed of silt, sand, and clay. The region is characterized as having highly erodible soils due to the hilly topography. Stream levels fluctuate greatly after precipitation events. In the Mississippi River drainage, sections of the Wapsipinicon, Cedar, Iowa, lower Skunk, and Des Moines rivers are dominant. In the Missouri River basin, portions of the Floyd, Maple, Little Sioux, Soldier,
Boyer, Nishnabotna, Nodaway, Platte, Thompson Fork of the Grand, and Chariton rivers fall into the ecoregion.

**Western Loess Hills**

The Loess Hills landform is a band of high relief that runs the length of the Missouri Valley in Iowa. The landscape is composed of thick deposits of loess-based soil. Erosion has carved the loess into narrow ridges and steep sideslopes. Although the highly erodible landscape is distinctly different from the lowland features of the Missouri Alluvial Plain, its origin is tied to that of the alluvial landform. Lower reaches of the Floyd, Little Sioux, Maple, Soldier, Boyer, and Nishnabotna rivers traverse the region. Waters are turbid, and substrates are composed of mud, clay, and sand.

**Alluvial Plains**

Valleys in the Missouri and Mississippi alluvial plains are much wider than the rivers within the state, indicating that excavation by flood flows occurred during glacial melting. These river channels have numerous pools, sloughs, side channels, and floodplain lakes (Menzel 1987).

**Vegetation Communities of Iowa**

Maps of vegetative communities from 1832 to 1859 federal land surveys indicate that prior to European settlement of Iowa, about 79.5% of the 14.6 million hectares were in tallgrass prairie (Table 2.1, Smith 1998). Wetlands (sloughs, marshes, springs/bogs, and swamps) constituted 1.4% (198,015 ha) of the land (Smith 1998). Extensive wetland complexes were located in the floodplains and backwaters of the Mississippi and Missouri
rivers and their tributaries (Bishop and Van der Valk 1982).

The Wisconsin glacier left the "prairie pothole" region of the Des Moines Lobe with a landscape containing prairies interspersed with potholes and marshes. This covered an area of about 3.0 million ha (Bishop et al. 1998). About 11.7% of the state was covered in forest. Forested areas were concentrated in the eastern one-third of the state with timber forming a border along most rivers.

The first pioneers entered Iowa in the early 1830s. Within 70 years of settlement, virtually all the native prairie was tilled. At present, only scattered fragments (0.1%) of the 11.6 million ha of original Iowa prairie remain (Table 2.1, Smith 1998). More than 90% of Iowa's original landscape has been converted to agriculture and urban development.

About 11% of Iowa's original 198,015 ha of wetlands remain today (Bishop et al. 1998). The most extensive loss has occurred in the "prairie pothole" region of northcentral

<table>
<thead>
<tr>
<th>Vegetation Type</th>
<th>1832-1859 Hectares</th>
<th>Percent</th>
<th>1975-1996 Hectares</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prairie</td>
<td>11,576,165</td>
<td>79.5%</td>
<td>11,576</td>
<td>0.1%</td>
</tr>
<tr>
<td>Forest</td>
<td>1,707,472</td>
<td>11.7%</td>
<td>810,000b</td>
<td>5.6%</td>
</tr>
<tr>
<td>Savanna</td>
<td>974,063</td>
<td>6.7%</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Wetland</td>
<td>198,015</td>
<td>1.4%</td>
<td>21,782c</td>
<td>0.1%</td>
</tr>
<tr>
<td>Other</td>
<td>113,638</td>
<td>0.8%</td>
<td>111,981</td>
<td>0.8%</td>
</tr>
<tr>
<td>Agriculture</td>
<td>--</td>
<td>--</td>
<td>~13,383,000</td>
<td>92.0%</td>
</tr>
<tr>
<td>Urban</td>
<td>1,395</td>
<td>&lt;1.0%</td>
<td>239,063</td>
<td>&lt;1.6%</td>
</tr>
<tr>
<td>Total hectares</td>
<td>14,570,000</td>
<td></td>
<td>14,577,948d</td>
<td></td>
</tr>
</tbody>
</table>

aSmith 1998    bJungst et al. 1998
cBishop et al. 1998
dMixed sources result in inequality of total hectares
Iowa. Recently, wetland areas have increased as a result of the development of the North American Waterfowl Management Plan, other wetland legislation, and purchase and restoration of wetlands through programs of various conservation agencies and groups. Since the early 1980s, natural marshes have increased from 10,717 ha to 14,922 ha. Although the area of oxbows, sloughs, and floodplains was difficult to assess in the 1800s, river oxbows and overflow areas have increased from 16,194 ha in 1980 to 30,317 ha in 1997 (Bishop et al. 1998).

Substantial reductions in forestland occurred in the mid-1800s in eastern and southern Iowa (Van der Linden and Farrar 1984). Settlers used the timber for lumber and fuel and later found that there was profit in hardwoods like hickory and oak for furniture and other uses. Thomson and Hertel (1981) reported that the area of forestland declined to a low of 0.65 million ha in 1974, but increased to 0.81 million ha (5.6%) by 1990 (Jungst et al. 1998).

**Human Influences on Aquatic Habitats**

Landscape changes such as draining of floodplains, timber harvest, urban sprawl, and the intensification of agriculture have collectively led to the degradation and fragmentation of aquatic habitat. Of these activities, agriculture has been reported as the leading source of impairment in our nation’s rivers and streams (Waters 1995), and it is the activity thought to be most responsible for the loss of fish species in the Midwest (Karr et al. 1985).

Bulkley et al. (1975) reported that over 4,827 km of Iowa streams have been lost to channelization. Today, one-third of the total assessed river kilometers in Iowa have been impaired by habitat alterations, primarily related to stream channelization (IDNR 1997).
Removal of river bends and oxbows (channel straightening) increases the amount of tillable land, but alters stream hydrology and aquatic habitat. Channel straightening creates shorter paths increasing stream velocities, which can cause extensive streambank and streambed erosion and an increase bedload. Channel straightening also changes internal and external energy sources. Ultimately, aquatic plant, macroinvertebrate, and fish community composition are substantially altered.

Loss of riparian vegetation from channelization, and intensive agricultural practices results in the destabilization of banks and increases sediment input to the stream carrying nutrients and pesticides. Removal of streamside vegetation also reduces cover for fish, raises water temperature, and reduces inputs of leaf litter as an energy source.

Many rivers and streams in Iowa have been altered by the presence of hydroelectric dams, mill dams, and recreational dams. The first dams present in Iowa were mill dams, constructed in the early 1830s (ICC 1979). Dams can be barriers to upstream and downstream movement by fish (ICC 1979, Trautman 1981). In a 1979 inventory of Iowa dams, over 200 lowhead dams were present in Iowa's rivers and streams, ranging from 0.3 meters to about 11.5 meters in height (ICC 1979). In addition to the presence of dams, levees and dikes have further reduced connections between rivers and their floodplains. Through these hydrological and habitat modifications, water tables are lowered, making droughts and floods more common.
Distribution of Walleye in Iowa Rivers

Walleye are generally associated with larger and deeper rivers and drainage lakes (Meek 1890, Forbes 1908, Trautman 1981, Scott and Crossman 1973, Becker 1983, Pflieger 1997). Fish fauna surveys did not begin in Iowa until the late 1800s, after a substantial part of Iowa was already modified by agriculture. Walleye were not collected in the first recorded fish fauna work conducted in the state of Iowa by Jordan and Meek (1885) on the lower Des Moines and Chariton rivers. Few walleye were taken in the Big Sioux, Iowa, and Cedar rivers in surveys by Meek (1892) from 1889-1891. Call (1892) did not report collection of walleye in a survey of the Des Moines River and several of its tributaries (Squaw, Beaver, Raccoon, Middle and North Rivers).

Starrett (1950) sampled the Des Moines River in Boone County, and several prairie creeks in 1946 and 1947. He collected walleye in the Des Moines River, however they were not abundant (Starrett 1950). A 1946-1948 survey by Harrison (1949) in the upper Des Moines River watershed was the first to indicate walleye occurrence in some abundance. He reported that walleye were common in the river above Fort Dodge. In 1951, Harrison (1951) sampled the Des Moines River and its major tributaries below the city of Des Moines. Walleye, 203 mm-254 mm in length, were collected at several sites and were thought to come from a successful spawning in 1950 (Harrison 1951).

Cleary (1952) made extensive collections throughout the Wapsipinicon River drainage from 1948 through 1951, but walleye were found only in the middle reaches of the river. Cleary (1953) also published a checklist of fishes in the Iowa and Cedar rivers based on 254 collections between 1948-1952. This checklist also included earlier unpublished
surveys by Hubbs, Salyer, and Bailey in the 1930s and early 1940s on the Iowa and Cedar rivers. These surveys indicated walleye were occasionally found in the Shell Rock and upper and middle reaches of the Iowa and Cedar rivers (Cleary 1953).

Harrison and Speaker (1954) made collections from 17 rivers and streams of the Missouri drainage between 1949 and 1952. No walleye were collected in their sampling, but they reported that anglers caught walleye in the Rock and Little Sioux rivers. Walleye were not found in collections made from 1954-1959 on the Boone River, however, in the six-year study, a number of walleye were collected in the East and West Fork of the Des Moines River and in the Raccoon River (Harrison 1960). In 1958, the Iowa Conservation Commission treated a portion of the Winnebago River with a piscicide to reduce the density of carp and other rough fish. No walleye were found in the river prior to, or during the eradication (Harrison 1961). In 1961, no walleye were captured in an 11.3 km stretch of the Iowa River north of Iowa Falls when it was treated with rotenone to remove rough fish (Cleary and Moen 1961).

Walleye were not found in creel and fish surveys conducted in 1962-1963 on the Des Moines River at the construction site of the Red Rock Dam (Harrison 1963). Walleye were not reported in the Chariton River prior to impoundment of Rathbun Lake (Meek 1892, Harrison and Speaker 1954, Mayhew 1965). Walleye were not present in fish surveys conducted on the upper and lower Skunk River and its tributaries (Zach 1968, Laser et al. 1969, Coon 1971).

Kline (1969, 1970a, 1970b) did not collect walleye from the Floyd, Maple, and Soldier rivers in surveys carried out in 1969 and 1970. No walleye were found in collections
made in several tributaries of the Des Moines, Cedar, and Iowa Rivers (King 1976).

Paragamian (1986) sampled 69 sites on Iowa’s major rivers and tributaries in a statewide fish distribution survey from 1983-1985. Few walleye were collected, with the greatest abundance in the Iowan Surface Region and second highest numbers collected in the Des Moines Lobe. Walleye were collected in the Maquoketa and West Fork of the Cedar River in the Iowan Surface, the Iowa and North and Middle Raccoon rivers of the Des Moines Lobe, and North Skunk, Chariton, West Nishnabotna rivers, and South Avery Creek of the Southern Iowa Drift Plain.

**Contribution of Stocked Walleye Fry and Fingerlings in Iowa Rivers**

The earliest fish surveys indicated walleye were rare in inland rivers of Iowa. The natural scarcity of walleye in Iowa streams prompted the state fisheries agency to stock fry and fingerling walleye to satisfy angler’s interests in this species. Stocking of walleye in some interior rivers and lakes of Iowa occurred as early as 1874 (Gengerke et al. 1991). After some success in stocking walleye fry in Iowa lakes, the fry stocking program was expanded to include major rivers in the state in 1951 (Cleary and Mayhew 1961). Fry stockings were made on an alternate-year basis. In the early 1950s, walleye were stocked in the Des Moines, Raccoon, Iowa, Cedar, Wapsipinicon, and Iowa rivers (Gengerke et al. 1990). Studies assessing survival of stocked fry in the Cedar River showed that alternate-year stocking did not influence year class abundance (Cleary and Mayhew 1961). Cleary and Mayhew (1961) suggested that river discharge and air temperature were important factors affecting spawning success and survival of walleye in the Cedar River. Degan (1978) also
reported meager natural reproduction and survival of stocked walleye fry in the Cedar River.

Paragamian (1990b) evaluated survival of stocked walleye in the Shell Rock, Cedar, and Wapsipinicon Rivers. From 1986-1990, walleye fry were stocked primarily in April on the three rivers (Table 2.2). Fingerlings were released later in the spring and summer. Young-of-the-year (YOY) walleye were seldom collected prior to stocking of fingerlings. The average contribution of stocked fingerling walleye to YOY populations in the study was 71%, 93%, and 75% for the Cedar, Shell Rock, and Wapsipinicon Rivers, respectively (Kingery 1991). Thus, stocked fingerlings in these rivers made substantial contributions to year classes. Beginning in 1991, fingerling plantings replaced sac fry releases (Siegwarth 1996). From 1991-1995, stocked fingerling walleye in the Cedar River accounted for over 80% of the population, and stocked walleye fingerlings in the Wapsipinicon River accounted for over 90% (Siegwarth 1996).

Table 2.2. Stocking records of walleye fry and fingerlings in the Cedar, Shell Rock, and Wapsipinicon rivers, 1986-1990 (Kingery 1991).

<table>
<thead>
<tr>
<th>Year</th>
<th>Cedar River</th>
<th>Shell Rock River</th>
<th>Wapsipinicon River</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>fry</td>
<td>fingerlings</td>
<td>fry</td>
</tr>
<tr>
<td>1986</td>
<td>650,000</td>
<td>6,522</td>
<td>0</td>
</tr>
<tr>
<td>1987</td>
<td>650,000</td>
<td>5,000</td>
<td>100,000</td>
</tr>
<tr>
<td>1988</td>
<td>650,000</td>
<td>1,700</td>
<td>391,000</td>
</tr>
<tr>
<td>1989</td>
<td>650,000</td>
<td>6,976</td>
<td>700,000</td>
</tr>
<tr>
<td>1990</td>
<td>650,000</td>
<td>5,859</td>
<td>450,000</td>
</tr>
<tr>
<td>Total</td>
<td>3,250,000</td>
<td>26,057</td>
<td>1,641,000</td>
</tr>
</tbody>
</table>
Survival of Stocked and Wild Walleye Fry and Fingerlings in Other River Systems

Larval and fingerling walleye plantings in rivers and lakes have met with varied success. Timing of fry stocking has been found to be important to the survival and contribution to the year class. Larval walleye are vulnerable to river currents, pollutants, predation, disease, and starvation. In the Saginaw River, Michigan, starvation of naturally spawned larval walleye was presumed to occur when river currents were not fast enough to transport natural larvae downstream to a nursery area in time (Jude 1992). Strong river currents may have directly increased mortality of natural larval walleye in the Maumee and Sandusky Rivers, Ohio (Mion et al. 1998).

Scarcity of zooplankton and possible predation were the suspected causes of poor survival of 3,200,000 and 2,500,000 stocked fry in the lower Current River in 1967 and 1968, respectively (Russell 1973). Low survival of 11 million fry stocked in the Kaskasia River, a tributary of Lake Shelbyville, Illinois was most likely related to fluctuation of water temperature when fry were stocked, scarcity of prey during larval development, and susceptibility to predation by fish (Heidinger and Kohler 1992). Survival of fingerlings stocked later that spring was more successful (Heidinger and Kohler 1992).

Iowa River Walleye Populations

Annual sampling has provided some long-term information about population dynamics of walleye in some Iowa Rivers (Table 2.3). Sampling on the Shell Rock, Cedar, and Wapsipinicon rivers by the fisheries section of the Iowa Department of Natural
Table 2.3. Population estimates (PE) of adult walleye and standing stock reported in five Iowa rivers. Estimates are reported by Kingery (1991) and Siegwarth (1993-1996).

<table>
<thead>
<tr>
<th>Year</th>
<th>Cedar River</th>
<th>Shell Rock River</th>
<th>Wapsipinicon River</th>
<th>Des Moines River</th>
<th>Raccoon River</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PE</td>
<td>kg/ha</td>
<td>PE</td>
<td>kg/ha</td>
<td>PE</td>
</tr>
<tr>
<td>1988</td>
<td>1442</td>
<td>33.2</td>
<td>246</td>
<td>15.9</td>
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\textsuperscript{a} population estimate not calculated due to insufficient sample size.

\textsuperscript{b} years in which standing stock was expressed as kg/km.
Resources has been part of a sampling regime for a number of years. Walleye populations vary widely from year to year and are determined by the survival of fingerlings stocked each year. The carrying capacity of these rivers for walleye is not known, but ranges of standing stock provide some information as to the numbers that can be successfully planted in river reaches to increase populations.

**Habitat Use of Walleye**

Stream depth, gradient, current velocity, slope of the bank, and bottom type, are several factors that influence the distribution and abundance of fish. These factors are important in the survival of walleye in all life stages. Telemetry studies have shown that habitat used by adult walleye differs widely throughout the season (Kingery 1991).

**Seasonal habitat use**

Paragamian (1989b) reported that stream velocity in the Cedar and Shell Rock rivers was an important factor governing use of different substrates, cover, and pool depths. Adult walleye were found over gravel substrates during spring spawning, summer, and autumn on the Cedar River, and in deep sheltered habitats out of the main current in fall and winter. Pools greater than 1.8 m in depth were most frequently sought after in winter in the Cedar River downstream of the Waverly dam (Paragamian and Kingery 1992). Overwintering habitat of adult walleye in the Wapsipinicon River occurred in pools greater than 2 m in depth (Siegwarth 1996). In a 9.6 km stretch of the Wapsipinicon River, several species of radio tagged gamefish all migrated and overwintered in a single pool of more than 6 m deep (Siegwarth 1996). This was the deepest available habitat in a 24 km reach of river.
Cover, in the form of streamside vegetation, logs, or brush can provide resting and hiding places for stream fish. Walleye were not closely associated with cover in the study, but use of cover was highest in the fall and after spawning in the spring (Kingery 1991).

Preferred walleye habitat was nearly nonexistent in many stretches of the Cedar River system (Paragamian 1989a). Walleye were most abundant in a downstream stretch of river within 9.7 km of the Waverly dam. This reach or river contained several deep intermittent pools and gravel-cobble and boulder substrates that were suitable spawning sites. Beyond 10 km of the dam, pools were shallow, the banks were eroded, and the substrate was sand (Paragamian 1989a). Walleye were reported to pass through this river reach, but not to inhabit it.

**Spawning habitat**

When water temperatures reach about 2.8°C on the Cedar River, walleye move out of wintering pools and migrate to spawning sites (Kingery 1991). Walleye spawn in relatively shallow water, varying from a few centimeters to several meters (Colby et al. 1979). They spawn over various bottom types in rivers and streams, but they generally prefer to spawn over clean, hard substrates like coarse gravel or small boulders, usually below impassable dams or falls of rivers, and along rocky shoals of lakes. Walleye spawned in several tributaries and along the lakeshore of Oneida Lake, New York (Forney 1966). Walleye spawned over gravel and rock in Apsley Creek, Ontario, sand in Redmond Creek, Ontario (Corbett and Powles 1986), coarse rock and gravel in high gradient areas below the dams of Poultnney and Missisquoi rivers, Vermont (Mitro and Parrish 1997), rocky areas of the Current River, Missouri (Russell 1973), and over gravel, cobble, and mussel shell substrate in
upper Pool 13 of the Mississippi River (Pitlo 1989). Walleye also spawn over vegetative mats in the flooded marshes adjacent to the Fox River, Wisconsin (Priegel 1970). In the Cedar River, Iowa, walleye spawn over riffles consisting of large cobble and small boulders downstream of dams (Paragamian and Kingery 1992).

**Nursery habitat**

Shortly after hatch, larval walleye drift downstream from spawning sites to nursery areas for refuge and to seek food. In rivers, quiet areas out of the main current are critical to the survival of larval walleye. Lakes encompassed by tributary rivers serve as nursery areas to walleye (Forney 1966, Priegel 1970, Elrod et al. 1977, Heidinger and Kohler 1992, Johnston et al. 1995, Mitro and Parrish 1997). Larval walleye also find refuge and food in large bays (Forney 1966, Jude 1992, Mion et al. 1998), and reservoirs (Schademann 1987).

**Feeding Ecology of Larval Walleye**

Most mortality in fish is predicted to occur early in life. More specifically, the change from endogenous to exogenous feeding is critical to the survival of larval fish (Li and Mathias 1982). Upon hatch, walleye fry are usually 6-8.6 mm in length (Priegel 1970, Scott and Crossman 1973). Larvae must drift downstream to areas where suitable prey are abundant, before their energy reserves are depleted. Feeding usually begins within five days of hatch when the yolk sac is absorbed (Priegel 1970, Colby et al. 1979, Li and Mathias 1982), but first feeding has been observed in larval walleye before the yolk sac has been depleted (Hohn 1966, Houde 1967).
There is considerable variation in prey of first feeding larval walleye in both laboratory and field conditions. Hohn (1966) observed diatoms in the gut of larval walleye collected from Lake Erie. Smith and Moyle (1945) observed rotifers and copepod nauplii in the gut of larval walleye collected from ponds, and Johnson (1969) reported rotifers in the stomachs of larval walleye in Little Culfoot Sioux Lakes, Minnesota. In Clear Lake, Iowa, cladocerans and copepods were the main prey items of larval walleye even though copepod nauplii and rotifers were abundant in the lake (Bulkley et al.1976). Other researchers have reported cladocerans and copepods in the diet of first feeding walleye (Houde 1967, Priegel 1970, Raisanen and Applegate 1983, Shademann 1987, Fox 1989, Graham and Sprules 1992, Heidinger and Kohler 1992).

Raisanen and Applegate (1983) observed that as mean length of larval walleye increased, larger prey such as cladocerans were preferred over smaller prey such as copepod nauplii. Schademan (1987) observed walleye less than 13 mm in length feeding on small cyclopoids, and as they grew, replaced smaller cladocerans, such as Bosmina sp., with larger cladocerans, particularly Daphnia sp. Adequate numbers and size of prey, preferred prey, and successful feeding reduces the risk of starvation in larval walleye and ensures growth. Macroinvertebrates may also be a part of the diet of larval walleye as well as fingerling walleye. When the walleye reaches about 50 mm in length, fish are added to their diet.

Plankton in Rivers

Variation in phytoplankton and zooplankton abundance is influenced by water temperature, stream flow, biological oxygen demand (BOD), water quality, predator pressure,
and turbidity (Greenberg 1964, Lack 1971, June 1977, Tait et al. 1984). Each river system has its own seasonal pattern. Zooplankton populations in rivers, river impoundments, and tributary lakes are generally lower in spring and increase in late spring and early summer (Cushing 1964, June 1977, Paragamian 1980, Martin et al. 1981, Fielder 1992). Depending on environmental conditions, zooplankton densities have been reported to peak in some waters in mid or late June (June 1977, Martin et al. 1981, Fielder 1992). During larval walleye sampling, zooplankton concentrations were <1/L in the Maumee and Sandusky rivers, Ohio, but increased later in the spring (Mion et al. 1998). Coincident to sampling for larval walleye, zooplankton densities were 0.71/L-5.0/L in Pool 13 of the Mississippi River (Pitlo 1997), <26/L throughout Shelbyville Lake, Illinois (Heidinger and Kohler 1992), and 91/L in Clinton Reservoir, Kansas (Schademann 1987).

Timing of food availability is important to the survival of young walleye. Johnston (1969) found survival of larval walleye was related to the spring pattern of zooplankton abundance, and Priegel (1970) suggested that the scarcity of zooplankton was responsible for the poor 1966 year-class on the Wolf River, Wisconsin.

**Zooplankton abundance in rivers**

Presence of lakes and impoundments in a watershed are an important source of zooplankton to a river. Lakes along the length of the Saskatchewan River, Canada had abundant populations of plankton, which supplied tremendous concentrations to the lower reaches of the river (Cushing 1964). Adjacent stagnant waters are also critical to the establishment of zooplankton. Paragamian (1980) suggested that most zooplankton in the Maquoketa River, Iowa, originated in the backwaters.
Abundance of zooplankton tends to be higher in lakes than rivers, because residence times are longer in lakes allowing plankton numbers to build up, due to their short generation times. Williams (1964) suggested that heavy stream flow was a prime factor governing zooplankton populations. Hynes (1970) reported that zooplankton cannot maintain position in even the slightest flows of millimeters per second, therefore populations would not likely flourish in many rivers.

Rate of water replacement greatly affects the composition and size of plankton (Brook and Woodward 1956, Allan 1995). Zooplankton are rarely numerous in the open water of rivers, and those that are found, usually belong to the genera, *Cyclops* or *Bosmina* (Hynes 1970).

**Effects of Suspended Solids on the Early Life Stages of Fish**

Most rivers contain suspended matter from natural sources or from the activities of humans. The deposition of suspended sediment in streams degrades habitat by filling in pools and backwaters and covering coarse substrates used by spawning fish. This can be detrimental to the hatching success of fish eggs, and affect the survival, growth, and behavior of larval and juvenile fish in different ways.

Walleye eggs deposited on rock and gravel fall through the cracks and crevices where they are protected from predators and moderate currents. Sufficient water flow is needed to keep the eggs aerated. Slow currents may allow silt and organic material to fill the pore spaces between the rocks and coat the eggs. These suspended solids can smother eggs by preventing oxygen from reaching the developing embryo, and it can adhere to the chorion of
eggs and increase susceptibility to disease. Studies have shown that suspended solid concentrations of 1,000 mg/L reduce hatching success of white perch (*Morone americana*) and striped bass (*Morone saxatilis*), and at concentrations ≥500 mg/L, the survival of striped bass and yellow perch is reduced (*Perca flavescens*) (Auld and Schubel 1978).

Chronic exposure to suspended sediment can affect the growth, survival, and development of fish. Growth of 30-65 mm steelhead (*Salmo gairdneri*) and coho salmon (*Oncorhynchus kisutch*) was significantly reduced when exposed to benite clay turbidity levels of 25-50 Nephelometric turbidity units (NTU) for 14-21 days in experimental streams (Sigler et al. 1984). In laboratory experiments, yearling rainbow trout (*Oncorhynchus mykiss*) exposed to concentrations of 270-810 mg/L for up to six months, usually died from disease (Herbert and Merkens 1961). Red-clay turbidity of concentrations ranging from 0-48 FTU for 62 days, however, did not influence growth, disease occurrence, or survival of larval lake herring (Swenson and Matson 1976).

High turbidities can alter social and feeding behavior of larval fish. In Lake Texoma, Oklahoma, larval gizzard shad, which are normally abundant in deep water, congregated closer to the surface as intense rains increased turbid inflows, and larval freshwater drum were distributed throughout the water column in contrast to their normal concentration near the bottom (Matthews 1984). Larval lake herring (*Coregonus artedi*) densities were higher near the water surface when turbidity levels increased under laboratory conditions (Swenson and Matson 1976).

High suspended solid concentrations in the natural environment for long periods of time may reduce the consumption of prey and ultimately limit survival in fish. Reduced
feeding has been observed in some species of fish under laboratory conditions. Johnston and Wildish (1982) reported larval Atlantic herring (*Clupea harengus*) ate less *Artemia* nauplii in high suspended sediment concentrations than fish in clear water. Larval striped bass feeding mainly on copepods, consumed about 40% fewer prey in suspended concentrations of 200 and 500 mg/L than in 0 or 75 mg/L (Breitburg 1988). In contrast, capture of *Daphnia pulex* by larval striped bass was unaffected at all suspended solid concentrations tested (Breitburg 1988).

Larval walleye reared in turbid water and fed a formulated diet, fed one to two days earlier than those reared in clear water, and length and weight of larval walleye in turbid water was greater than those in clear water, respectively (Bristow and Summerfelt 1994). Bristow et al. (1996) also reported feeding, growth, and survival of walleye fry in a cultural system was greater in water with turbidity of 23.8 NTU than in water with a turbidity of 0.4 NTU. Phillips (1996) reported that larval walleye did not seem to be sensitive to suspended sediment concentrations up to 360 mg/L. In fact, feed acceptance, survival, growth, and gas bladder inflation were higher in larval walleye exposed to concentrations between 16-360 mg/L compared to those in clear water (2.3-2.7 mg/L) (Phillips 1996).

**Water Quality**

The quality of water is determined by factors such as temperature, pH, alkalinity, dissolved oxygen, turbidity, and dissolved nutrients. Human activities in the watershed such as land use, water use, and human encroachment along rivers also influence the quality of water. Water quality monitoring, water quality studies, and other sources of water quality
data have been used to assess the health of the state’s lakes, rivers, and streams. Before water quality standards developed in the mid-1970s, much of the poor water quality was attributed to point sources such as pulp mills and wastewater treatment plants. Today, major impacts on rivers and streams in Iowa are caused more from habitat alterations, mainly from agricultural activities, than from any other type of impairment (IDNR 1997).

**Quality of water in the Iowan Surface region**

Water quality studies conducted on the Cedar River and its tributaries throughout the 1970s showed elevated levels of ammonia, nitrates, fecal coliforms, turbidities, and suspended solids, usually downstream of wastewater treatment plants or during high flows, caused by runoff (UIHL 1976a, 1976b, 1976c, 1977, 1980). Poorest water quality was found in the Cedar River around the Cedar Rapids area, but water quality in that area improved from the mid-1970s to 1989, because of the consolidation of waste discharges by a treatment plant built in the 1980s (UIHL 1989).

The Environmental Protection Division of the Iowa DNR monitors water quality on rivers and streams in Iowa to determine if waters are meeting their designated uses. Stations set up for ambient water quality monitoring in the Iowan Surface Region are located on the West Fork of the Cedar, Wolf Creek, and Beaver Creek, which are tributaries of the Cedar River, and on Black Hawk Creek and the Wapsipinicon River.

Mean water quality values for seven years of monitoring from 1987-1993, along the Cedar and Wapsipinicon Rivers were: hardness 290 mg/L as CaCO₃, pH, 8.03 mg/L, turbidity, 25 NTU, suspended solids, 55 mg/L, nitrate + nitrite nitrogen, 7.0 mg/L, and total ammonia, 0.13 mg/L (IDNR 1994).
**Pesticides in Iowa rivers**

Pesticide use is important to the production of agricultural crops by controlling pests, fungus, and disease. About 98% of the corn and soybeans grown in Iowa are treated with herbicides (Baker and Lawlor 1996). The most frequently detected in Iowa streams are alachlor (Lasso), atrazine (Aatrex), carbofuran (Furadan), cyanazine (Bladex), and metolachlor (Dual) (IDNR 1997). Generally, herbicides are detected in the dissolved phase. They are transported from fields through surface runoff, through tiles that drain fields, and through ground water (Squillace and Engberg 1988).

In a 1984-1985 study of the Cedar River basin, the largest number of herbicides and the highest concentrations of herbicides were found after application in the spring (Squillace and Engberg 1988). Presence of alachlor, atrazine, cyanazine, and metolachlor also persisted through the fall and winter (Squillace and Engberg 1988). Although detectable levels of herbicides are found in Iowa rivers, no impairments to either aquatic life or to drinking water use were observed in 1994-1995 (IDNR 1997).

About 25 to 30% of the corn grown in Iowa is treated with insecticides, primarily for rootworm control (Baker and Lawlor 1996). Historically, major pesticide related impacts on rivers, streams, and lakes were from organochlorine insecticides. These insecticides are lipid-soluble and accumulate in the fatty tissue of fish. Insecticides like DDT, dieldrin, and chlordane, were banned in the 1970s and 1980s. They adsorb to the soil and persist longer in the environment. DDT and chlordane are still detected, but levels have declined since the 1980s (IDNR 1997). In the 1992-1995 interval, no streams in Iowa were identified as having moderate/Minor impacts from high levels of pesticides (IDNR 1997).
Fish tissue monitoring

The Regional Ambient Fish Tissue (RAFT Program) Program is an annual fish contaminant monitoring program conducted to protect the health of persons that consume fish taken from Iowa waters. In 1994, 28 samples of fish were collected from 21 sites across the state and analyzed for 23 contaminants (Olson 1996). Fish used in the analysis include bottom dwelling fish like common carp (Cyprinus carpio) and channel catfish (Ictalurus punctatus), and predatory fish like largemouth bass (Micropterus salmoides), smallmouth bass (Micropterus dolomieu), northern pike (Esox lucius), and walleye (Olson 1996). No pesticide concentrations in the study exceeded federal guidelines. Chlordane, used to kill cutworms in corn, was found in channel catfish at 0.15 ppm, but this concentration was lower than the FDA action level of 0.30 ppm (Olson 1996). Chlordane also was used on lawns and gardens, and to kill termites. Other banned pesticides detected in the samples were heptachlor, DDT, and DDE, a metabolite of DDT.

In the 1994 survey, trifluralin (Treflan) was the only pesticide detected that is currently used today. Tissues contaminated by this pesticide contained <0.05 ppm. Several common pesticides were not detected in tissue samples analyzed from 1986-1992. Since these pesticides were not detected in the six years of monitoring in Iowa and surrounding states, they were dropped from the RAFT program list (Olson 1996). Low levels of contamination are not believed to present a significant health risk to consumers of locally caught fish (Olson 1996).
Fish kills in Iowa streams

Fish populations in rivers may be adversely affected by catastrophic events such as natural and pollution-caused fish kills. It may take years for populations to recover if there are large losses of fish that are reproductive age. Fifty pollution-caused fish kills were reported by the IDNR from 1994 to 1996 (IDNR 1997). In 1997 and 1998, 69 natural and pollutant caused fish kills were reported (INDR 1998 unpublished). High levels of pesticides, nitrogen-based fertilizers, and ammonia are commonly cited as pollutants causing fish kills in Iowa waters. Fish kills reported for rivers from 1994 to 1996 and between 1997 and 1998 were largely from high levels of ammonia and low dissolved oxygen (DO). Common sources of BOD materials and ammonia were from improper disposal of animal waste from feedlots.

The highest reported fish kill was in 1996 on North Buffalo creeks in Kossuth and Winnebago Counties. The number of fish killed was estimated at 586,000. The fish kill covered 35.4 km, which was the most extensive fish kill during the 1994 to 1996 time period.

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CHAPTER 3. HISTORICAL PERSPECTIVES AND CURRENT STATUS OF WALLEYE DISTRIBUTION IN IOWA'S INTERIOR RIVERS

A paper submitted to the Journal of the Iowa Academy of Science

Louise M. Mauldin and Robert C. Summerfelt

ABSTRACT

Natural recruitment of walleye (Stizostedion vitreum) has been limited in Iowa's interior rivers as shown from studies conducted by the Fisheries Bureau of the Iowa Department of Natural Resources (IDNR). To satisfy angling demand, walleye have been stocked in many rivers and lakes since the 1870s by the Iowa Conservation Commission, now the Iowa Department of Natural Resources. To understand factors limiting distribution and abundance, we characterized the historical distribution and abundance of walleye in Iowa rivers by compiling taxonomic studies, fish surveys, and pre-impoundment studies from published and unpublished literature. We also surveyed IDNR fish management biologists to determine the current status of walleye distribution in Iowa's interior rivers and to obtain their opinions of factors affecting reproductive success. The earliest Iowa fish surveys indicated walleye were rare in inland rivers, found in the Big Sioux of the Northwest Iowa Plains and in the Iowa and Cedar river systems of the Des Moines Lobe, Iowan Surface and Southern Iowa Drift Plain. In 1997 and 1998, fish management biologists collected walleye in the Little Sioux River of the Northwest Iowa Plains, the Winnebago River, and the upper
Des Moines river system of the Des Moines Lobe. Walleye were also collected in mid to lower reaches of the Iowa, Cedar, Wapsipinicon, and Maquoketa rivers of the Iowan Surface and Southern Iowa Drift Plain. Biologists identified poor walleye recruitment as a chronic problem, and that lack of quality spawning and nursery habitat along with effects of sedimentation were principal factors influencing low reproductive success in Iowa rivers. In addition to stocking and human influences in the watershed, physical, biological, and chemical characteristics of rivers in distinct landforms help shape the abundance and distribution of walleye in Iowa rivers.

INTRODUCTION

Iowa has over 30,400 km of warmwater streams (Harlan et al. 1987). A 1994 survey of licensed Iowa anglers indicated that 26% of the 364,246 anglers preferred to fish inland streams (Lutz et al. 1995), and in the same survey, 15% of the fishing public preferred to catch walleye (Stizostedion vitreum). The walleye is a coolwater, piscivorous fish, indigenous to North America and although it is highly sought after, it represents less than 5% of the total sportfish harvest in Iowa (Lutz et al. 1995). Since the demand for walleye is much greater than the supply and because natural reproduction is limited (Degan 1978, Paragamian and Kingery 1992), walleye populations have been sustained in rivers and lakes through stocking programs of the state fisheries agency (Cleary and Mayhew 1961). Presently, the cause of low natural reproduction in Iowa inland rivers is not certain. Insights to the physical habitat and water quality requirements may be used to assess factors affecting recruitment. In addition, past and present distribution patterns of walleye in Iowa
provide some insight into the spatial and temporal tolerance of this species in Iowa waters.

The objectives of this study were 1) to characterize the historic distribution of walleye in Iowa’s rivers and streams, 2) to report on the current distribution of young-of-the-year (YOY) and adult walleye, and 3) to provide an assessment of environmental factors contributing to the lack of natural recruitment in Iowa’s interior rivers.

**Human Influences on Fish Communities**

Fish communities of the Midwest began an immediate decline when agricultural development of land began over 100 years ago (Menzel 1981). Maps of vegetative communities from 1832-1859 federal land surveys indicate that prior to the settlement of Iowa, about 79.5% of the 14.6 million hectares were in prairie (Smith 1998). The conversion of Iowa prairie to agriculture was quite rapid, occurring within 70 years of settlement. At present, only scattered fragments (0.1%) of the 11.5 million ha of original Iowa prairie remain (Table 3.1, Smith 1998). More than 90% of Iowa’s original landscape has been converted to agricultural uses and urban development.

Wetlands (sloughs, marshes, springs/bogs, and swamps) during the 1832-1859 period constituted 1.4% of the land (Smith 1998). Only about 11% of Iowa's original wetlands (198,015 ha) remain today (Bishop et al. 1998). Since the early 1980s, however, conservation efforts have restored 4,205 ha of wetlands, and similar efforts have increased river oxbows and overflow areas from 16,194 ha in 1980 to 30,317 ha in 1997 (Bishop et al. 1998).

About 11.7% of the state was covered in forest, concentrated in the eastern one-third of Iowa and along river corridors. Substantial reductions occurred in the mid-1800s (Van der
Linden and Farrar 1984). Settlers used the timber for lumber and fuel and later found that there was profit in hardwoods like hickory and oak for furniture and other uses. In a 1990 inventory, forest area was estimated at 0.81 million ha (5.6%) (Jungst et al. 1998).

Landscape changes such as draining of floodplains, timber harvest, urban sprawl, and the intensification of agriculture have collectively led to the degradation and fragmentation of aquatic habitat and have altered stream hydrographs. Of these activities, agriculture has been reported as the leading source of impairment in our nation's rivers and streams today (Waters 1995), and it is the activity thought to be most responsible for the loss of fish species in the Midwest (Karr et al. 1985).

Agricultural related activities such as channel straightening or stream channelization have had a major influence on the character of Iowa rivers. Over 4,827 km of Iowa streams have been lost to channelization (Bulkley 1975). Loss of riparian vegetation from channelization, and intensive agricultural practices have resulted in the destabilization of banks, and have increased deposition of sediment to streams, carrying nutrients and pesticides. Removal of streamside vegetation also has reduced cover for fish, and inputs of leaf litter supplying streams with a source of energy.

Most rivers in Iowa have lowhead and/or mill dams. The first of these dams were mill dams, constructed in the early 1830s (ICC 1979). In a 1979 inventory of Iowa dams, over 200 lowhead dams were present in Iowa's rivers and streams, ranging from 0.3 meters to about 11.5 meters in height (ICC 1979). Also, four major impoundments have been developed by the U.S. Army Corps of Engineers for flood control in Iowa. Dams are barriers that can limit upriver movement of fish (ICC 1979, Trautman 1981). Destruction of
headwater spawning habitat by presence of dams has decimated many mid river species in Ohio prairie streams (Trautman and Gartman 1974). These fish historically have migrated to headwater areas to spawn.

**METHODS**

The historical distribution of walleye in Iowa’s rivers and streams was characterized by compiling taxonomic studies, checklists, fish surveys, and pre-impoundment studies from published and unpublished literature. Sites sampled by the investigators were divided into Prior's (1991) seven landforms so that consistent comparisons could be made between all studies.

In 1998, a questionnaire was sent to 11 IDNR fish management biologists to determine the present distribution of YOY walleye and adult walleye, and to obtain their assessment of river segments that may support spawning and nursery habitat. In addition, biologists were asked their opinions of factors influencing recruitment of walleye in interior rivers.

Each biologist has responsibilities for an average of nine counties. Thirty-nine major interior rivers were listed in the survey (Table 3.2). The listed rivers were divided by counties and grouped into the state's 11 fish management areas. Responses to the questions used in the survey were related to river sections by county in 1997 and/or 1998 (Table 3.3).

Spatial analysis was used to view similarities and differences between rivers and Iowa landforms. Two digital GIS coverages were obtained from the Iowa State University GIS facility. The data were used to produce distribution maps from the Landform and Rivers 500
digitized coverages. ArcView3.1 was used to map (1) river sections sampled in 1997 and 1998, (2) occurrence of YOY walleye and other cohorts, (3) sections that support natural reproduction, and (4) sections that contain suitable spawning and nursery habitat.

Biologists provided data on river sections sampled by county in 1997/1998, but not on specific sampling areas. Thus, the river stretches shown on the maps in each county are approximations. All river sections sampled in one or both years were tallied and percentages were obtained for these areas, (1) presence of YOY walleye and other cohorts, (2) YOY abundance categories, (3) sections thought to support natural reproduction, and (4) sections indicated to possess spawning and/or nursery habitat. Environmental factors influencing natural recruitment were summarized in order of importance.

RESULTS

Historical Perspective

Fish fauna surveys did not begin in Iowa until the late 1800s, after a substantial part of Iowa was already modified by agriculture. In the first recorded fish fauna survey of Iowa, Jordan and Meek (1885) did not collect walleye in the lower Des Moines and Chariton rivers in southern Iowa (Table 3.4). Meek (1892) continued to collect and identify fish from rivers and streams across the state from 1887 to 1891. Few walleye were taken in the Big Sioux, Iowa, and Cedar rivers. Call (1892) did not report collection of walleye in a survey of the Des Moines River or in several of its tributaries (Raccoon, Middle, and North rivers).

In 1946 and 1947, Starrett (1950) sampled the Des Moines River and several prairie creeks in Boone County. Some walleye were collected in the Des Moines River, however
they were not abundant (Starrett 1950). A 1946-1948 survey by Harrison (1949) in the upper Des Moines River watershed was the first to indicate walleye occurrence in some abundance. He reported that walleye were common in the river above Fort Dodge. In 1951, Harrison (1951a) sampled the Des Moines River and its major tributaries below the city of Des Moines. Walleye, 203 mm-254 mm long, were collected in several sites and were thought to come from a successful spawning in 1950 (Harrison 1951a).

Cleary (1952) made extensive collections throughout the Wapsipinicon River drainage from 1948 through 1951, but walleye were found only in the middle reaches of the river. Cleary (1953) also published a checklist of fishes in the Iowa and Cedar rivers based on 254 collections between 1948-1952. This checklist also included earlier unpublished surveys by Hubbs, Salyer, and Bailey in the 1930s and early 1940s on the Iowa and Cedar rivers. These surveys indicated walleye were occasionally found in the Shell Rock and the upper and middle reaches of the Iowa and Cedar rivers (Cleary 1953).

Harrison and Speaker (1954) made collections from 17 rivers and streams of the Missouri drainage between 1949 and 1952. No walleye were collected in their sampling, but they reported that anglers caught walleye in the Rock and Little Sioux rivers. Walleye in the Little Sioux River may have come from the outlet of the Okoboji Lakes (Harrison 1951b).

Walleye were not found in collections made from 1954-1959 on the Boone River. However, a number of walleye were collected in the East and West Fork of the Des Moines River, and in the Raccoon River (Harrison 1960). In 1958, the Iowa Fish Commission treated a portion of the Winnebago River with a piscicide to reduce the density of carp and other rough fish. No walleye were found in the river prior to or during eradication (Harrison
1961). In 1961, walleye were not captured in an 11.3 km stretch of the Iowa River north of Iowa Falls, when it was treated with rotenone to remove rough fish (Cleary and Moen 1961).

Walleye were not found in creel and fish surveys conducted in 1962-1963 on the Des Moines River at the construction site of the Red Rock Dam (Harrison 1963). Walleye were not reported in the Chariton River prior to impoundment of Rathbun Lake (Meek 1892, Harrison and Speaker 1954, Mayhew 1965), and they were not present in fish surveys conducted on the upper and lower Skunk River and its tributaries (Zach 1968, Laser et al.1969, Coon 1971).

Kline (1969, 1970a, 1970b) did not collect walleye from the Floyd, Maple, and Soldier rivers in western Iowa surveys carried out in 1969 and 1970, and walleye were not found in collections made in several tributaries of the Des Moines, Cedar, and Iowa Rivers (King 1976).

Paragamian (1986) sampled 69 sites on Iowa’s major rivers and streams in a statewide fish distribution survey from 1983-1985 (Fig. 3.1). A few walleye were collected, with greatest abundance in the Iowan Surface region and second highest numbers in the Des Moines Lobe. Walleye were collected in the Maquoketa, West Fork of the Cedar, Iowa, North Raccoon, Middle Raccoon, North Skunk, Chariton, West Nishnabotna, and South Avery Creek.

Collections from historical surveys show that walleye were primarily found in the Mississippi River drainage, in the larger rivers passing through the Iowan Surface and the Des Moines Lobe (Table 3.5). Collections were also made in the Big and Little Sioux rivers of the Northwest Plains and the Iowa River in the Southern Iowa Drift Plain. Walleye were
not reported as abundant in the interior rivers sampled, but were occasional or common in some sites along the Des Moines, Iowa, and Cedar rivers.

**Current Status**

***Young-of-the-year***

IDNR biologists sampled 34 river sections representing 1,750 km of river in 1997 and 1998 (Fig. 3.2), with 903 km of river sampled in 1997 and 847 km in 1998. YOY walleye were found in 34% of the total sampled river sections, or 592 km of river (Fig. 3.3). They were collected in 307 km of river in 1997 and 285 km of river in 1998. YOY were collected in the North Raccoon, Middle Raccoon, and West Fork of the Des Moines rivers, which are tributaries of the upper Des Moines River in the Des Moines Lobe. YOY were also collected in the lower Iowa, the Maquoketa, and middle portions of the Wapsipinicon and Cedar rivers in the Iowan Surface.

Stocked walleye were identified in 77% of the river sections where YOY were collected. Stocked walleye can usually be identified by freeze brands and fin clips that are made prior to plantings in rivers and streams. In the Wapsipinicon River, Linn County, there was some uncertainty as to whether natural fish were mixed in with stocked fish, and in Jones County, YOY walleye were identified as a combination of both stocked and naturally produced fish.

Abundance rankings were assigned to river stretches containing YOY walleye. A ranking of rare was reported in 17% of the segments, occasional in 42%, common in 17%, and abundant in 25%. Walleye abundance was occasional in reaches of the Cedar, Wapsipinicon, and Maquoketa Rivers, common in the North Raccoon, and abundant in the
West Fork of the Des Moines River and the lower reaches of the Iowa and Wapsipinicon rivers.

**Multiple age cohorts**

Walleye older than age 0 were collected in 64% (1,126 km) of the total river sections sampled in 1997 and 1998 (Fig. 3.4). Different year classes were collected in 74% of the areas sampled in 1997 and 53% in 1998. Walleye were collected in the Little Sioux, Winnebago, throughout the Des Moines River drainage, the Chariton, and in portions of the Iowa, Cedar, Wapsipinicon, and Maquoketa rivers in the eastern part of the state. Sites in which both YOY and adult walleye were collected were located in the Des Moines Lobe, the Iowan Surface, and the Southern Iowan Drift Plain.

**Spawning and nursery habitat**

Most IDNR biologists feel that of the 2,955 km of river they are familiar with or sampled the previous two years, spawning occurs in about 33% of the reaches (Fig. 3.5). Biologists indicate that natural reproduction is limited to the Little Sioux, Iowa, tributaries of the Des Moines River in the Des Moines Lobe, and the Cedar and Wapsipinicon Rivers in the eastern part of the state.

About 738 km of the total selected river sections were reported by the biologists to contain spawning habitat or nursery habitat, but not both. These areas appear scattered along the larger rivers of the state (Fig. 3.6). Areas containing both potential spawning and nursery habitat made up about 26% of the total selected areas. The Maquoketa River contains both spawning and nursery habitat according to the respondent, but surveys indicate that these areas do not support natural reproduction, suggesting that factors other than habitat may limit
the success of natural reproduction in those river reaches.

Surveys show that natural reproduction of walleye did not likely occur in 63% of the river sections. Most river segments lacking natural reproduction of walleye are located in the Missouri River drainage in the southwestern section of the Southern Iowa Drift Plain and the western part of the state. Natural reproduction is more likely to occur in the upper portions of the Big Sioux and Little Sioux rivers of the Northwest Plains. The Big and Little Sioux rivers are the dominant rivers in this ecoregion. Gently rolling landscape and bedrock covered by layers of glacial drift and wind-blown silt (loess) are characteristic of this region.

Segments not supporting natural reproduction, such as in the Southern Iowa Drift Plain, were indicated in the surveys to lack necessary spawning and nursery habitat. The Southern Iowa Drift Plain is characterized as having highly erodible soils due to the hilly topography, resulting in rivers with steep banks, and substrates composed of silt, sand, and clay.

**Factors affecting abundance**

In the opinion of management biologists, scarcity and irregular recruitment of walleye in Iowa rivers is due to sedimentation, resulting in poor quality habitat, and lack of spawning nursery habitat (Table 3.6). Inadequate numbers of broodstock ranked 4th in influential factors. Predation on young by yellow perch (*Perca flavescens*), smallmouth bass, (*Micropterus dolomieu*) and other fish in the community, and poor water quality, ranked 5th and 6th, respectively (Fig. 3.7).

Nine of eleven fisheries management biologists commented that failure of natural reproduction of walleye in Iowa's interior rivers was due to lack of habitat. They stated that
poor quality or lack of spawning and nursery habitat in many river portions was critical, and that sedimentation contributed to poor spawning conditions and poor spawning habitat.

**DISCUSSION**

**Walleye Habitat**

Walleye are generally associated with larger and deeper rivers and drainage lakes (Meek 1890, Forbes 1908, Scott and Crossman 1973, Trautman 1981, Becker 1983, Pflieger 1997). Many factors affect the distribution and range of fish species. Fish communities that inhabit particular stream sections reflect the prevailing physical and chemical conditions.

Physical habitat (including gradient, width, depth, substrate type, and stream current) is one factor that affects the distribution and abundance of fish (Orth and White 1993). There is a general consensus among the surveyed Iowa fisheries biologists, that limited recruitment in inland rivers is due in part to insufficient spawning and nursery habitat, with sediment deposition regarded as the major factor affecting habitat quality.

To a large extent, Iowa anglers also indicate that poor quality habitat has a negative impact on fish populations (Lutz et al. 1995). Paragamian (1990) found that the major factor responsible for differences in total standing stock in rivers of Iowa was habitat. Walleye were seldom encountered in the 1983-1985 study, but were most abundant in stream reaches with good habitat (Paragamian 1990).

In rivers, spawning walleye prefer clean rock-cobble substrates with moderate to strong currents for successful hatch of eggs (Russell 1973, Corbett and Powles 1986, Jude 1992, Mitro and Parrish 1997, Mion et al. 1998). They also spawn over rocky shoals along
shorelines and in flooded marshes adjacent to rivers (Priegel 1970).

Survival of larval walleye depends largely on finding a suitable food source (Colby et al. 1979, Priegel 1970). Habitats that are optimal for spawning and successful incubation of eggs are usually not suitable for feeding larvae. Shortly after hatch, larval walleye drift downstream to lower order streams where there is a greater chance of encountering food (Colby et al. 1979). In river systems, bays, lakes, impoundments, and reservoirs serve as nursery areas for larval walleye (Priegel 1970, Fielder 1992, Jude 1992, Johnston et al. 1995, Mitro and Parrish 1997, Mion et al. 1998). These areas provide refuge from main river currents, and have the capability of producing adequate populations of zooplankton, the initial food of first feeding walleye fry (Houde 1967, Bulkley et al. 1976, Raisanen and Applegate 1983, Graham and Sprules 1992).

**Fish Communities and Landforms**

Fish communities of the Paleozoic Plateau region are a mix of coldwater and warmwater species. Coldwater species like the native brook trout (*Salvelinus fontinalis*) and slimy sculpin (*Cottus cognatus*) inhabit the headwaters in this region, and minnows, suckers, and darters mainly compose the fish community of the Upper Iowa, Volga, and Turkey rivers.

This region has a rugged topography with steep valleys, lined with forest. Upper reaches of streams in this region have high gradients and substrates comprised of limestone bedrock, cobble, gravel, and sand. Lower reaches have lower gradients and contain silt-rock substrates. These cool river reaches provide spawning habitat for walleye, but sedimentation and insufficient nursery habitat for larval walleye is considered the limiting factor in this
management area. In the Paleozoic Plateau region, walleye were not present in historical surveys or by the IDNR fisheries management personnel in 1997 and 1998.

In the Iowan Surface region, smallmouth bass are the important sportfish in the headwater streams, and channel catfish and carp in the lower reaches (Paragamian 1990). Paragamian (1986) collected walleye in the Maquoketa, Wapsipinicon, and West Fork of the Cedar rivers in this ecoregion. In the present survey, both YOY and adult walleye are present in reaches of the Maquoketa, Wapsipinicon, and Cedar rivers. Success of stocked fingerlings as a result of a good forage base and habitat may explain a higher abundance of walleye in this region. The quality and diversity of habitat are provided by forested river floodplains and scattered marshes and backwaters, which are present throughout the lengths of these rivers.

Spawning and nursery habitat in this region were considered to be adequate in the middle part of this region, with poor water quality and high water levels during spring to be problematic in successful reproduction. In the lower Iowan Surface, short reaches of river provide good spawning habitat, but sufficient nursery habitat is lacking.

Carp are dominant in rivers of the Des Moines Lobe (Paragamian 1990). Walleye biomass was second to that in the Iowan Surface (Paragamian 1990). In the rivers sampled by Paragamian (1990), walleye were collected in the Iowa River, North Raccoon River, and Middle Creek. Survival of stocked fingerling walleye has been good in the East and West Fork of the Des Moines River and the Winnebago River. Small marshes and low relief are characteristic of the Des Moines Lobe. Suitable spawning substrate exists in certain stream segments, but poor habitat and sedimentation are indicated to be the major limiting factors of
natural reproduction in the northern part of the ecoregion. Walleye are also commonly found in the North Raccoon and Des Moines rivers in this management district. Insufficient spawning habitat and poor water quality (suspended solids) during the spring are the indicated factors affecting natural recruitment in these rivers.

As the Des Moines River flows through the Southern Iowa Drift Plain, the river changes character as well as species composition (Harrison 1951a). In this management district, few walleye collections have been made in the lower Des Moines River.

The Northwest Iowa Plains is represented by a carp-catfish-sucker community. Species diversity is low in this ecoregion (Paragamian 1990). Meek (1892) collected walleye from the Big Sioux River, and later collections were made in the Rock and Little Sioux rivers, but walleye were not collected in this ecoregion in the 1983-1985 study (Paragamian 1990). Although natural reproduction is questionable in the Big Sioux, available habitat can be found in sections of the Big and Little Sioux rivers. In this ecoregion, the Big and Little Sioux rivers have the most potential to support natural populations of walleye.

The southern and western rivers of the Southern Iowa Drift Plain, Western Loess Hills, and Missouri Alluvial Plain usually are regarded as channel catfish (*Ictalurus punctatus*) streams. Poor habitat may account for low walleye populations in these regions. The breaking of the land with the plow, and channelization of these reaches have undoubtedly exposed the soil to more erosion since the arrival of settlers. However, due to the nature of the topography and loess soils of this region, there probably was exposure of raw soils pre-dating settlement. Walleye were collected from the Chariton, West Nishnabotna, North Skunk rivers, and South Avery Creek in the 1983-1985 study.
Present surveys show that walleye were collected from the Chariton and Iowa rivers, and anglers have reported catching walleye on the Thompson and Nodaway rivers, but these walleye were derived from lake stockings. Historically, walleye probably did not inhabit the low gradient, turbid, prairie streams of the Southern Iowa Drift Plain. Mud and silt substrates are common in these rivers. Turbidities are high during the spring, resulting in poor spawning conditions, and nursery areas are not in abundance.

**Conclusion**

Much of the Iowa landscape was in agriculture when the first fish surveys were conducted. Immediate changes in the landscape upon settlement and stocking efforts probably obscured original distributions. Based on historical records and observations on walleye occurrence in midwestern rivers, if walleye were ever locally abundant, they most likely occurred in mid coolwater reaches to lower reaches of larger Iowa rivers that were mainly tributary to the Mississippi River.

In recent time, walleye still achieve greater abundance in larger rivers of the Mississippi River drainage, including the Iowa, Cedar, Wapsipinicon, Maquoketa, and the Des Moines River and its tributaries, because of stocking and prevalence of desirable instream and riparian habitat.

The quality, quantity, and diversity of habitat in rivers play a large role in the capacity of walleye to function in all life stages. The present survey shows that spawning and nursery habitat are limited and widely dispersed. This fragmentation in habitat most likely has reduced the natural process of the walleye and other riverine species.

Inadequate numbers of broodstock and predation by other fish may, to a lesser extent,
contribute to limit walleye recruitment in some areas. In the current surveys, presence of pesticides during spawning, incubation, and feeding periods of larval walleye were not considered likely reasons for continued limited natural reproduction.

Rivers and streams in Iowa are important fishery resources. Geology, soils, glacial deposition, and drainage patterns all shape the physical, biological, and chemical characteristics of rivers in each landform and rivers within a landform. Human modifications of the landscape have greatly altered the physical-chemical processes of Iowa streams, adversely affecting the distribution and abundance of walleye.

LITERATURE CITED


MEEK, S. E. 1890. The native food fishes of Iowa. Proceedings of the Iowa Academy of Science 1:68-76.


PARAGAMIAN, V. L. 1990. Fish populations of Iowa rivers and streams. Technical Bulletin No. 3. Iowa Department of Natural Resources, Des Moines, Iowa.


TRAUTMAN, M. B. 1981. The fishes of Ohio. The Ohio State University Press, Columbus, Ohio.


Fig. 3.1. Approximate river sections sampled in Paragamian's (1986) statewide survey and the locations where walleye were collected.
Fig. 3.2. River sections sampled by IDNR fish management personnel in 1997 and 1998.

Fig. 3.3. River sections where YOY walleye were collected in 1997 and 1998 by IDNR fish management personnel.
Fig 3.4. Sites where several cohorts of walleye were caught in 1997 and 1998 by IDNR fish management personnel.
Fig. 3.5. River sections indicated by IDNR fish management personnel that may support natural reproduction.

Fig. 3.6. River sections indicated by IDNR fish management personnel that may contain spawning and nursery habitat.
Fig. 3.7. Opinions of IDNR fish management personnel of factors that limit natural reproduction in Iowa's interior rivers.
Table 3.1. Historical (1832-1859) and recent (1975-1996) vegetation of Iowa.

<table>
<thead>
<tr>
<th>Vegetation Type</th>
<th>1832-1859a Hectares</th>
<th>Percent</th>
<th>1975-1996 Hectares</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prairie</td>
<td>11,576,165</td>
<td>79.5%</td>
<td>11,576b</td>
<td>0.1%</td>
</tr>
<tr>
<td>Forest</td>
<td>1,707,472</td>
<td>11.7%</td>
<td>810,000c</td>
<td>5.6%</td>
</tr>
<tr>
<td>Savanna</td>
<td>974,063</td>
<td>6.7%</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Wetland</td>
<td>198,015</td>
<td>1.4%</td>
<td>21,782d</td>
<td>0.1%</td>
</tr>
<tr>
<td>Other</td>
<td>113,638</td>
<td>0.8%</td>
<td>111,981</td>
<td>&lt;0.8%</td>
</tr>
<tr>
<td>Agriculture</td>
<td>--</td>
<td>--</td>
<td>~13,383,000</td>
<td>92.0%</td>
</tr>
<tr>
<td>Urban</td>
<td>1,395</td>
<td>&lt;1.0%</td>
<td>239,063</td>
<td>&lt;1.6%</td>
</tr>
<tr>
<td>Total hectares</td>
<td>14,570,000</td>
<td></td>
<td>14,577,948e</td>
<td></td>
</tr>
</tbody>
</table>

a Anderson et al. 1996  
b Smith 1998  
c Jungst et al. 1998  
d Bishop et al. 1998  
e Mixed sources result in inequality of total hectares
Table 3.2. Rivers listed in the 1998 Iowa walleye distribution survey.

<table>
<thead>
<tr>
<th>River</th>
<th>SubRiver</th>
<th>SubRiver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big Sioux</td>
<td>Maple</td>
<td>Skunk</td>
</tr>
<tr>
<td>Boone</td>
<td>Maquoketa</td>
<td>South Raccoon</td>
</tr>
<tr>
<td>Boyer</td>
<td>Middle South Skunk</td>
<td>South Skunk</td>
</tr>
<tr>
<td>Cedar</td>
<td>Middle Raccoon</td>
<td>Thompson</td>
</tr>
<tr>
<td>Chariton</td>
<td>Nishnabotna</td>
<td>Turkey</td>
</tr>
<tr>
<td>Des Moines</td>
<td>Nodaway</td>
<td>Upper Iowa</td>
</tr>
<tr>
<td>East Fork Des Moines</td>
<td>North Raccoon</td>
<td>Volga</td>
</tr>
<tr>
<td>East Nishnabotna</td>
<td>North Skunk</td>
<td>Wapsipinicon</td>
</tr>
<tr>
<td>English</td>
<td>Occheydan</td>
<td>West Des Moines</td>
</tr>
<tr>
<td>Floyd</td>
<td>Platte</td>
<td>West Fork Cedar</td>
</tr>
<tr>
<td>Grand</td>
<td>Raccoon</td>
<td>West Nishnabotna</td>
</tr>
<tr>
<td>Iowa</td>
<td>Rock</td>
<td>Winnebago</td>
</tr>
<tr>
<td>Little Sioux</td>
<td>Shell Rock</td>
<td>Yellow</td>
</tr>
<tr>
<td>Little Wapsipinicon</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3.3. Questions asked of IDNR fisheries management biologists in the river walleye distribution survey.

Question 1: Of the river segments listed, mark the segments sampled in 1997 and/or 1998.

Question 2: If river segments were sampled in one or both years, were YOY walleye present?

Question 3: If YOY were present, could they be identified as stocked (S), natural (N), uncertain (U) or a combination of both?

Question 4: On a scale of 1-5, rank the abundance of YOY in the areas sampled
   1 = none  2 = rare  3 = occasional  4 = common  5 = abundant

Question 5: If YOY walleye were not present in samples, were walleye of any age group represented?

Question 6: Do you think natural reproduction occurs in the river sections that were sampled or familiar with?

Question 7: Do you think there is suitable spawning habitat?

Question 8: Do you think there is suitable nursery habitat for young walleye?
   (lakes, bays, backwaters, reservoirs)

Question 9: Please rank in order of importance, six factors affecting natural reproduction of walleye in Iowa rivers.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>___</td>
<td>A) inadequate numbers of broodstock</td>
</tr>
<tr>
<td>___</td>
<td>B) lack of spawning habitat</td>
</tr>
<tr>
<td>___</td>
<td>C) sedimentation smothering eggs</td>
</tr>
<tr>
<td>___</td>
<td>D) lack of nursery habitat</td>
</tr>
<tr>
<td>___</td>
<td>E) toxic problems (presence of pesticides)</td>
</tr>
<tr>
<td>___</td>
<td>F) predation by smallmouth bass or other fish</td>
</tr>
</tbody>
</table>

Question 10: What do you think is the reason for lack of natural reproduction in rivers under your management area?
Table 3.4. Historical summary (1885-1986) of both published and unpublished ichthyofaunistic studies on rivers and streams in the Missouri River and Mississippi River drainages.

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Missouri River drainage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jordan and Meek</td>
<td>1885</td>
<td></td>
</tr>
<tr>
<td>Meek</td>
<td>1892</td>
<td>R</td>
</tr>
<tr>
<td>Call</td>
<td>1892</td>
<td></td>
</tr>
<tr>
<td>Harrison</td>
<td>1949</td>
<td></td>
</tr>
<tr>
<td>Starrett</td>
<td>1950</td>
<td></td>
</tr>
<tr>
<td>Harrison</td>
<td>1951a</td>
<td></td>
</tr>
<tr>
<td>Cleary</td>
<td>1952</td>
<td></td>
</tr>
<tr>
<td>Cleary</td>
<td>1953</td>
<td></td>
</tr>
<tr>
<td>Harrison and Speaker</td>
<td>1954</td>
<td>R</td>
</tr>
<tr>
<td>Harrison</td>
<td>1960</td>
<td></td>
</tr>
<tr>
<td>Harrison</td>
<td>1961</td>
<td></td>
</tr>
<tr>
<td>Cleary &amp; Moen</td>
<td>1961</td>
<td></td>
</tr>
<tr>
<td>Mayhew</td>
<td>1965</td>
<td></td>
</tr>
<tr>
<td>Zach</td>
<td>1968</td>
<td></td>
</tr>
<tr>
<td>Laser et al.</td>
<td>1969</td>
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<tr>
<td>Kline</td>
<td>1969</td>
<td>X</td>
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<tr>
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<td>X</td>
</tr>
<tr>
<td>Kline</td>
<td>1970b</td>
<td></td>
</tr>
<tr>
<td>Coon</td>
<td>1971</td>
<td></td>
</tr>
<tr>
<td>King</td>
<td>1976</td>
<td></td>
</tr>
<tr>
<td>Paragamian</td>
<td>1986</td>
<td>X</td>
</tr>
</tbody>
</table>

C= common  O= occasional  P= present  R= rare  X= rivers sampled
Table 3.4. Continued.

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>East Nishnabotna</th>
<th>West Nishnabotna</th>
<th>Nishnabotna</th>
<th>Nodaway</th>
<th>Platte</th>
<th>Thompson (Grand)</th>
<th>Chariton</th>
<th>Missouri</th>
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<tbody>
<tr>
<td>Jordan and Meek</td>
<td>1885</td>
<td>X</td>
<td>X</td>
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<tr>
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<td>Call</td>
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<td>1961</td>
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<td>Cleary</td>
<td>1952</td>
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<td>1953</td>
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CHAPTER 4. ENVIRONMENTAL FACTORS INFLUENCING RECRUITMENT OF WALLEYE IN THE CEDAR AND WAPSIPINICON RIVERS, IOWA

A paper submitted to the Journal of the Iowa Academy of Science

Louise M. Mauldin and Robert Summerfelt

ABSTRACT

Natural recruitment of walleye (*Stizostedion vitreum*) is uncommon in interior rivers of Iowa. We evaluated environmental factors influencing success of natural recruitment in the Cedar and Wapsipinicon rivers. Walleye eggs and larvae were collected in the spring of 1998. At the same time, water temperature, suspended solids, river flow, turbidity, and zooplankton abundance were monitored. Water and sediment samples were analyzed for four herbicides and insecticides, and walleye eggs were analyzed for an array of organochlorine pesticides.

Few eggs and larvae were collected on the Cedar and Wapsipinicon rivers. A total of 6 eggs were collected at Waverly on the Cedar River in 100 net days of sampling. In 80 net days of sampling, 52 eggs were collected at Independence on the Wapsipinicon River. Mean CPUE of larval walleye was 1.4 larvae/1000 m³ on the Cedar River and 2.1 larvae/1000 m³ on the Wapsipinicon River. Detectable levels of DDD, DDE, and dieldrin were found in two samples of walleye eggs, but the concentrations were insignificant. Mean CPUE of zooplankton in both rivers from 4 April to 27 May was <1 organism/L. Suitable spawning habitat occurs below the Waverly dam on the Cedar River and the Independence dam on the
Wapsipinicon River. Lack of quiet water areas such as backwaters, and scarcity of zooplankton were determined to be important factors limiting natural recruitment of walleye in the Cedar and Wapsipinicon rivers.

INTRODUCTION

Iowa has over 30,400 km of interior streams, and they are preferred fishing sites by 26% of Iowa anglers (Lutz et al. 1995). In Iowa, walleye (*Stizostedion vitreum*) are an important sportfish sought after by 15% of the fishing public (Lutz et al. 1995). Walleye inhabit large rivers and drainage lakes throughout the Midwest (Forbes 1908, Trautman 1981, Becker 1983, Pflieger 1997). As determined from surveys by Meek (1892), walleye were found in the Big Sioux, Iowa, and Cedar rivers. Today, walleye are present in rivers throughout Iowa, but walleye are most abundant in large rivers of the Mississippi River drainage including the Iowa, Wapsipinicon, Cedar, Maquoketa, and the Des Moines River system (Mauldin 1999). Walleye also are captured by anglers mainly in the Big and Little Sioux rivers of the Missouri River drainage.

To mitigate low walleye populations in Iowa's waters, walleye fingerlings and fry (1 to 2 day-old prolarvae) are stocked by the state fishery agency (Cleary and Mayhew 1961). Studies on the Cedar, Shell Rock, and Wapsipinicon rivers revealed that natural reproduction of walleye is rare, that survival of stocked walleye fry is low, and fry stockings ineffective in establishing a fishery (Cleary and Mayhew 1961, Degan 1978, Paragamian 1988, Paragamian and Kingery 1992). Stocking of fingerlings, however, has contributed substantially to river populations of the Cedar, Shell Rock, and Wapsipinicon rivers (Paragamian and Kingery...
Lack of natural recruitment in rivers has been attributed to scarcity of suitable spawning substrate, nursery habitat, and food for first feeding larvae, as well as adverse environmental conditions such as high river flows, high suspended solids in spring, water level fluctuations, low water temperature during egg development, and predation (Cleary and Mayhew 1961, Priegel 1970, Walburg 1972, Russell 1973, Busch et al. 1975, Koonce et al. 1977, Corbett and Powles 1986, Paragamian 1987, Fielder 1992, Heidinger and Kohler 1992, Jude 1992, Mion et al. 1998). In a 1998 questionnaire, Iowa fisheries management biologists indicated poor quality or deficiency of spawning and nursery habitat, and effects of sedimentation as the main factors limiting natural recruitment of walleye in Iowa's inland rivers (Mauldin 1999).

Our objectives were to determine the underlying factors associated with spawning success and survival of walleye eggs and larvae in the upper Cedar and Wapsipinicon rivers. Factors that were examined included water quality, presence and concentrations of pesticides in water, sediment, and walleye eggs from the Cedar River, physical characteristics of the study areas, relative abundance of walleye eggs and larvae, and relative abundance of zooplankton before and following hatch of walleye. Information on the critical factors affecting the early life stages of Iowa river walleye will allow management biologists to develop strategies to overcome the lack of natural recruitment and to enhance survival of stocked fish in these rivers.
STUDY SITES

Cedar River

The Cedar and Wapsipinicon are two of three major rivers draining the Iowan Surface landform (Fig. 4.1). The Cedar River originates in the lake region of south-central Minnesota (Dodge County), near the city of Hayfield. The river is 482 km long and joins the Iowa River, 48.3 km upstream from the confluence of the Mississippi River near Keokuk, Iowa. The Cedar River basin is the largest in the Iowan Surface region, draining about 20,383 km² of which 87% is in Iowa.

Meek (1892) described the Cedar River basin as prairie, with timber along the main river and its tributaries. Maps of Iowa vegetation shows that land used in the basin is predominantly agricultural (93%) with a narrow timber corridor (3.5%). The riverbed consists mainly of rock and rubble with shifting sandbars and limestone outcroppings. Limestone bluffs line the upper Cedar River valley in Iowa, and as the river proceeds southward into Bremer County, the floodplain becomes wider and flatter with small ponds becoming more abundant (Meek 1892). The lower portion of the river is said to have lost its “rugged character” and has been compared to slow-flowing prairie streams of central Iowa (Harlan et al.1987). There are 11 lowhead dams on the Cedar River in Iowa (Harlan et al. 1987). The largest impoundment formed by a mainstream dam is 81 hectares, located at Nashua. Immediately downstream from the dams, the stream bottom consists of boulders and rock, changing to segments of gravel and sand. Tributaries of the Cedar River include the Shell Rock (4,618 km²), Beaver Creek (1,013 km²), Black Hawk Creek (891 km²), Wolf Creek (850 km²), and Little Cedar River (686 km²) (Larimer 1957).
Five egg net sites were located downstream of the Waverly dam, Bremer County, Iowa. The study reach where water and sediment samples were taken extended from the Waverly dam, 16.4 km down river to Janesville, which is located 334 km upstream from the river mouth. Drainage area upstream of Waverly, Iowa, is about 4,012 km$^2$. The largest city in the watershed upstream of Waverly is Austin, Minnesota, population 21,907. The drainage area of river upstream of Janesville is about 290 km$^2$ ($4,302$ km$^2$) more than at Waverly. Mean flow at Janesville for the 93-year interval, 1905 through 1998 was 26.1 m$^3$/s (USGS 1998).

**Wapsipinicon River**

The Wapsipinicon River originates in Mower County, Minnesota and flows some 362 km southeast to the Mississippi River. The upper valley is flat, and a few ponds and marshes dot the floodplain. The lower reach of the river is characterized as a slow-flowing prairie stream. The substrate varies from limestone rubble and gravel to sand. There are 15 lowhead dams on the river. The largest impoundment is at Independence, covering 113.4 hectares (Harlan et al. 1987). The Wapsipinicon River basin is 6,579 km$^2$, 32% of that of the Cedar River basin. The river basin is dominated by agriculture (96%), but the river has a dense woodland riparian zone. Major tributaries of the Wapsipinicon include the Little Wapsipinicon and Buffalo Creek. A few small towns line the river, the largest being Independence, which has a population of 5,972.

Five egg net sites were located downstream of the dam at Independence, Buchanan County. Spawning substrate below the dam consisted of rock and boulders, and was free of silt. Elevation of the river at Independence is about 315 meters, the same as Waverly.
Drainage area upstream of Independence is 2,714 km$^2$. The average river volume at Independence for the 64-year interval, 1934 through 1998 is 19 m$^3$/s (USGS 1999).

**METHODS**

**Water Quality Measurements**

Several water quality parameters were measured at each site on each sample date from the 2 April to 27 May, 1998. Temperature ($\pm 0.1^\circ$C) was recorded each sample date. Dissolved oxygen (DO) was measured to the nearest $\pm 0.1$ mg/L using an oxygen meter (Yellow Springs model 95 meter). The oxygen meter was air calibrated for an elevation of 315 m on each sample date. Specific conductance was measured to the nearest $\pm 0.001$ us/cm using a platinum-electrode conductivity cell (Hach CO., Loveland, CO 1989). An Orion 1090A meter was used to determine pH ($\pm 0.1$ pH), standardized with pH 4.0, 7.0, and 10.0 buffers. Turbidity was measured to the nearest 0.01 (NTU) using a model 21000P Hach turbidimeter, standardized with 1, 10, and 100 (NTU) standard solutions.

Water samples were taken once a week during the spawning period and once a week during larval drift sampling. Water samples were collected with a 5 cm diameter tube sampler similar in design by Graves and Morrow (1988). Samples were stored in a 1.5 liter nalgene bottle and placed in an ice chest with ice and brought back to the laboratory for analysis.

Total alkalinity was measured to the nearest 0.1 mg/L by titration with 0.02N H$_2$SO$_4$ (APHA et al. 1995). Hardness (0.1 mg/L calcium carbonate, CaCO$_3$) was determined using the Man Ver 2 burette titration method (Hach CO., Loveland, CO. 1989). Total ammonia-
nitrogen (TAN) (Nessler method), nitrite (NO$_2$) (diazonation method), and nitrate (low-range cadmium reduction method) were measured to the nearest 0.001 mg/L with a Hach DR/3000 spectrophotometer (Hach CO., Loveland, CO 1989).

Total suspended solids were determined by filtering 100 ml of river water through a glass microfibre filter. The residue was dried to a constant weight at 103°C. Total suspended solids were expressed as mg/L and were determined by calculation described by APHA (1995).

**Pesticide Analysis on the Cedar River**

Water and sediment samples were taken in the spring of 1998 at Janesville, Iowa. Water samples were analyzed by Iowa State Hygienics Lab (Iowa City) for the presence of four commonly used herbicides: atrazine, alachlor, cyanazine, and metolachlor. Samples also were analyzed for four organophosphate insecticides: chlorpyrifos, phorate, fonofos and terbufos.

Eggs from two spawning females were collected in April of 1998 and 1999 from the Cedar River in Waverly, Iowa, downstream of the dam. Eggs were sent to the Iowa State Hygienics lab and analyzed for the presence and concentrations of an array of chlorinated hydrocarbon pesticides (Table 4.1).

**Egg Sampling**

Walleye egg sampling was conducted from 2 April to 22 April on the Cedar River and 30 March to the 15 April on the Wapsipinicon River. Sample sites were about 0.4 km downstream of the Waverly dam and 0.8 km downstream of the Independence dam. Walleye eggs were collected using rectangular drift nets (14.61 cm x 45.72 cm). These nets were
constructed using 1.6 mm ace mesh attached to a 3 mm rolled rectangular steel bar frame, forming a 53.3 cm bag.

Nets were staked to the river bottom with a 5.0 m rope tied to a steel rod and staked into the substrate. A flat weight was attached about 0.6 m from the mouth of the net to ensure the net was at the river bottom. An orange buoy was attached to the net in order to locate the net as well as retrieve it without having to reset the stake. Because nets were not set for precisely 24-h, catch per unit effort (CPUE) was adjusted to a 24-h net day.

Walleye eggs were separated from debris in a white pan and then counted. Viable eggs were placed in a clean container of river water and brought back to the laboratory where they were hatched in 0.5 L glass jars. Newly hatched fry were identified using keys by Nelson (1968) and Holland-Bartels et al. (1990).

**Larval Sampling**

Larval sampling was conducted on the Cedar and Wapsipinicon rivers twice weekly on each river for five weeks, 22 April to 27 May 1998. One sampling transect was chosen 1.4 km downstream of the dam at Waverly and 1.6 km downstream of the dam at Independence. Samples were taken on a bank-to-bank transect, on the east bank, west bank, and in the main channel. Larval fish were sampled using a single conical net, 0.3 m in diameter and with a 0.9 m tapered bag made of 560 µm Nitex mesh. A detachable 550 ml bucket was connected to the distal end of the net to collect plankton. Samples were taken from an anchored boat with bow facing upstream. The drift net was attached to a 7.5 m rope tied to one side of the boat and trailed about 5.8 meters behind the boat. Swift current resulted in placement of the net near the surface. The volume of water filtered through the
net was measured with a mechanical flow meter (model 2030R General Oceanics, Miami, Florida 1996) placed in the center of the net mouth. Sampling duration was 20 minutes. Counter readings on the flow meter and time were recorded at the beginning and end of each sample. Volume of water filtered was expressed in m$^3$ and determined using the equations described by General Oceanics (General Oceanics, Miami, Florida 1996).

(a) distance = \( \text{count} \times \text{rotor standard} \)

\[ \frac{999999}{999999} \]

where the difference in counts was multiplied by the rotor standard of 26,873

(b) volume = \( 3.14 \times (\text{diameter})^2 \times \text{distance} \)

\[ \frac{4}{4} \]

and where diameter equals 0.3 m and distance is used from equation (a).

Ichthyoplankton contents were preserved in 10% formalin (Kelso and Ruthford 1996) and transported back to the laboratory for subsequent identification. Larval walleye and sauger (\textit{Stizostedion canadense}) have similar characteristics, but sauger have not been collected in the study areas. Thus, characteristics of \textit{Stizostedion} are identified as walleye.

Because of the difficulty in identifying larval suckers to species, they were grouped by family (Catostomidae). Larval fish abundance was expressed as number/1000 m$^3$. Lengths of larval walleye were measured to the nearest 0.1 mm (TL) using a dissecting microscope containing an ocular micrometer. Developmental stage was determined as described by Holland-Bartels et al. (1990).
River Discharge

Current velocities and depth were recorded concurrently with larval sampling at three stations along the bank-to-bank transect on each sampling date. Current velocities were measured with a Swoffer current velocity meter at 0.2 m and 0.8 m from the substrate. Depth was measured using a pole marked off in 0.1 m intervals. Total discharge and water level information was obtained from USGS gaging stations at Independence (gage ID 05421000) and Janesville (gage ID 05458500) (USGS 1999).

Zooplankton Sampling

Zooplankton samples were taken during the spawning period and simultaneously with larval sampling on each sample date. Zooplankton samples were taken from the main river, areas of low current within the main river, and side channel sites on the Cedar River. Zooplankton sample sites from the Wapsipinicon River included the main river, pools, and the impoundment above the Independence dam. Water samples (11 L) were collected with a tube sampler (Graves and Marrow 1988). The entire 11 L were filtered through a 363 μm mesh field plankton net. Contents were concentrated into a 240 ml plastic bottle and preserved in 5% buffered formalin.

Zooplankters were identified and enumerated in the laboratory. Five, 1 ml subsamples were collected using a Hensen-Stempel pipette and were placed in a Sedgewick Rafter cell. A microscope with a 10x magnification was used to identify zooplankton as cladocerans, copepods, and rotifers. Numbers were expressed as organisms/liter and determined using the equation described by APHA (1995).
organisms/liter = \( \frac{C \times V'}{V'' \times V'''} \)

Where:

- \( C \) = number counted
- \( V' \) = volume of concentrated sample (mg/l)
- \( V'' \) = volume counted, (mg/l)
- \( V''' \) = volume of grab sample (liters)

**Analysis**

To normalize the larval walleye and zooplankton data, sample counts were converted to geometric means by log \((x + 1)\) of the catch per unit effort (CPUE) on larval walleye and zooplankton. Pearson correlation analysis was used to examine relationships of larval walleye and zooplankton CPUE with physical and chemical variables. A multiple linear regression was performed on variables having a correlation that had an alpha level of \( \alpha = 0.1 \). Analysis of variance (ANOVA) was used to determine significant differences in walleye and zooplankton CPUE across dates, physical and chemical values across dates, and zooplankton CPUE among the three habitats in the Cedar River and Wapsipinicon rivers. Differences were considered significant at \( P < 0.05 \). Differences in CPUE of larvae and zooplankton, and physical and chemical values between the Cedar and Wapsipinicon rivers were determined by performing t-tests. Differences were considered significant at \( P < 0.05 \).

**RESULTS**

**Water Quality**

Water samples were collected on seven dates in April and May on the Cedar River and five dates on the Wapsipinicon River. Mean water temperature on the Cedar River during sampling was \( 14.0^\circ C \), and \( 19.4^\circ C \) on the Wapsipinicon River (Table 4.2). During
May, conductivity differed between the Cedar and Wapsipinicon rivers ($P = 0.003$). There also was a significant difference in alkalinity ($P = 0.02$) and hardness ($P = 0.001$) between the two rivers. Suspended solid concentrations were at moderate levels in both rivers, but were higher in the Cedar River ($P = 0.02$). Ammonia, nitrate, and nitrite concentrations were similar in both rivers and concentrations in each river were similar on different collection dates.

**Pesticides**

Water and sediment samples were collected on five dates from April-May at Waverly. On the 16 April, desethyl atrazine was detectable in water samples at a concentration of 0.12 $\mu$g/L, just over the minimum detection limit of 0.1 $\mu$g/L. On 3 May, metolachlor was detected at a concentration of 0.35 $\mu$g/L. Of the four organophosphate insecticides tested for in water and sediment samples, none exceeded their detection limits.

One sample of walleye eggs from the Cedar River was analyzed for chlorinated hydrocarbons in 1998 and one sample from 1999. Concentrations of tested insecticides were less than the minimum detectable concentration. Low concentrations of DDE (0.16 mg/kg) and DDD (0.018 mg/kg), which are metabolites of DDT, and dieldrin (0.039 mg/kg) were present in walleye eggs collected from 1999. DDE (0.034 mg/kg) was the only insecticide present in egg samples collected from 1998.

**Egg Collection**

Egg nets were deployed from 2 April to 22 April (Table 4.3). Water temperature during egg collection on the Cedar River ranged from 6.5-11.9°C. Only six walleye eggs were collected in 100 net-days of effort. Walleye eggs were first collected on 8 April and
peak abundance occurred on 13 April with a mean CPUE of 0.083 (Table 4.4). Water
temperature between the first date of egg collection and the first date of larvae collection
ranged from 7.5-17.9°C in the Cedar River.

Egg nets were deployed from 30 March to 15 April on the Wapsipinicon River.
Water temperature during the egg collection period ranged from about 7.8-10.0°C. A total of
52 eggs were collected in 80 net days on the Wapsipinicon River. The first collection of
walleye eggs was 3 April, several days earlier than first collection on the Cedar River. Peak
collection was on the 7 April with a mean CPUE of 4.0. Egg collection terminated seven
days earlier than on the Cedar, due to high water and floating debris. Eggs were still being
collected the last net-day.

**Larval Walleye**

Meter net sampling for larval walleye on the Cedar River occurred on nine sample
dates. Seven larval walleye were collected in filtering 1,329 m³ of water between 22 April
and 27 May (Table 4.5). The first larval walleye was collected on 6 May. Highest CPUE of
larval walleye was 6.0/1000 m³ on 26 May (Table 4.6). The overall mean of walleye
collected in the spring of 1998 on the Cedar River was 1.4/1000 m³. Six of seven larval
walleye were collected on the Cedar River between 1923-2330 central standard time (CST).
All but one larval walleye collected on the Cedar River was in the prolarval stage (containing
a yolk sac). Mean overall length of walleye caught on the Cedar River was 6.8 mm (Table
4.5). Six of seven larvae were <7.0 mm (Table 4.7).

Meter net sampling on the Wapsipinicon River occurred on 11 sample dates between
24 April and 27 May. Twenty larval walleye were collected in 3,594 m³ of filtered water.
The first walleye was collected on 4 May. The peak CPUE was 7.1/1000 m$^3$ on 13 May (Table 4.6). The overall mean of walleye collected in the spring of 1998 on the Wapsipinicon River was 2.1/1000 m$^3$. Larval walleye were collected from 1935-2400 CST.

Length of captured larval walleye on the Wapsipinicon ranged from 6.0 mm to 11.0 mm. Mean length of walleye captured in the drift sampling area was 6.2 mm. Five of the larvae were postlarvae and 15 were prolarvae.

Water temperature continuously rose in both rivers during the egg incubation period and through May when larvae were in the drift (Fig. 4.2).

**Current Velocity and Depth**

Current velocities during drift sampling on the Cedar River at Waverly ranged from 0.56 to 0.88 m/s. Surface velocities on the Wapsipinicon varied from 0.59 m/s on 24 April to 1.17 m/s on 18 May.

Water depth at the sample site on the Cedar River varied from 0.6 to 2.28 m. On 21 May, the Waverly dam was closed for maintenance, dropping water levels to 0.72 m along the east bank and less than 0.15 m on the west bank of the sample site at Brookwood park boat ramp. River stage at the Janesville gage station ranged from 0.646 to 1.06 m.

Water depth at the sample site on the Wapsipinicon ranged from 0.76 to >3.0 m. River stage at the Independence gage station, upstream of the drift site, ranged from 1.69 to 2.01 m. Low water levels in the middle of May made it difficult to reach the sample site. Differences in depth between the two drift sites were not significantly different, but current velocity at the drift site on the Wapsipinicon River was significantly higher (P < 0.05).
Environmental Correlates to Larval Drift

Correlations between CPUE of larval walleye and environmental correlates were not significant on the Cedar River (Table 4.8). On the Wapsipinicon River, however, the correlation between CPUE of larval walleye and pH ($P = 0.077$) and current velocity ($P = 0.088$) was significant (Fig. 4.3). A multiple linear regression using pH and velocity explained 44% of the variability in CPUE of larval walleye.

Zooplankton samples taken simultaneously with larval walleye sampling revealed low CPUE in both study areas. Thirty-five samples were collected on the Cedar from 4 April to 27 May. Mean CPUE peaked at 0.33 organisms/L on the Cedar. The overall mean was 0.14 organisms/L. A correlation between CPUE of zooplankton and conductivity ($P = 0.012$) on the Cedar River and turbidity on the Wapsipinicon River was significant. ANOVA of the 12 means over sampling dates was not significant. Means for channel, side channel, and low flow areas were 0.14/L, 0.05/L, and 0.09/L, respectively. Mean CPUE did not significantly differ between the three habitats. Rotifers were the only zooplankton represented in samples from the Cedar River.

In the Wapsipinicon River, 39 samples were taken from 20 April-28 May. Mean CPUE over 11 collection dates ranged from 0-0.62 organisms/L. The overall mean was 0.21 organisms/L. ANOVA for 11 means was not significant over dates on the Wapsipinicon River. Abundance was low in all habitats; the highest CPUE was in the impounded area at 0.48/L. An ANOVA for mean CPUE of zooplankton in the three habitats was not significant.
Zooplankton from the Wapsipinicon River consisted mainly of rotifers, but a few cladocerans (*Bosmina*) and copepod nauplii were present. CPUE of zooplankton was correlated with turbidity ($P = 0.05$). The correlation between CPUE of zooplankton and CPUE of larval walleye was not statistically significant on the Wapsipinicon River. The differences in mean CPUE of zooplankton between rivers were not significant.

**DISCUSSION**

Few walleye eggs were collected on the Cedar and Wapsipinicon rivers in April and May 1998, and low numbers of larval walleye were collected in both rivers. The mean peak CPUE on the Wapsipinicon River was 7.1 larvae/1000 m$^3$, and 6.0 larvae/1000 m$^3$ on the Cedar River. Greatest CPUE of larval walleye on the Poultney River, Vermont, was 2,000/1000 m$^3$ and 2,800/1000 m$^3$ on the Missisquoi River, Vermont (Mitro and Parrish 1997). Highest CPUE of walleye and sauger in Pool 13 of the Mississippi River, Iowa, in 1996 was 23/1000 m$^3$ (Pitlo 1996). However, in 1997, peak CPUE was 1.5-8.0/1000 m$^3$ (Pitlo 1997).

**Factors Affecting Abundance**

*Water quality in the Iowan Surface region*

The two river basins lie in the Devonian-Silurian geologic system, a region known for shallow aquifers and karst terrain consisting of sinkholes and weathered limestone. Water quality values observed in this study in 1998 were satisfactory. They were similar to mean values reported by the Environmental Protection Division (EPD) of the Iowa Department of Natural Resources (IDNR) in seven years of monitoring (1987 to 1993) the Iowan Surface
region. On the Wapsipinicon River, the correlation between pH and larval CPUE was statistically significant, accounting for 55% of the variability in larval CPUE.

Water quality on these two rivers was only monitored in April and May of 1998. Water quality did not seem to be a limiting factor on these two rivers during the reproductive period. However, fish kills throughout the year may reduce the size of broodstock in these rivers. Over 68 natural and pollutant caused fish kills on rivers and streams within the state were reported by the IDNR in 1997 and 1998 (IDNR unpublished 1998). Most pollutant caused fish kills resulted from runoff of manure from open dairy and hog lots (IDNR 1994). Total number of fish killed in 1997 and 1998 was over 300,000. Mortality of fish from these kinds of events have a substantial impact on the ability of a species to successfully reproduce.

**Pesticides**

Herbicides and insecticides are commonly applied to corn and soybeans, the principal grain crops planted in the Cedar and Wapsipinicon river basins. These pesticides can enter streams through overland flow, tile drains, or through groundwater (Squillace and Engberg 1988). In a 1984 to 1985 study of the Cedar River, herbicides such as alachlor, atrazine, cyanazine, and metolachlor persisted through the spring and summer and sometimes into the fall and winter (Squillace and Engburg 1988). Herbicides are usually transported with water, and insecticides adsorbed to clay or organic matter and are transported with the soil to the stream by overland flow.

Largest concentrations of some herbicides in the Cedar River study were detected during peak river discharge (Squillace and Engburg 1988). Some were detected in larger concentrations after application in spring and early summer (Squillace and Engburg 1988).
coinciding with walleye spawning, egg incubation, and when larvae are present in the drift. Herbicides like atrazine may persist throughout the year. Alluvial aquifers can contribute significantly to the transport of chemicals by storing them during excessive rainfall and then releasing them in dry periods, during baseflow. In our study, desethly atrazine and metolachlor were detected in low levels in water samples in mid-April and early May. This time interval coincided with egg incubation and emerging larvae.

In 1995 and 1996, concentrations of insecticides such as dieldrin, heptachlor, DDT, and toxaphene were below detectable levels in sediment samples taken in June at Tripoli (north of Independence) and Charles City (north of Waverly) for the National Water Quality Assessment Program (NAWQA) (Akers et al.1996). No insecticides were found above the detectable limits in sediment samples taken from the Cedar River in our study.

**Fish tissue monitoring in Iowa**-Commonly used agricultural herbicides such as atrazine, alachlor (Lasso), cyanazine (Bladex), and metolachlor (Dual) do not accumulate in fish tissue (Olson 1996). The Regional Ambient Fish Tissue Monitoring Program (RAFT Program) involves annual collection of fish across the state and the analysis of tissue for toxic contaminants. The program enables the IDNR to document trends and identify problem areas in lakes, rivers and streams. In 1994, 28 samples were collected from streams across Iowa and analyzed for pesticides, toxic organic compounds and metals (Olson 1996). Fish species collected for analysis were catfish (*Ictalurus punctatus*), carp (*Cyprinus carpio*), and northern pike (*Esox lucius*), walleye, and smallmouth bass (*Micropterus dolomieu*). The most common contaminants of fish were chlordane and dieldrin, PCBs, heptachlor, DDE, and
mercury (Olson 1996). Olson (1996) identified chlordane and dieldrin, both insecticides, and PCBs as contaminants of most concern in fish.

Fish tissue samples taken from the Wapsipinicon River near Tripoli, for the NAWQA program contained small amounts of DDT compounds. Values were also similar to those reported by U.S. Geological Survey (USGS), in the spring of 1996 at Tripoli and at Carville (north of Waverly) on the Cedar River (Akers et al. 1999).

Low levels of dieldrin, DDE, and DDD were detected in walleye eggs from the Cedar River in our study. These organochlorine contaminants, are lipophilic compounds and accumulate in the fatty tissue of fish. DDT was banned in the 1970's, but still persists in the environment as evidence through fish tissue samples (Olson 1996).

**Spawning substrate**

Low natural recruitment of walleye has been observed in the Shell Rock, Cedar, and Wapsipinicon Rivers (Paragamian 1989a). Paragamian (1989a) suggested quality and quantity of substrate might be a limiting factor in spawning success. The substrate downstream of the dams in both rivers consists of rock, gravel, and small boulders. Sediment deposition below these dams is insignificant; due to turbulence, most silt is transported downstream. Through the use of radio telemetry, studies of walleye movement on the Cedar and Wapsipinicon rivers indicate that walleye move from overwintering pools upstream and congregate below the dams at Waverly and Independence (Paragamian 1989b, Siegwarth 1996).

The composition of substrate in the two study areas resembles what is usually described as suitable spawning habitat for walleye in other rivers (Russell 1973, Corbett and
Suspended solid concentrations in the two Iowa Rivers during the study were moderate. Habitat quality does not seem to limit spawning in the study reaches of the Cedar and Wapsipinicon rivers.

**Nursery habitat**

Nursery or rearing habitat is important for the survival of larval walleye. Typically, nursery habitat for larval walleye are in low current areas within the main river, backwaters of a river, lakes or reservoirs, located downstream from the river in which walleye spawn (Colby et al. 1979). These localities provide protection from the main current and are capable of supplying a food source. Tributary embayments were reported as the principal nurseries of larval walleye in Lake Sharpe, a Missouri River reservoir in South Dakota (Elrod et al. 1977). In Michigan, larval walleye drifted 88 to 110 km downstream from river dams to reach Saginaw Bay, Michigan, nursery area for these populations (Jude 1992). Other lakes, reservoirs, and bays have been documented as nursery areas for river spawned walleye (Priegel 1970, Colby et al. 1979, Corbett and Powles 1986, Franzin and Harbicht 1992, Mion et al. 1998).

No suitable nursery areas (backwaters) were present in the downstream kilometers of the selected spawning sites in the study reaches. The presence of backwater areas would provide the best habitat for young walleye on the Cedar and Wapsipinicon rivers. Lack of this type of habitat in our study reaches contributes to the mortality of first feeding walleye in these rivers.
Water temperature

Many studies implicate water temperature as an important factor regulating year class strength of walleye. Busch et al. (1975) found a strong relationship between water temperature and survival of YOY walleye over a 10-year period in Lake Erie. Eshenroder (1977) reported a similar relationship for yellow perch in Saginaw Bay over a 24-year period. Heidinger and Kohler (1992) reported temperature as one of the factors that limited survival of stocked walleye fry in Shelbyville Lake, Illinois.

Temperatures during April and May were similar in both rivers. The correlation between temperature and larval walleye CPUE was not significant. In our study, temperature does not seem to be a primary factor limiting survival of natural walleye fry in the Cedar and the Wapsipinicon rivers. Poor survival of stocked walleye fry has been documented for a number of years in the Shell Rock, Cedar, and Wapsipinicon Rivers (Cleary and Mayhew 1961, Degan 1978, Paragamian 1987, 1988, 1989a, 1990a). They did not find evidence for natural recruitment.

Velocity and discharge

The correlation between current velocity and CPUE of larval walleye in the Wapsipinicon River was statistically significant. Larval walleye of lengths 6.0 to 10.0 mm did not have the ability to swim in the swift currents of the study rivers. Velocities most likely transported larval walleye passively downstream and out of the sample area. At this stage of development fins and musculature are not fully developed resulting in limited mobility. Harvey (1987) reported that larval cyprinid and centrarchid species less than 10 mm were susceptible to downstream displacement in small streams, whereas individuals 10-25
mm long were able to maintain position. Both walleye and yellow perch larvae, less than 9.5 mm could not maintain position when velocities exceeded 3.0 cm/s in currents, but as they grew from 7.0 to 20.0 mm, swimming ability increased (Houde 1969).

No relationship between river discharge and CPUE of larval walleye was evident in the Cedar and Wapsipinicon rivers. Larval drift studies of the Upper Mississippi River also did not reveal effects of river discharge on abundance of drifting larvae (Bodensteiner and Lewis 1994, Pitlo 1997). However, positive relationships between larval drift and river discharge have been documented on the upper Colorado River (Carter et al. 1986) and on the Valley River, Manitoba (Johnston et al. 1995). In the Maumee and Sandusky Rivers, Ohio, larval walleye survival was inversely related to river discharge (Mion et al. 1998). Mion et al. (1998) stated that direct mortality was most likely due to the increase in suspended solids with the increase in turbulent discharge.

Daily average discharge of the Cedar River from March to June of 1998 was in the normal range of the 93-year interval for average flows during the spring months (Fig. 4.4). River discharge in early April was above average at 160 m$^3$/s, however it was below the maximum discharge level. Daily average discharge on the Wapsipinicon River exceeded the maximum average flow for a 63-year interval in late March and early April. High flows during the spring in the present study may have contributed to the fate of walleye eggs and larvae, thus high current velocity and high flow rates may have been a significant influence on survival in 1998.
**Food availability**

Newly hatched walleye feed largely on copepods and cladocerans (Houde 1967, Priegel 1970, Bulkley et al. 1976, Raisanen and Applegate 1983, Schademann 1987, Graham and Sprules 1992, Heidinger and Kohler 1992). They rarely have been reported to feed on rotifers (Smith and Moyle 1945). Zooplankton in the Cedar and the Wapsipinicon rivers in May 1998, consisted mainly of rotifers and the cladoceran, *Bosmina*. Higher CPUE of copepods have been reported in larger, deeper rivers like the Mississippi River. Cyclopoid copepod was the dominant zooplankter followed by the cladocerans, chydorinae, and *Bosmina* in Pool 13 of the Mississippi River (Pitlo 1997).

Most mortality of a fish cohort occurs early in life. The critical period of survival or the greatest mortality in fish is predicted by some researchers to occur after yolk sac depletion, when the larvae switch from endogenous to exogenous energy sources (Li and Mathias 1982). Depending on the water temperature, this occurs about five days after hatch in larval walleye. During the transition to exogenous food, availability of food is required to prevent starvation (Colby et al. 1979, Li and Mathias 1982). Priegel (1970) suggested that the scarcity of zooplankton was responsible for the poor 1966 year-class on the Wolf River, Wisconsin. Russell (1973) postulated that mortality of stocked fry in the Current River, Missouri was limited by food.

Survival of walleye fry in the Cedar and Wapsipinicon rivers may be affected by scarcity of zooplankton. Paragamian (1980) reported 18 copepods/L in the Maquoketa River in May of 1979. Mion et al. (1998) reported <1.0 organism/L during larval sampling in the Maumee and Sandusky rivers, Ohio, and concentrations did not increase until late May.
when larval walleye had already passed through the rivers (Mion et al. 1998). Zooplankton CPUE in the Cedar and Wapsipinicon Rivers in April and May of 1998 were <1/L in both rivers. Elsewhere, low zooplankton abundance have been reported in tributary lakes and river impoundments in early May, but larger numbers were present in late spring and early summer (Cushing 1964, June 1977, Paragamian 1980, Martin et al. 1981, Fielder 1992, Mion et al. 1998).

There was significant correlation between CPUE of zooplankton and turbidity on the Wapsipinicon River. This relationship is due to the increase in river discharge during time of sampling, flushing zooplankton from backwaters into the main part of the river, thus increasing abundance. CPUE of zooplankton on the Cedar River was positively correlated with conductivity, an ambiguous relationship. This may be explained by the concentration of electrolytes increasing inversely with river flows of the Cedar River, thereby increasing phytoplankton production, which in turn, causes an increase in zooplankton abundance.

Zooplankton populations are generally sparse in fast flowing streams like the Cedar and Wapsipinicon rivers (Welch 1952, Hynes 1970), because residence times in streams can be short enough to limit the buildup of plankton populations (Allan 1995). Hynes (1970) stated that zooplankton cannot maintain position in the slightest of flows. Paragamian (1980) suggested that most zooplankton in the Maquoketa River, Iowa, originated in the backwaters. Therefore, the presence of lakes, ponds, sloughs-bays, backwaters, and impoundments are important to seed the main river with plankton.

The Cedar and Wapsipinicon rivers do not encompass natural lakes, but small impoundments behind the numerous lowhead dams could be an important source of food for
larval walleye and other planktivorous larvae in these rivers. No difference in CPUE of zooplanton was evident in the different habitats sampled on the Cedar and Wapsipinicon rivers. Zooplankton CPUE in the impounded area above the Independence dam was <1/L. The observed lack of depth and mud/silt bottoms in the impounded area also provides evidence that this is not suitable habitat for larval walleye. In 1989, a single larval walleye was captured in the Cedar Falls impoundment on the Cedar River (Paragamian 1989a). Such a low CPUE would suggest that few larval walleye reached the area from upstream spawning sites or that the impoundment did not provide an adequate abundance of food to sustain fish.

**Conclusion**

Successful spawning in the Cedar and Wapsipinicon rivers does not seemed to be limited by quality of spawning sites at Waverly and Independence. Water flow and bottom substrates were favorable for walleye spawning and sufficient for development of eggs.

Fluctuations in water temperature during the early part of May 1998 may have prolonged spawning and incubation of eggs, leading to a higher percentage of mortality. However, in this study, there was no direct evidence that water temperature contributed to low natural recruitment.

Water quality did not seem to be a limiting factor in the survival of eggs and larvae in 1998. Suspended solid concentrations in upper river reaches of the Cedar and Wapsipinicon rivers were not likely to affect the survival of eggs, but higher concentrations may be more problematic in downstream reaches of the rivers where larval walleye are trying to find food and refuge.
Pesticide concentrations were mainly undetectable in water, sediment, and egg samples in the study, but presence and concentrations vary throughout the year depending on natural events and effects of human activities in the watershed.

High current velocities and flows may have a significant influence on the survival of eggs and drifting larvae on the Cedar and Wapsipinicon rivers. Scarcity of zooplankton in these rivers may be a direct cause of low survival of young. Lack of suitable nursery habitat containing sufficient food was a major contributing factor to the poor survival of larval walleye.

Active measures can be taken to improve environmental conditions for naturally spawned and stocked walleye. Establishment of riparian wetlands would result in an increase in habitat diversity and provide a source of food. Establishment of riparian wetlands would also reduce peak river flows, sediment, and contaminant inputs to the rivers. Important in-stream habitat in these rivers would include establishing more deep pools for winter refugia for walleye broodstock.

LITERATURE CITED


TRAUTMAN, M. 1981. The fishes of Ohio. The Ohio State University Press, Columbus, Ohio.


Fig. 4.1. Study sites on the Cedar River and Wapsipinicon River, 1998.
Fig 4.2. CPUE of walleye eggs and larvae collected and water temperature on the Cedar River (upper) and Wapsipinicon River (lower), 1998.
Fig. 4.3. Relationship between velocity and CPUE of larval walleye on the Wapsipinicon River, 1998.
Fig. 4.4. Daily discharge in spring 1998 in relation to the monthly mean for the 93-year interval on the Cedar River (upper) and the 63-year interval on the Wapsipinicon River (lower). Solid line represents the mean daily flow for 1998, dashed lines represent the average maximum and minimum discharge over the years.
Table 4.1. Chlorinated hydrocarbon insecticides analyzed in fertilized eggs of walleye collected from the Cedar River at Waverly, Iowa, in 1998 and 1999.

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Aldrin</th>
<th>DDD</th>
<th>Endosulfan II</th>
<th>Heptachlor</th>
<th>Alpha-chlordane</th>
</tr>
</thead>
<tbody>
<tr>
<td>alpha-BHC</td>
<td>DDE</td>
<td>Endosulfan sulfate</td>
<td>Heptachlor epoxide</td>
<td>Gamma-chlordane</td>
<td></td>
</tr>
<tr>
<td>beta-BHC</td>
<td>DDT</td>
<td>Endrin</td>
<td>Methoxychlor</td>
<td>cis-Nonachlor</td>
<td></td>
</tr>
<tr>
<td>delta-BHC</td>
<td>Dieldrin</td>
<td>Endrin aldehyde</td>
<td>Chlordane</td>
<td>trans-nonachlor</td>
<td></td>
</tr>
<tr>
<td>Lindane</td>
<td>Endosulfan I</td>
<td>Endrin ketone</td>
<td>Toxaphene</td>
<td>Oxychlordane</td>
<td></td>
</tr>
</tbody>
</table>
Table 4.2. Mean (± SD) water quality parameters taken from the Cedar and Wapsipinicon rivers April-May of 1998.

<table>
<thead>
<tr>
<th></th>
<th>Temp (°C)</th>
<th>DO (mg/L)</th>
<th>Conductivity (us/cm)</th>
<th>Turbidity (NTU)</th>
<th>Alkalinity (mg/L)</th>
<th>Hardness (mg/L)</th>
<th>TAN (mg/L)</th>
<th>NO₃ (mg/L)</th>
<th>NO₂ (mg/L)</th>
<th>Total SS (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cedar River</td>
<td>14.0ᵃ</td>
<td>12.4ᵃ</td>
<td>0.486ᵃ</td>
<td>25.6ᵃ</td>
<td>112.0ˢ</td>
<td>263.5ᶜ</td>
<td>0.696ᶜ</td>
<td>6.91ᶜ</td>
<td>0.169ᶜ</td>
<td>98.0ᶜ</td>
</tr>
<tr>
<td></td>
<td>(5.9)</td>
<td>(1.3)</td>
<td>(0.051)</td>
<td>(6.97)</td>
<td>(41.4)</td>
<td>(7.7)</td>
<td>(0.230)</td>
<td>(0.39)</td>
<td>(0.152)</td>
<td>(33.0)</td>
</tr>
<tr>
<td>Wapsipinicon River</td>
<td>19.4ᵇ</td>
<td>11.0ᵇ</td>
<td>0.434ᵇ</td>
<td>23.3ᵇ</td>
<td>67.0ᵈ</td>
<td>104.2ᵈ</td>
<td>0.502ᵈ</td>
<td>8.59ᵈ</td>
<td>0.165ᵈ</td>
<td>54.5ᵈ</td>
</tr>
<tr>
<td></td>
<td>(2.3)</td>
<td>(1.9)</td>
<td>(0.046)</td>
<td>(8.01)</td>
<td>(7.5)</td>
<td>(10.0)</td>
<td>(0.107)</td>
<td>(1.68)</td>
<td>(0.890)</td>
<td>(15.2)</td>
</tr>
</tbody>
</table>

ᵃN = 18,ᵇN = 10,ᶜN = 8,ᵈN = 6
Table 4.3. Egg collection interval and water temperatures on the Cedar and Wapsipinicon rivers in 1998.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Cedar</th>
<th>Wapsipinicon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg netting period</td>
<td>April 2-April 22</td>
<td>March 30-April 15</td>
</tr>
<tr>
<td>First walleye egg collection</td>
<td>April 8</td>
<td>April 3</td>
</tr>
<tr>
<td>Peak collection</td>
<td>April 13</td>
<td>April 7</td>
</tr>
<tr>
<td>Temperature during egg netting period</td>
<td>6.5-11.9°C</td>
<td>~7.8-10°C</td>
</tr>
<tr>
<td>Temperature during incubation period</td>
<td>7.5-17.9°C</td>
<td>~7.8-16.4°C</td>
</tr>
</tbody>
</table>

Table 4.4. Date and mean CPUE of walleye eggs on the Cedar and Wapsipinicon rivers, 1998.

<table>
<thead>
<tr>
<th>Cedar River</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CPUE Set</td>
<td>0 0 0.017 0.017 0.083 0 0 0.013 0 0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wapsipinicon River</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>3/30 4/03 4/06 4/07 4/10 4/13 4/15 - - - -</td>
</tr>
<tr>
<td>CPUE Set</td>
<td>0.67 1.67 4.0 0.42 0.42 0.25 - - - -</td>
</tr>
</tbody>
</table>
Table 4.5. Larval walleye measurements on the Cedar and Wapsipinicon rivers, 1998.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Cedar River</th>
<th>Wapsipinicon River</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larval sampling dates</td>
<td>April 22-May 27</td>
<td>April 24-May 27</td>
</tr>
<tr>
<td>Number of sample dates</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>Number of samples</td>
<td>57</td>
<td>67</td>
</tr>
<tr>
<td>Total volume filtered</td>
<td>1,329 m³</td>
<td>3,594 m³</td>
</tr>
<tr>
<td>First larval walleye collected</td>
<td>May 6</td>
<td>May 4</td>
</tr>
<tr>
<td>Peak CPUE (geomean)</td>
<td>May 26</td>
<td>May 13</td>
</tr>
<tr>
<td></td>
<td>6.0/1000 m³</td>
<td>7.1/1000 m³</td>
</tr>
<tr>
<td>Geometric mean</td>
<td>1.4/1000 m³</td>
<td>2.1/1000 m³</td>
</tr>
<tr>
<td>Mean length</td>
<td>6.8</td>
<td>6.2</td>
</tr>
</tbody>
</table>

Table 4.6. Geometric means (#/1000 m³) of walleye CPUE on the Cedar and Wapsipinicon rivers, 1998.

<table>
<thead>
<tr>
<th>Cedar River</th>
<th></th>
<th>Wapsipinicon River</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geomean</td>
<td>0 0 1.0 0 5.8 0 0 6.0 0</td>
<td>0 0 1.2 1.8 4.2 7.1 1.0 2.8 3.5 0 1.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date</th>
<th>5/27</th>
<th>5/27</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geomean</td>
<td>1.8</td>
<td>1.8</td>
</tr>
</tbody>
</table>
Table 4.7. Length frequency distribution of larval walleye collected in May 1998, Cedar and Wapsipinicon rivers.

<table>
<thead>
<tr>
<th>Length (mm)</th>
<th>April</th>
<th>May</th>
<th>Total number</th>
</tr>
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**Cedar River**

<table>
<thead>
<tr>
<th></th>
<th>24</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>11</th>
<th>14</th>
<th>18</th>
<th>21</th>
<th>26</th>
<th>27</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td>6</td>
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<td>1</td>
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<td></td>
<td></td>
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<td></td>
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<td></td>
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**Wapsipinicon River**

<table>
<thead>
<tr>
<th></th>
<th>24</th>
<th>1</th>
<th>4</th>
<th>8</th>
<th>11</th>
<th>13</th>
<th>14</th>
<th>18</th>
<th>20</th>
<th>21</th>
<th>27</th>
<th>Total</th>
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<tbody>
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<td></td>
<td></td>
<td>1</td>
<td>2</td>
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</tbody>
</table>
Table 4.8. Correlation of CPUE of larval walleye and zooplankton with physical and chemical correlates for the Cedar and Wapsipinicon rivers. The top value is the Pearson correlation coefficient and the bottom value is the p value.

<table>
<thead>
<tr>
<th></th>
<th>Date</th>
<th>Temp</th>
<th>DO</th>
<th>pH</th>
<th>Cond</th>
<th>Turbidity</th>
<th>Depth</th>
<th>Discharge</th>
<th>Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cedar River</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WYE</td>
<td>0.131</td>
<td>0.046</td>
<td>0.346</td>
<td>0.151</td>
<td>-0.463</td>
<td>0.208</td>
<td>0.217</td>
<td>-0.156</td>
<td>0.269</td>
</tr>
<tr>
<td></td>
<td>0.735</td>
<td>0.914</td>
<td>0.401</td>
<td>0.720</td>
<td>0.248</td>
<td>0.622</td>
<td>0.640</td>
<td>0.688</td>
<td>0.520</td>
</tr>
<tr>
<td>ZOO</td>
<td>0.157</td>
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<td>0.159</td>
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<td>0.388</td>
<td>0.116</td>
<td>0.430</td>
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<tr>
<td><strong>Wapsipinicon River</strong></td>
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<td></td>
<td></td>
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<tr>
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<td>-0.554</td>
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CHAPTER 5. GENERAL CONCLUSION

Low survival of stocked larval walleye and limited natural recruitment occurs in the Cedar, Shell Rock, and Wapsipinicon rivers (Cleary and Mayhew 1961, Degan 1978, Paragamian 1991). Early mortality of walleye in rivers has been attributed to lack of spawning substrate, low water temperatures, lack in the availability of food, high river flows, and predation (Bush et al. 1975, Corbett and Powles, Fielder 1992, Heidinger and Kohler 1992). The objectives of this study were 1) to characterize the historical and current distribution of walleye in Iowa’s interior rivers, 2) to assess the opinions of IDNR fisheries management biologists as to factors contributing to the lack of natural recruitment in Iowa's interior rivers, and 3) to describe environmental conditions occurring in the Cedar and Wapsipinicon that are associated with walleye spawning sites and survival of eggs and larvae.

The first fish surveys of Iowa showed that walleye were present, but scarce in the Big Sioux, Cedar, and Iowa rivers. Today, walleye are present in many rivers in the state, but are most abundant in larger rivers of the Mississippi River drainage.

IDNR fish management biologists indicated that poor quality habitat due to sedimentation and lack of spawning and nursery habitat were important factors limiting successful recruitment of walleye in Iowa rivers.

In our study of the Cedar and Wapsipinicon rivers, collection of eggs and larvae from the Cedar and Wapsipinicon rivers provide evidence of successful spawning and incubation, however, length frequency distribution of larvae suggests poor survival of larvae. Factors
that did not seem to be critical to the recruitment success of walleye on the Cedar and Wapsipinicon rivers were spawning substrate, presence of pesticides, water temperature, and water quality.

Important factors influencing survival of larval walleye in the Cedar and Wapsipinicon rivers seem to be high current velocities and flows, low availability of food in the main stem of the river, and lack of backwater areas. Backwaters, sloughs, lakes, and large impoundments provide refuge from high river currents, and are capable of supplying an abundant food source, critical to survival of young walleye of these rivers. In general, fragmentation of critical habitat for walleye in Iowa rivers results in limited movement and the capability of walleye to produce natural offspring.

Management efforts should focus on establishing riparian wetlands to provide refuge for young walleye, and it should focus on the establishment of large, in-stream pools, providing seasonal habitat for potential walleye broodstock.

**Literature Cited**


ACKNOWLEDGEMENTS

Foremost, I would like to thank my major Professor, Dr. Robert Summerfelt for taking me under his wing and playing a strong role in my graduate education. Thank you for your patience, providing direction on the project, and intensive editing on the thesis. I also would like to thank Barbara Mack and Jane Pedersen for their encouragement and help through graduate school. Thanks to Dr. George Jackson, for partially funding my assistantship. My sincere thanks to the four of you for believing in my abilities to accomplish my goal of obtaining a Masters of Science.

Thanks to Dr. Bruce Menzel and Dr Edwin Powell, for serving as committee members. Thank you for your concerns and advice early on in the project and for comments on the manuscripts.

I would like to thank Aaron Griffiths for his invaluable help in the field. There were some long tiring nights spent in the field and your help was appreciated. I also would like to thank Gary Siegwarth, Greg Simmons, and Mike Hawkins for taking the time to assist us in the field and give their insights on the project. I would like to thank Todd Phillips for sharing his water quality data for the project and for the discussions we had on environmental problems of the river.

Special thanks to Scott Gritters, no words can express the appreciation I have for your help in the development of my professional career. Over the years you have consistently provided me with lectures, advice, and encouragement, and for that my deepest thank you.

To Gregg Moothart, Melvin Bowler, Liesl Hohenshell, Theresa Blackburn, Kevin Hanson, and Scottt Gritters, thank you all for your friendship and good memories through
the years. I know there will be plenty more to come.

To my older brother Chuck, thanks for checking in on me from time to time.

Finally, to my parents, Charles and Pauline, a special thanks to you not only for your emotional support, but also for your financial support throughout my college career. Thanks for always supporting what I have wanted to do.