Department of Agriculture, Trade and Consumer Protection
Division of Agricultural Development
Agricultural Development & Diversification Program (ADD)
Grant Project Final Report

Contract Number: 16015

Grant Project Title: Use of the Hilsenhoff Biotic Index to assess the environmental impact of a commercial aquaculture operation

Project Beginning Date: July 1, 2001 Project End Date: July 1, 2003

Amount of Funding Awarded: $11,420

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Please use the following questions as a guide for writing your grant project final report. In your final report, please answer each question as it relates to your grant project.

1) What did you want to accomplish with the grant?

The overall goal of this study is to use the (HBI) in conjunction with water quality measurements to assess the environmental impact of an aquaculture production facility.

What steps did you take to reach your goal?

Objectives:

(1) generate upstream, proximal downstream (within 10 meters of the effluent source) and distal downstream (~100 meters from the effluent source) HBI values and water quality measurements for three distinct sites each associated with different types of production facilities (production ponds, broodstock ponds and hatchery/ holding facilities);
(2) compare upstream and downstream HBI indices to assess impact;
(3) compare assessments based on the HBI with assessments based on measurements of water quality; and
(4) calculate the costs associated with performing an HBI assessment.

What worked? All aspects of the generation of HBI values for the chosen sites were successful. Technician time for organism sampling (5 min/location) and identification (68 min/sample) were similar to published results.

What did not work? Water samples were analyzed for phosphorus and nitrate. A change in the cost of sample analysis prevented us from obtaining ammonia levels for the collected water samples.

What would you do differently? While sampling and analysis protocols were adequate, many more sites need to be studied before the use of the HBI as a sole measure of impact can be validated. Future studies should consider more and a wider variety of sample sites associated with aquaculture.

What were you able to accomplish? We successfully demonstrated the use of the HBI to assess the impact of aquacultural effluent.

What challenges did you face? At times access to the sample sites was difficult due to undergrowth.

What do you plan to do in the future as a result of this project? We have already proposed further studies but have yet not received grants on the subject. Future proposals will be made.

How should the agricultural industry or the State of Wisconsin use the results from your grant project? See comments.

Use of the Hilsenhoff Biotic Index to assess the environmental impact

of a commercial aquaculture operation

Gollon Bait & Fish Farm
5117 Hwy 191
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(608) 935-2098

contract number16015

Amount Requested: $11,420
Matching Funds: $15,900

Project Duration: 2 years

PROJECT SUMMARY

The single most important issue facing aquaculture development in the State of Wisconsin is environmental impact. Because of the wide range of environmental circumstances that are encountered it is difficult assess the impact that aquaculture production facilities have on receiving bodies of water. Traditional water quality assessments based on measurement of the physical characteristics of the water (e.g. temperature, dissolved oxygen, total nitrogen) can provide valuable information, but do little to directly measure the impact of aquaculture effluents on the organisms living in the receiving stream. While multiparametric assessments take a range of water quality and population analyses into consideration, they are laborious, expensive and generally not able to be undertaken by the average producer.

A standardized test is needed to: 1.) allow producers to assess the environmental impact of their operations, 2.) allow regulatory agencies to base regulations on direct measurement of the impact of effluent on the biota of a given site and 3.) allow prospective aquaculture developers to assess the potential for environmental impact on a given site.

The Hilsenhoff Biotic Index (HBI) provides an accurate, affordable and available technique to evaluate the water quality of streams. This technique was developed for use in Wisconsin streams, and has been used extensively in Wisconsin and other states to evaluate thousands of stream sites. The HBI is a measure of organic and nutrient pollution based on the tolerance of a variety of species of arthropods to withstand lowered dissolved oxygen levels.

The overall goal of the proposed study is to use the (HBI) in conjunction with water quality measurements to assess the environmental impact of an aquaculture production facility. As specific objectives we will: (1) generate upstream, proximal downstream (within 10 meters of the effluent source) and distal downstream (~100 meters from the effluent source) HBI values and water quality measurements for three distinct sites each associated with different types of production facilities (production ponds, broodstock ponds and hatchery/ holding facilities); (2) compare upstream and downstream HBI indices to assess impact; (3) compare assessments based on the HBI with assessments based on measurements of water quality; and (4) calculate the costs associated with performing an HBI assessment.

The plan of work for the project will be as follows: Samples of benthic insects along with important water quality parameters (water temperature, flow, pH, dissolved oxygen, biological oxygen demand, total suspended solids, ammonia nitrogen and total phosphorus) will be collected from selected sites two times each during the spring and fall. In addition, water quality parameters will be sampled twice during the summer (a time when HBI evaluations can be misleading). Insect samples will be individually sorted and identified to the species level as needed to generate a biotic index for the given site. Environmental impact will be assessed by comparing the upstream and downstream indices and comparing the indices with the water quality data. Costs associated with the generation of the indices will be calculated, and findings will be presented and published in appropriate forums.

Aquaculture is an opportunity for Wisconsin to expand its rich agricultural heritage into the new century. The industry has the potential to provide thousands of jobs and millions of dollars of agricultural productivity. How much of this potential Wisconsin will realize may ultimately depend on environmental issues. The establishment of a an accurate, affordable and available technique to evaluate the impact of aquaculture effluent on the water quality of Wisconsin streams is the key to environmentally responsible aquaculture production and properly regulated expansion of the aquaculture industry.

IDENTIFICATION OF NEED

The aquaculture industry in Wisconsin is poised to undergo a period of unprecedented expansion. Industry growth elicits concerns about the environmental impact of aquaculture production facilities. Producers and regulatory agencies agree that it is in everyone's best interest to develop and practice aquaculture in the most environmentally responsible manner possible.

Because of the diversity of circumstances and virtually infinite interactions that occur between an aquaculture production site (e.g. pond, hatchery, raceway) and the environment in which it is set, it is difficult assess the impact that such sites have on receiving bodies of water. The traditional water quality assessments based on measurement of the physical characteristics of the water (e.g. temperature, dissolved oxygen, biological oxygen demand, nutrient concentrations) can provide valuable information, but do little to directly measure the impact of aquaculture effluents on the organisms living in the receiving stream. While multiparametric assessments take a range of water quality and population analyses into consideration, they are laborious, expensive and generally not able to be undertaken by the average producer. The method of measuring impact must be accurate, affordable and available.

Hilsenhoff Biotic Index

In 1977, William Hilsenhoff, an entomologist at the University of Wisconsin working in cooperation with the Wisconsin Department of Natural Resources, put forth the idea of using aquatic insects to evaluate water quality in Wisconsin streams (Hilsenhoff 1977). Since that time the Hilsenhoff Biotic Index (HBI) has proven to be one of the most powerful tools available for assessing the impact of organic pollution on streams. In brief, the method samples and classifies (to the species level) benthic insects, amphipods and isopods. Species are assigned pollution tolerance values based on field studies. The biotic index is the average tolerance value of 100 specimens collected (Hilsenhoff 1982).

The accuracy of the HBI has been repeatedly demonstrated in stream assessments done in several states where it has become one of the methods of choice. The Wisconsin Department of Natural Resources has used the HBI to evaluate literally thousands of Wisconsin stream sites.

Another aspect that recommends the HBI for use is its likely affordability. Field sampling time is kept to a minimum (5-30 min per site). Laboratory time (1-2 hr per sample) is limited to sorting and identification and not reliant on highly technical and expensive procedures. Therefore per sample costs (primarily labor) are controlled. Hilsenhoff (1982) indicated and average time of 85 min/site to produce a biotic index. As part of this research project we will calculate the cost of generating a biotic index for a single site.

Finally, because it was developed here in Wisconsin, the HBI should be tailor-made for this application. As the demand for testing grows, it is easy to envision a service that, for a moderate fee, provides an HBI based on samples collected by a producer.

STATEMENT OF OBJECTIVES

The principal goal of this project is to demonstrate the use of the Hilsenhoff Biotic Index to assess the environmental impact of three types of aquaculture production facilities on receiving waterways.

Specific objectives are to:

(5) generate upstream, proximal downstream (within 10 meters of the effluent source) and distal downstream (~100 meters from the effluent source) HBI values and water quality measurements for three distinct sites each associated with different types of production facilities (production ponds, broodstock ponds and hatchery/ holding facilities);
(6) compare upstream and downstream HBI indices to assess impact;
(7) compare assessments based on the HBI with assessments based on measurements of water quality; and
(8) calculate the costs associated with performing an HBI assessment.

Methods

This study was performed at Gollon Bait & Fish (Dodgeville, WI) during the spring and fall of 2002. Two samples during each season were collected from three distinct sites each associated with different types of production facilities. Minnow production ponds (top draw) discharged into the northern most unnamed branch of the Dodge Branch, Hatchery/ holding facilities with interrupted flow into the central Dodge Branch and broodstock ponds (bottom draw) into the southern unnamed branch of the Dodge Branch (just north of the Bloetz Branch). Within each site, three locales were identified for sampling. All sampling locales displayed characteristics that were well suited to arthropod collection (rocky riffles, adequate flow). The first locale at each site was within 10m upstream of the aquaculture effluent discharge, the second was within 10m downstream of the discharge (near discharge), and the third approximately 100m downstream of the discharge. To document economic inputs all activities were time recorded.

HBI

At each sampling locale, a walking kick-sample technique and 1/8" mesh "D style" net was used to dislodge and collect arthropods and other organic matter (weeds, sticks, etc.) into a bucket until approximately 150 arthropods could be seen. Arthropods and organic matter were then transferred into plastic containers and preserved with 70% ethanol.

In the laboratory, arthropods from each sample were sorted from other matter using care to inspect plants and other flotsam for clinging or encased insects. All arthropods were collected from each sample. Within each sample, arthropods were sorted by Family and identified to the genus and species (when necessary) level for tabulation. An HBI value was calculated for each locale using published tolerance values (Hilsenhoff 1987).

Water Quality

At each sampling locale, water samples were collected and water quality characteristics were measured and recorded. Water temperature and D.O. were measured using a YSI model 50 dissolved oxygen meter. Stream depth, width and speed were measured to calculate stream flow rate.

In the laboratory, pH was measured with a Fisher Scientific Accumet pH meter. BOD and suspended solids were determined using standard methods. Nitrate and total phosphorus levels were measured by the University of Wisconsin-Madison Soil and Plant Analysis Lab. Ammonia analysis was not conducted due to budgetary considerations.

Statistics

The data were analyzed by three-way analysis of variance (ANOVA). Variables examined were the main effects of Season, Site, and Locale, and the interaction of Site x Locale. Differences between means were compared at the 0.05 level of significance using protected LSD tests. Regression analyses was performed by plotting HBI values against each water quality parameter (r^2>0.80). We believe these analyses to be an appropriate and conservative approach. As with many out-of-the lab experiments, however, low numbers of replicates limit the power of the analysis. We plan to review this report with a statistical consultant to consider alternative analyses, and will update this report if needed. All data are reported as mean $\pm$ SEM.

Results and Discussion

HBI and water quality data are summarized in Table 1. Results of ANOVA analyses of the data reveal agreement between HBI values and many of the water parameters tested. Not surprisingly, we measured differences between Spring and Autumn in HBI values as well as water temperature, dissolved oxygen, flow rate, suspended solids, and nitrate. We also found differences between the 3 Sites (North Central and South) in mean HBI values as well as dissolved oxygen, flow rate, suspended solids, nitrate, and total phosphorous. No differences between HBI values or any water quality parameters were found for the main effect of Locale or the interaction of Site x Locale (Data not shown). Statistical analyses between locales within each site was not possible due to the lack of repeated observations. Both positive and negative changes in HBI values were noted when comparing upstream and far downstream locales within each site, but no overall pattern could be discerned. Regression analyses revealed no significant correlation ($r^2 \geq 0.80$) between HBI values and any individual water quality parameter.

The economic input to generate an HBI value was 68 min of technician time per sample (@$15.00/hr= $17.00). Tools needed to accomplish the task were basic sampling equipment (net, bucket, and jars), a variety of trays and screens for sorting, a good dissecting microscope, and most importantly a key for aquatic arthropods. The economic input used to attain the selected water quality characteristics was 66 min of technician time per sample ($16.50). In addition to laboratory supplies (glass-ware, filters, etc.,) several expensive measuring devices were used to characterize the water samples. An outside source for nitrate and phosphorus analysis was used at a cost of $13.50 per sample. Ammonia testing ($4.50) would have raised the total per sample cost to $34.50. When you add in interpretation of the water quality results, per sample costs might easily exceed $50.00. Two to three times the cost of the HBI technique.

Conclusion

This study successfully demonstrates the use of the Hilsenhoff Biotic Index to assess the environmental impact of aquaculture production facilities on receiving waterways. Supporting this conclusion is the fact that our ANOVAs revealed similar differences in HBI and water quality parameters between season and site. The lack of any significant correlations (r^2>0.80) between HBI values and individual water quality parameters was somewhat surprising, since the HBI is based primarily on DO tolerance. However, it serves to remind us of the real power of the HBI. The HBI uses living organisms to summarize the complex interactions of the individual water quality parameters. The interpretation of the HBI is straightforward, a value is generated and the corresponding assessment is read from a table

(Table 2). Analysis of multi-parametric water quality data is a daunting task, with even the most basic interactions subject to interpretation.

The facts that we measured no differences in HBI and water quality parameters relative to the location of the aquaculture discharge (upstream, near, or downstream), nor any location x site interactions, support the conclusion that the aquacultural effluents examined in this study are not impacting the receiving waterways to a significant degree. Not always the case, in an HBI evaluation of Rock Creek (running through the Lake Mills State Fish Hatchery) a graduate student reported high HBI values near fingerling pond discharge sites (7.78), but lower HBI values downstream of the hatchery (4.83) than those just upstream (5.91). This suggests that the individual nature of each operation and each receiving waterway requires individual analysis. It also suggests that the HBI can be used to identify problem areas along the waterway, as well as document the effects of habitat improvement

In conclusion we find the HBI technique to be an affordable and available method to measure the impact of aquaculture facilities on receiving waters. The accuracy of the HBI has yet to be adequately evaluated under aquacultural applications to be the sole regulatory criterion but the groundwork is laid. More study is needed … and quickly. This tool will define the very future of Wisconsin's Aquaculture Industry, an industry that has the potential to provide millions of dollars of agricultural productivity supporting many agricultural and processing jobs. How much of this potential Wisconsin will realize relies on our environment.

REFERENCES

Hilsenhoff , W.L. 1977. Use of arthropods to evaluate water quality of streams. Department of Natural Resources Tech. Bull. No. 100. Madison, WI. 15pp.

Hilsenhoff, W.L. 1982. Using a biotic index to evaluate water quality in streams. Department of Natural Resources Tech. Bull. No. 132. Madison, WI. 22pp.

Hilsenhoff, W.L. 1987. An improved biotic index of organic stream pollution. The Great Lakes Entomologist. 20:31-39.

Table 1. Data are presented as the mean ± s.e.m. (in parenthesis)

	Seasons (n=12)		Site (n=16-18)			Locale (n=16-18)		
Variable	Spring	Fall	Central Dodge Branch	South Dodge Branch	North Dodge Branch	Up-stream	Near Disch.	Down-stream
HBI	5.43* (0.20)	5.83* (0.21)	4.88* (0.10)	6.61* (0.12)	5.40* (0.18)	5.49 (0.29)	5.68 (0.26)	5.73 (0.22)
Temp. (°C)	7.6* (0.55)	4.5* (0.76)	5.2 (0.82)	6.4 (0.90)	6.5 (1.05)	6.0 (1.0)	6.2 (0.9)	6.0 (0.9)
DO (ppm)	12.8* (0.33)	12.0* (0.26)	13.4* (0.41)	12.8* (0.33)	12.1* (0.24)	12.7 (0.44)	12.2 (0.32)	12.4 (0.37)
Flow (m^3/sec)	0.11* (0.02)	0.08* (0.01)	0.15* (0.02)	0.11* (0.02)	0.08* (0.02)	0.08 (0.01)	0.09 (0.01)	0.11 (0.02)
pH	7.9 (0.02)	7.9 (0.02)	7.9 (0.02)	7.9 (0.02)	7.9 (0.01)	7.9 (0.02)	7.9 (0.02)	7.9 (0.03)
BOD (ppm)	0.43 (0.04)	0.37 (0.02)	0.44 (0.05)	0.34 (0.02)	0.42 (0.04)	0.44 (0.05)	0.41 (0.05)	0.35 (0.03)
SS (mg/L)	26.8* (2.3)	38.0* (6.0)	18.1* (1.1)	49.2* (5.7)	29.9* (5.1)	33.9 (5.96)	34.4 (6.1)	29.0 (5.5)
Nitrate (ppm)	5.48* (0.32)	6.57* (0.25)	6.37* (0.43)	4.90* (0.17)	7.03* (0.16)	6.25 (0.41)	5.96 (0.39)	6.01 (0.38)
Total P (ppm)	0.06 (0.02)	0.07 (0.02)	0.14* (0.02)	0.03* (0.01)	0.02* (0.01)	0.06 (0.02)	0.07 (0.02)	0.06 (0.02)

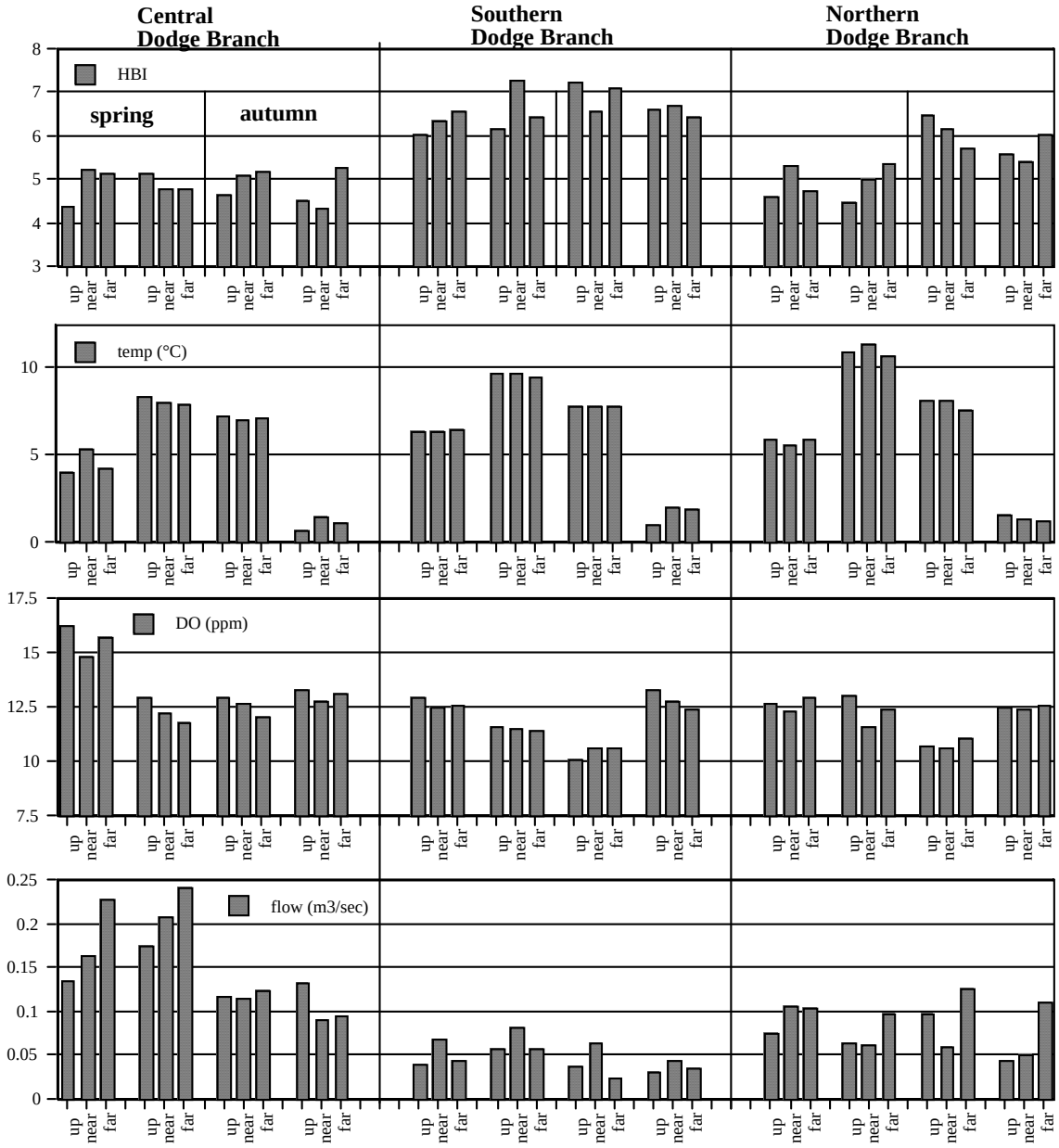
* significant at $p<0.05$

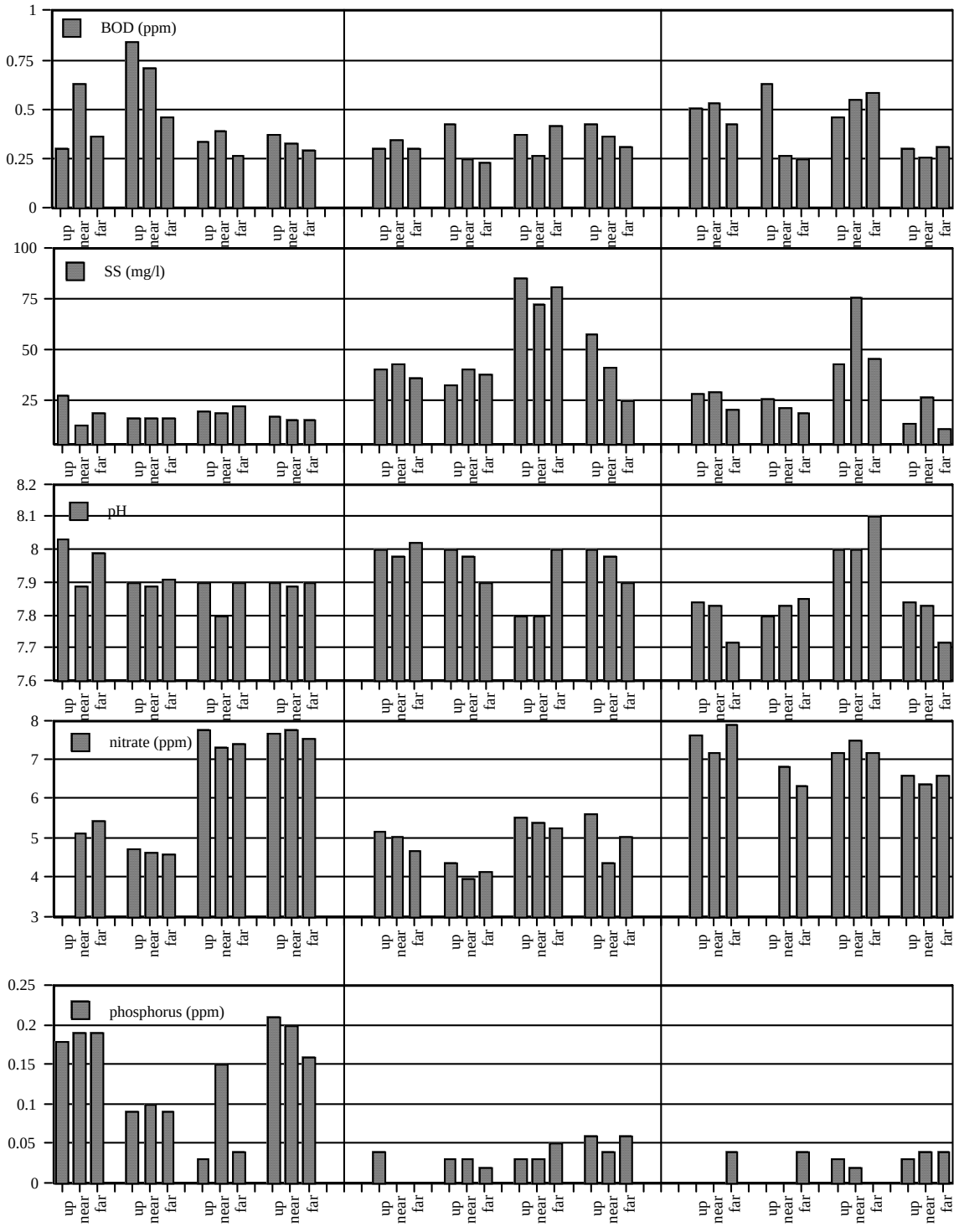
Table 2.

(Hilsenhoff 1987)

Biotic Index	Water Quality	Degree of Organic Pollution
0.00-3.50	Excellent	No apparent organic pollution
3.51-4.50	Very Good	Possible slight organic pollution
4.51-5.50	Good	Some organic pollution
5.51-6.50	Fair	Fairly significant organic pollution
6. 51-7.50	Fairly Poor	Significant organic pollution
7.51-8.50	Poor	Very significant organic pollution
8.51-10.00	Very Poor	Severe organic pollution

Graphic presentation of the data set


Central
Dodge Branch
Southern
Dodge Branch
Northern
Dodge Branch
HBI
spring
autumn
temp (°C)
DO (ppm)
flow (m3/sec)
up
near
far


BOD (ppm)
SS (mg/l)
pH
nitrate (ppm)
phosphorus (ppm)
up
near
far

Type, HBI tolerance value, and number of collected arthropods

EPHEMEROPTERA	
Centroptillum spp. 2	6
Cloeon spp. 4	4
Heptagenia hebe 0	1
Leucocruta hebe 1	1
Stenonema femoratum 5	1
S. integrum 3	2
S. puchellum 3	1
S. terminatum 4	5
ODONATA	
Aeshna spp. 5	2
Basiaescha janata 6	1
Chromagrion conditum 4	2
Lestes spp. 9	10
Leucorrhinia intacta 9	3
Neurocordulia yamaskanensis 0	1
Sympetrum spp 10	6
TRICHOPTERA	
Brachycentrus americanus 1	79
B. lateralis 1	29
Hydropsyche leonardi 0	253
Hydroptila spp. 6	1
Limnephilus spp. 3	1
COLEOPTRA	
Psephenus herricki 4	34
DIPTERA (except Chironomidae)	
Chrysops spp 6	6
Ephydridae 6	1
Limnophila spp. 3	1
Simulium aurium 7	1
S. pictipes 4	5
S. venustum 5	81
Tipula spp. 4	20
Chironomidae	
Pentaneura spp. 6	553
AMPHIPODA-ISOPODA	
Asellus intermedius 8	2042
Gammarus pseudolimnaeus 4	1621
total	4773