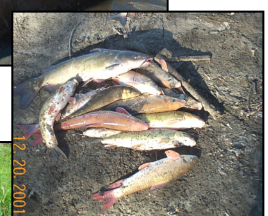
Stream Fish Kill Follow-up Assessment: Fish Community Sampling Results



Iowa Department of Natural Resources
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Summary

From 1999 to 2001, the Iowa Department of Natural Resources (IDNR) and University Hygienic Laboratory (UHL) sampled fish communities in 23 streams that were affected by major fish kills. The primary goal of the project was to assess the status of biological conditions in fish kill streams and evaluate recovery of fish populations. The length of time between fish kills and follow-up sampling ranged from 5 to 60 months.

Follow-up sampling results were compared with data from fish kill reports and stream ecoregion reference sites. Data analysis focused on three aspects of the fish community: abundance, community integrity, and species composition. Levels of fish abundance and community integrity varied greatly among the 23 follow-up streams. Fish abundance ranged from very low (17 fish/500ft.) to very high (2,506 fish/500ft.). Ratings of the Fish Index of Biotic Integrity (FIBI), a measure of fish community integrity developed for Iowa's streams, ranged from very poor (2) to excellent (73). Levels of fish abundance and/or fish community integrity were lower than reference expectations in twelve (52%) follow-up stream segments (Table 1).

Exploratory statistical tests were performed on data from a subset of follow-up streams. Analysis results should be viewed cautiously since the sample population was small and not obtained from a scientific experimental design. Eight streams each were sampled inside and outside a fish kill segment. Streams that had relatively poor fish communities in the kill segment also had poor fish communities outside the kill segment. As a group, fish abundance levels at sample sites inside kill segments actually ranked higher than fish abundance levels outside kill segments. FIBI levels did not differ significantly between sampling sites in kill and non-kill segments.

Among 15 fish kill segments sampled, there was an inverse correlation between FIBI score and length of stream killed. That is, low FIBI levels tended to occur in streams where the longest fish kills occurred. The length of time between fish kills and follow-up sampling was not correlated either with fish abundance or FIBI levels.

In terms of fish abundance and species composition, follow-up sampling results indicate that significant recovery can occur in some streams within several months to a few years after a major fish kill. Other streams, however, might not completely recover within this time frame. For example, several follow-up streams were missing at least one fish species that was reportedly present during the documented fish kills (Table 1; Appendix 1). This project's assessment of fish community status focused on fish abundance and species composition. Other fisheries indicators, such as biomass or age/size composition could be used to more effectively evaluate the long-term impacts of fish kills.

In addition to fish sampling data, IDNR staff also evaluate benthic macroinvertebrate, physical habitat, and water quality sampling data to obtain a more complete assessment of stream conditions. Final assessment results for fish kill follow-up streams will be reported in the 2002 biennial report on the status of Iowa's water quality. Assessment results will be used to establish water quality program priorities and support management decisions.

Table 1. Summary of fish community assessment results from 1999-2001 fish kill follow-up streams.
(*Numbers in parentheses refer to Figure 1, Table 2, Appendix 1)

Comparable to Reference Conditions	Potential Loss of Fish Species	Slightly - Moderately Impaired Fish Abundance and/or Community Integrity	Severely Impaired Fish Abundance and Community Integrity
Fish abundance and fish community integrity are comparable to reference stream levels. Virtually all fish species observed in the fish kill investigation were present in follow-up sampling.	Fish abundance and fish community integrity are comparable to reference stream levels. The majority of fish species reported in the fish kill investigation were present in follow-up sampling including one or more additional species; however, at least one fish species observed during the fish kill investigation was missing from follow-up sampling.	Fish abundance and/or fish community integrity are slightly lower than reference stream thresholds. Most or all of the fish species observed during the fish kill investigation were present in follow-up sampling.	Fish abundance and fish community integrity are not comparable to reference stream thresholds. At least one fish species observed in the fish kill investigation was not observed in follow-up sampling, or very low abundance and diversity of fish were reported in the fish kill investigation.
Big Creek – Linn Co. (15)* Buck Creek – Delaware Co. (3) Deer Creek – Worth/Mitchell Co. (20) East Big Creek – Linn Co. (15) Horton Cr. – Bremer Co. (2) Silver Creek – Jones Co. (10)	Crabapple Creek – Linn Co. (13) Tipton Cr. – Hamilton/Hardin Co. (5) Heather Branch – Henry Co. (6) Crane Creek – Worth Co. (7) Prairie Creek – Jackson Co. (8)	Buffalo Cr. – Jones Co. (11) Farmers Creek – Jackson Co. (9) Floyd River – O' Brien Co. (16) Indian Cr. – Linn Co. (14) N. F. Maquoketa R.–Dubuque Co. (4) Prairie Creek – Palo Alto Co. (17) W. Branch Floyd R. – Sioux Co. (19) Yellow River – Allamakee Co. (1)	Buffalo Cr. – Kossuth Co. (12) North Buffalo Cr. – Kossuth Co. (12) Sixmile Creek – Sioux Co. (18) Unn.Trib. Yellow R. – Allamakee (1)

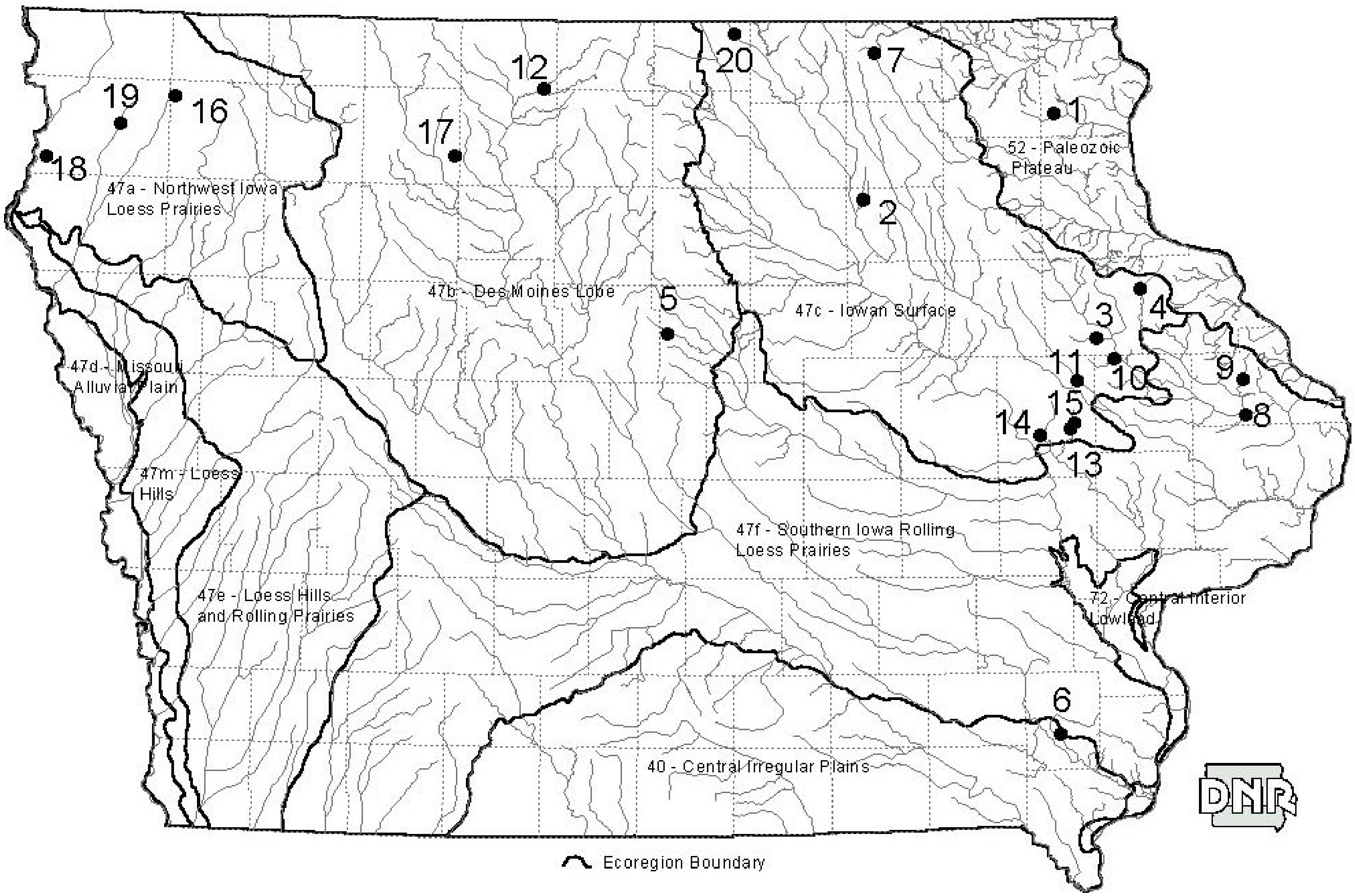


Figure 1. Locations of Fish Kill Follow-up Sampling Streams: 1999-2001 (numbers refer to Tables 1&2, Appendix 1).

Introduction

Fish kills are caused by pollution events and natural environmental circumstances that produce lethal water quality conditions. When conditions deteriorate quickly and refuge habitat is not accessible, fish populations and other aquatic life can be decimated. The most common causes of fish kills in Iowa include ammonia fertilizer, livestock waste, oxygen depletion, sewage, temperature fluctuation, and toxic chemicals. In recent years, fish kills have occurred at a rate that has raised concern among natural resource managers and the public. From 1996 through 2001, the IDNR reported 126 fish kills in Iowa's streams and rivers. 70% of the fish kills were attributed to human causes and 30% were attributed to natural or unknown causes. The end of 2001 was marked by a series of stream fish kills that included Iowa's largest documented kill. An estimated 1,295,205 fish valued at $147,713 were lost throughout 31 miles of Lotts Creek and 18 miles of the East Fork of the Des Moines River in northcentral Iowa. The fish kill was caused by ammonia fertilizer released from a ruptured underground pipeline.

Typically, an investigation is conducted immediately after a fish kill to determine the cause and source of the kill, evaluate water quality impacts, and assess fish losses. Because of cost, and because adequate baseline data are seldom available, stream recovery monitoring is not usually done. Most stream fish kills are relatively short-term disturbances. It might be assumed that aquatic life and water quality can eventually recover to pre-kill conditions; however, actual studies that document stream recovery in Iowa are not available.

To address the lack of information about recovery and potential long-term impacts from fish kills, the IDNR and University Hygienic Laboratory (UHL) conducted follow-up sampling in 23 streams that were affected by 20 major fish kills (Figure 1; Table 2). The primary sampling objectives were to assess the status of stream biological health, and to the extent possible, examine for long-term residual impacts from the documented fish kills. The project was not designed to monitor the recovery of fish populations or stream ecosystem function. A more detailed and costly study would be needed to accomplish those objectives.

The 20 fish kills chosen for follow-up sampling (Table 2) encompass 132 stream miles. Fish kill segment lengths ranged from 1.6 miles (Horton Cr. – Bremer Co.) to 22.6 miles (North Buffalo Cr. / Buffalo Cr. – Kossuth Co.). The median length was 5.1 miles. Livestock waste runoff and spills caused 70% of the fish kills. The remaining 30% were caused by fertilizer, municipal sewage, pesticides and unknown circumstances.

Table 2. Stream fish kills included in the 1999-2001 follow-up assessment.

Fig.1 Ref. No.	Stream Name	County	Kill Type	Kill Cause	Fish kill Date	Kill Length (Miles)	Total No. Fish Killed *	Follow-Up Sample Date	No. Months Sample After Fish kill	Sample Location(s)
1	Unn.Tributary / Yellow River	Allamakee	Unknown	Unknown	3/17/00	3.1	4,860	8/15/00	5	Upstr, KS Dstr
2	Horton Creek	Bremer	Unknown	Unknown	8/16/97	1.6	12,724	7/24/01	47	Dstr
3	Buck Creek	Delaware	Ag Run-off	Animal Wastes	7/20/98	4.0	* 92,404	8/13/01	37	Dstr
4	North Fork Maquoketa River	Dubuque	Ag Run-off	Animal Wastes	7/22/98	4.2	* 34,326	8/10/99 8/21/01	13	KS Upstr
5	Tipton Creek	Hamilton / Hardin	Spill	Animal Wastes	7/20/98	10.8	93,180	8/3/99	13	KS Dstr
6	Heather Branch	Henry	Sewage	Municipal	7/23/97	2.2	7,175	10/14/98	51	KS
7	Crane Creek	Howard	Spill	Animal Wastes	7/26/97	8.5	109,168	10/10/00	39	KS, Dstr
8	Prairie Creek	Jackson	Spill	Animal Wastes	9/18/97	5.1	* 93,403	8/14/01	47	KS
9	Farmers Creek	Jackson	Ag Run-off	Animal Wastes	9/22/97	13.0	133,134	8/18/99	23	KS
10	Silver Creek	Jones	Ag Run-off	Animal Wastes	7/26/99	6.0	64,104	7/31/01	24	KS
11	Buffalo Creek	Jones	Spill	Animal Wastes	8/21/96	6.4	5,850	8/27/01	60	Upstr, Dstr
12	No. Buffalo Creek / Buffalo Creek	Kossuth	Spill	Animal Wastes	9/6/96	22.6	586,881	8/24/00	48	Ustr, KS
13	Crabapple Creek	Linn	Ag Run-off	Animal Wastes	8/6/98	3.2	26,481	7/17/01	36	KS
14	Indian Creek	Linn	Urban Run-off	Pesticides	8/25/98	2.3	43,367	9/18-25/00	25	Ustr, Dstr
15	E. Big Creek / Big Creek	Linn	Spill	Other	4/23/97	2.0	11,013	7/18/01	51	KS, Dstr
16	Floyd River	O'Brien	Spill	Animal Wastes	5/17/97	6.5	5,558	9/14/99	28	KS
17	Prairie Creek	Palo Alto	Spill	Animal Wastes	8/18/98	2.4	10,997	10/2/01	38	KS
18	Sixmile Creek	Sioux	Ag Run-off	Animal Wastes	6/15/98	16.1	1,152	8/2/00	26	Ustr, KS
19	West Branch Floyd River	Sioux	Spill	Animal Wastes	7/8/98	5.0	7,978	9/13/01	38	Dstr
20	Deer Creek	Worth	Spill	Fertilizer	4/6/00	6.5	59,087	8/22/01	17	KS, Dstr
					Minimum	1.6	1,152		5	
					Maximum	22.6	586,881		60	
					Median	5.1	30,404		36	

Sampling location abbreviations: KS = Fish Kill Segment; Dstr = Downstream from Kill Segment; Ustr = Upstream from Kill Segment.
*Total number of fish killed is believed to be underestimated.

Methods

Follow-up sites were sampled using the same procedures as the IDNR's wadeable stream biological assessment project (IDNR 1994a, 1994b, 2000a, 2000b). A complete sample includes the following types of data: benthic macroinvertebrate community; fish community; physical habitat; water chemistry. This report only addresses fish community sampling results.

Fish sampling is conducted using DC electrofishing gear designed for wadeable streams. Backpack shockers are used in shallow streams, and a tow-barge shocker is used in deeper, wadeable streams. The objective is to obtain a representative sample of fish species composition and proportional abundance. Fish are collected in a single-pass through a pre-defined length of stream that ranges from 150 – 350 meters, depending on stream size and habitat repetition. Captured fish are identified, counted and examined for physical anomalies before they are released to the stream. Fish that are difficult to identify in the field are preserved and identified later in the laboratory.

Follow-up sampling sites were sampled only once. The intervals between fish kills and sampling ranged from five months to five years (Table 2). The median length of time was 36 months. 17 of the 23 follow-up streams were sampled within the stream segment where dead fish were observed (hereafter referred to as the "kill segment"). The other six follow-up streams were sampled within several miles upstream and/or downstream of the kill segment. Eight streams had follow-up sampling conducted both within the kill segment and outside the kill segment. This subset of streams was used in statistical tests (Wilcoxon rank-sum) that examined differences between kill and non-kill stream segments. Data summarization and statistical analyses were performed using *Statistix® for Windows* (Analytical Software 1996).

Data analysis focused on three aspects of the fish community: abundance, community integrity, and species composition. Fish abundance levels at follow-up sites were compared with estimates of the number of fish killed and fish abundance levels at stream ecoregion reference sites. To standardize for comparisons, the three types of abundance data were converted into the same units (i.e., total fish/500 ft. stream length).

Stream reference sites were used as a basis for assessing fish abundance and community integrity in follow-up streams. Reference sites represent least-disturbed stream conditions that are attainable by similar streams in the same ecoregion. Reference sites and ecoregions are an accepted framework for establishing biological reference conditions (U.S. EPA 1996). Currently, the IDNR has a network of 97 wadeable stream reference sites that are distributed across eight ecoregions. Follow-up stream sites were only evaluated against reference sites from the same ecoregion. According to published guidelines (Barbour et al. 1995; Yoder et al. 1995; U.S. EPA 1996), the reference 25^{th} percentile levels of fish abundance and fish community integrity were applied as impairment thresholds. Follow-up streams with fish abundance or community integrity levels ranking below either of these thresholds were considered impaired (Figure 2).

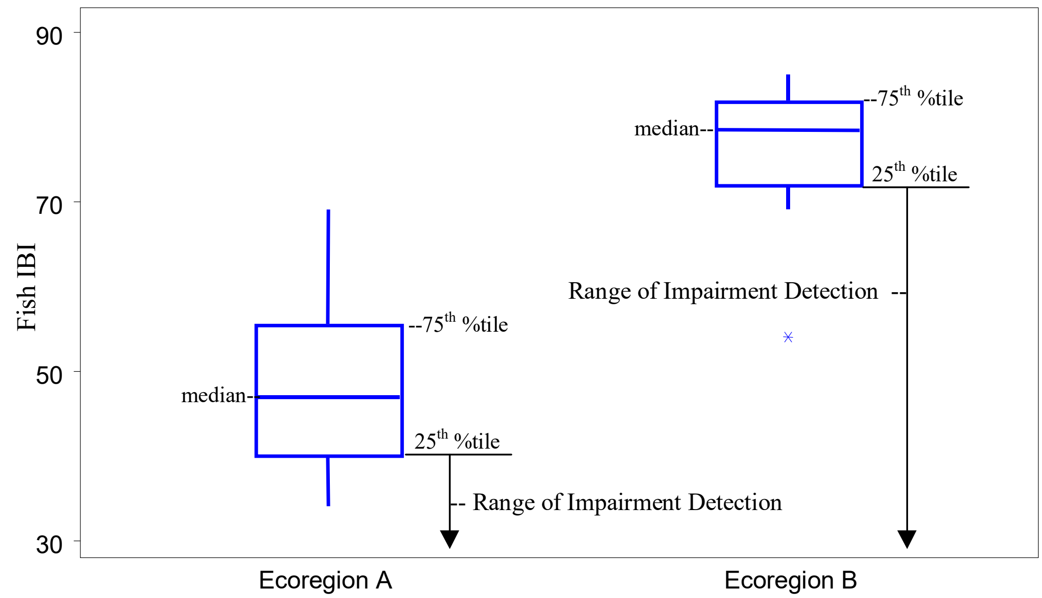


Figure 2. Example illustration using the 25th percentile of Fish Index of Biotic Integrity (FIBI) scores from stream ecoregion reference sites to establish fish community impairment thresholds.

Fish species composition data from fish kill reports and follow-up sample sites were compared in an effort to identify streams that might be missing species that were present when fish kills occurred. The fish kills selected for this study are among the best-documented in the IDNR data base. However, differences in the way data were gathered and recorded made it difficult to accurately and confidently compare fish kill reports with follow-up sampling results. For example, follow-up fish sampling data were typically recorded at the species level. In contrast, fish kill reports often grouped together several fish species of equal monetary value (e.g., chubs, minnows, dace). Ultimately, this made it difficult to compare species lists. Despite limitations, fish kill reports did provide very useful information about fish abundance and species composition that otherwise would not be available.

Results

Fish Abundance

Estimates of the number of fish killed and fish sampling abundance levels varied greatly among follow-up streams (Figure 3; Appendix 1). Fish kill estimates ranged from 7 fish / 500 ft. in Sixmile Creek (Sioux Co.) to 4940 fish / 500 ft. in North Buffalo Creek / Buffalo Creek (Kossuth Co.). Sampled fish abundance ranged from 17 fish / 500 ft. in Sixmile Creek (Sioux Co.) to 2506 fish / 500 ft. in Deer Creek (Worth Co.). Single-pass electrofishing samples represent only a fraction of the total number of fish present. Therefore, it might not be surprising that most kill segment sample sites (65%) had fish abundance levels that were less than corresponding fish kill estimates. Perhaps, it is more surprising that 35% of the kill segment sites had fish abundance levels that exceeded fish kill estimates. Possible explanations include: 1) the number of dead fish was underestimated; 2) the fish kill was not complete; 3) fish abundance was actually lower at the time of the fish kill than during follow-up sampling.

Several factors including obstructions, vegetation, and water clarity, are likely to cause the number of fish killed to be significantly underestimated by investigators (Bill Kalishek, IDNR Fisheries Bureau, personal communication). One study (Labay and Buzan 1999) simulated a fish kill in a small stream and evaluated different methods of estimating fish mortality. All methods resulted in significant underestimation, the amount of which was primarily affected by fish size, number of fish counted, and removal by scavengers. The highest estimate was only 39% of the total number of dead fish released in the stream. Three of the fish kill reports reviewed for this project contained comments indicating the number of fish killed was probably underestimated (denoted by an asterisk in Table 2).

Fish abundance levels at follow-up sample sites were also compared with abundance levels at stream ecoregion reference sites. 26% of the follow-up sampling sites had fish abundance levels that ranked below applicable impairment thresholds (Appendix 1). Four of 15 streams with sampling conducted in a kill segment had fish abundance levels that ranked below reference thresholds:

Fish Kill Segment:	Reference Impairment Threshold (fish/500ft.)	Follow-up. Sample (fish/500ft.)
1) North Buffalo Creek (Site 1, Kossuth Co.)	227	105
2) Sixmile Cr. (Sioux Co.)	396	17
3) Unnamed Trib. of Yellow R. (Allamakee Co.)	325	35
4) Yellow River (Allamakee Co.)	325	309

Each of these streams, except the Unnamed Tributary, also had fish abundance levels that were below reference thresholds at sample sites located outside the kill segment. This would suggest these streams have pervasive water quality and/or habitat problems in their watersheds that contribute to low fish abundance.

A paired, two-sample statistical test (Wilcoxon rank-sum) was performed using fish abundance data from eight streams that were sampled both within the kill segment and outside the kill segment. The length of time between fish kill and follow-up sampling in these streams ranged from 5 to 51 months. As a group, fish abundance levels in kill segments actually ranked higher than fish abundance in segments that were outside the kill segment ($p<0.005$).

After adverse conditions subside, fish respond quickly to fill the void created by a fish kill. Fish have been observed in a stream kill area within a few months of the event. Fish abundance may actually be reduced in adjacent stream reaches as fish migrate into the kill area (Bill Kalishek, IDNR Fisheries Bureau, personal communication). Fish abundance can also be bolstered by increased rates of reproduction and recruitment following a fish kill (Don Bonneau, IDNR Fisheries Bureau, personal communication).

Maximum levels of fish abundance do not equate with optimum stream health. Fish abundance will reach maximum levels in streams that have light to moderate levels of human disturbance and nutrient enrichment (OEPA 1990; Lyons 1992). In Iowa, 1994-1998 stream biocriteria data indicate fish abundance levels are highest at intermediate levels of fish community integrity and habitat quality (Tom Wilton, IDNR Water Quality Bureau, unpublished data).

Pearson correlation coefficients were calculated to examine for relationships between fish abundance, length of stream killed, and number of months after the fish kill (i.e., recovery time). Only the 15 follow-up streams with sampling data from within fish kill segments were included in the analysis. Correlation coefficients were not statistically significant, indicating a lack of linear relationship between fish abundance and miles of stream killed fish (Figure 4), or fish abundance and recovery time (Figure 5).

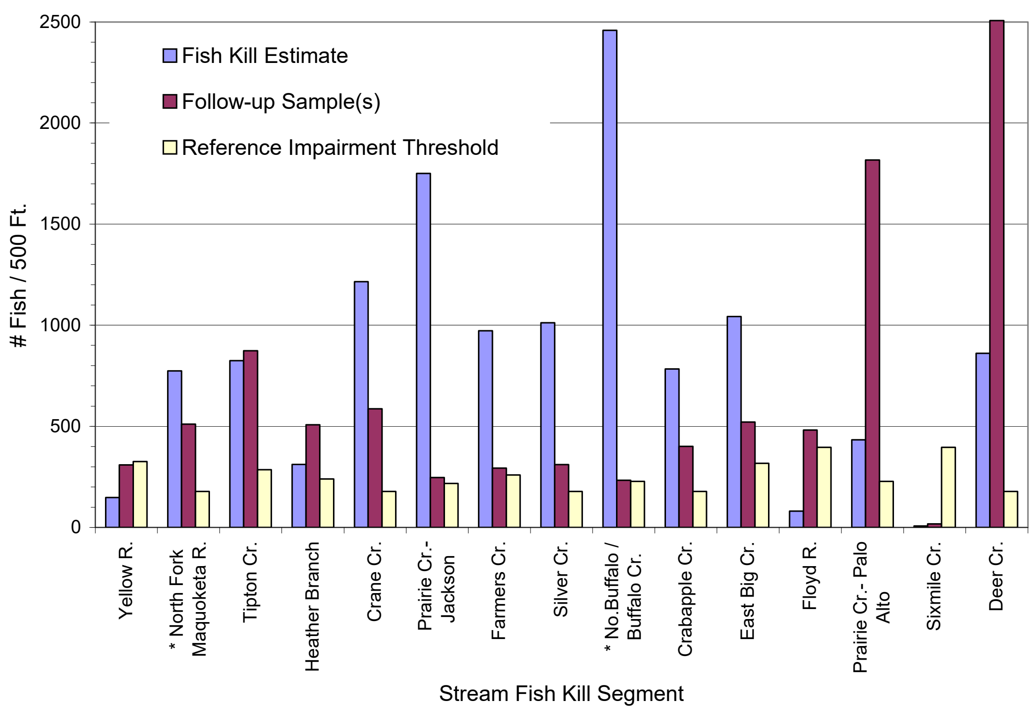


Figure 3. Estimated fish killed and fish abundance levels in 15 stream fish kill segments.
(* Sample fish abundance represents the average of three sample sites.)

Figure 4. Fish Abundance vs. Length of Stream Killed

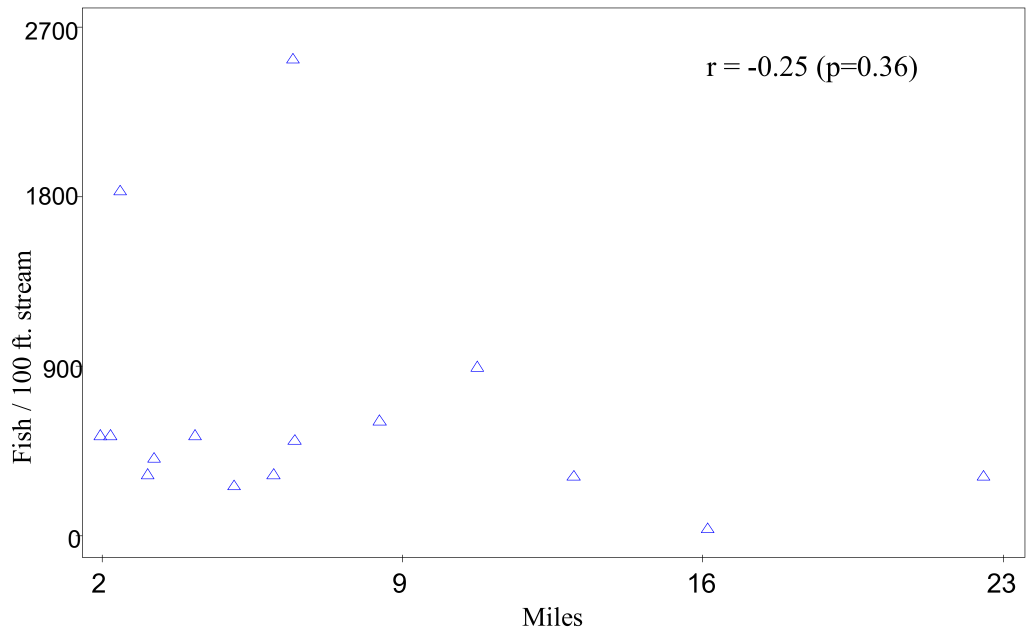
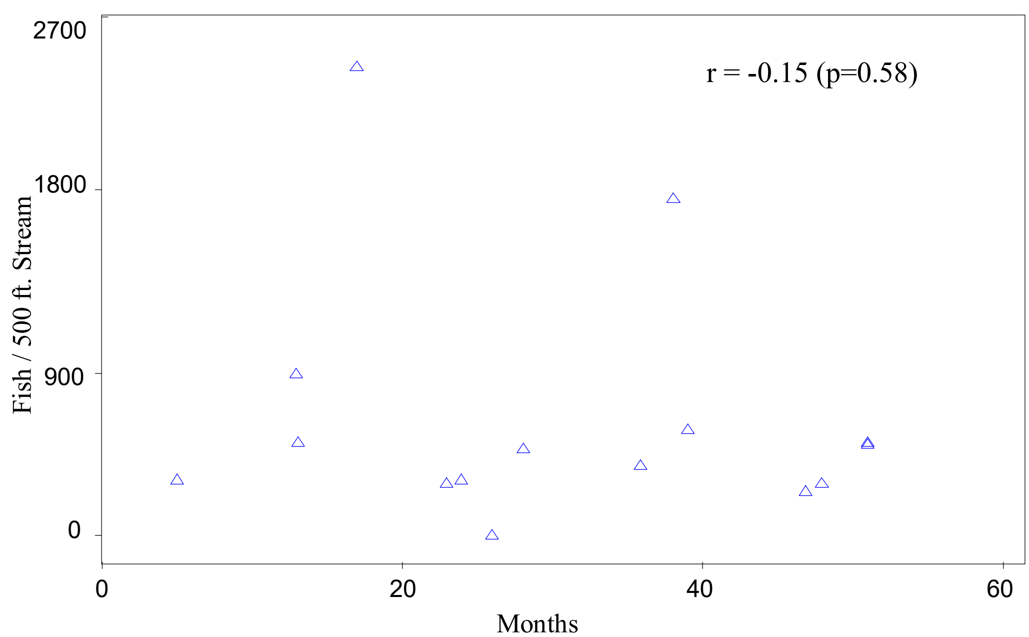


Figure 5. Fish Abundance vs. Months After Fish Kill



Fish Community Integrity

The IDNR uses the Fish Index of Biotic Integrity (FIBI) to assess stream biological health. The FIBI was adapted from several documented IBI's (Karr et al. 1986; Lyons 1992; Hughes et al. 1998) and calibrated using fish sampling data from steam ecoregion reference sites located throughout Iowa. The FIBI combines twelve metrics that quantify several types of fish community attributes including species richness, community balance, trophic (feeding) guild structure, fish abundance and health. The FIBI has a possible scoring range from 0 (worst) to 100 (best). Scoring ranges of the FIBI and qualitative descriptions are described in Appendix 2.

Data from fish kill reports were not detailed enough to allow pre-fish kill FIBI levels to be reconstructed. Therefore, FIBI levels from follow-up sites could only be compared with reference site FIBI levels. The 25th percentile of reference site FIBI scores was used as an impairment threshold to compare against FIBI levels from follow-up sites. FIBI levels that were below the 25^{th} percentile indicated impaired levels of fish community integrity (Figure 2).

Like fish abundance, FIBI levels among follow-up sites were highly variable. FIBI scores ranged from 2 (poor) – 73 (excellent); the median FIBI score was 30 (fair). Approximately one-half of follow-up sampling sites had FIBI scores below applicable reference site thresholds (Appendix 1; Figure 6). Four streams with FIBI scores rated as "poor" appear to have the most severely impacted communities:

1. Buffalo Creek - Kossuth Co.
2. North Buffalo Creek - Kossuth Co.
3. Sixmile Creek - Sioux Co.;
4. Unnamed Tributary of Yellow River - Allamakee Co.

All of these streams except for the Unnamed Tributary of the Yellow River, also had "poor" FIBI ratings at sample sites outside the kill segment. These results suggest there are pervasive water quality and/or habitat problems in the watersheds of these streams that contribute to low levels of fish community integrity.

A paired, two-sample statistical test (Wilcoxon rank-sum) was conducted on FIBI scores from eight streams that each were sampled inside and outside the kill segment. There was no significant difference in FIBI levels between the two groups of sites.

Pearson correlation coefficients were calculated to examine for relationships between FIBI levels, length of stream killed, and number of months after the fish kill (i.e., recovery time). Only the 15 follow-up streams with sampling data from within a fish kill segment were included in the analysis. A relatively weak, but statistically significant inverse relationship was found between FIBI score and length of stream killed (Figure 7). That is, FIBI scores tended to be lower in streams that had long kill segments. The correlation was strongly influenced by two long fish kill segments with low FIBI scores (Sixmile Cr.-Sioux Co.; Buffalo Cr./No. Buffalo Cr.–Kossuth Co.). FIBI levels were not significantly correlated with the recovery time length (Figure 8).

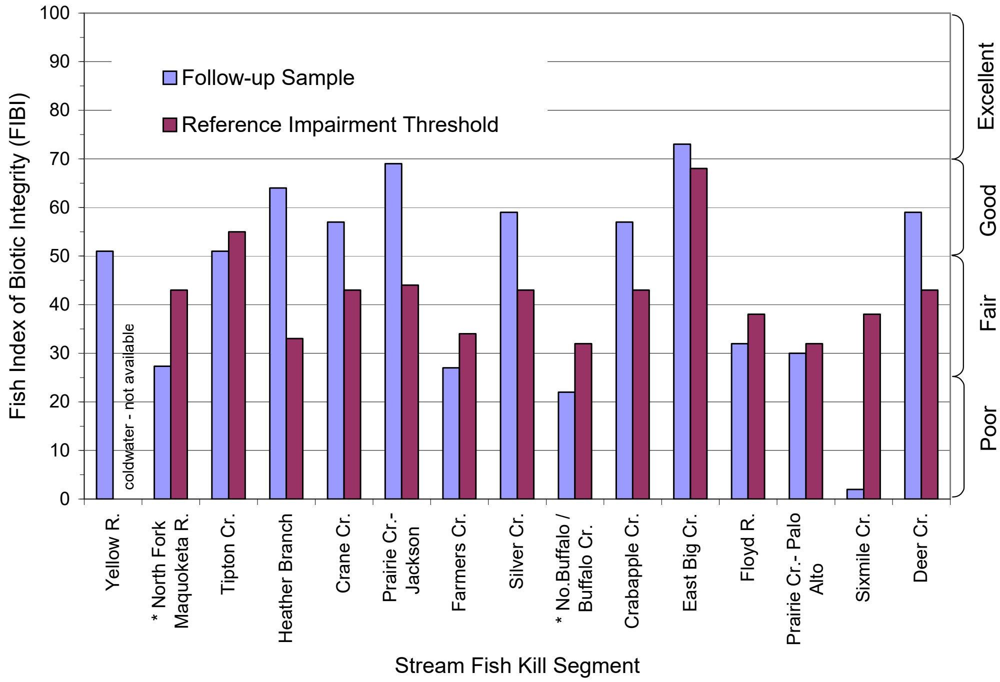


Figure 6. Fish Index of Biotic Integrity (FIBI) levels from 15 follow-up stream fish kill segments and 25th percentile reference FIBI impairment thresholds.
(* FIBI score represents the average of three sample sites.)

Figure 7. Fish IBI vs. Length of Stream Killed

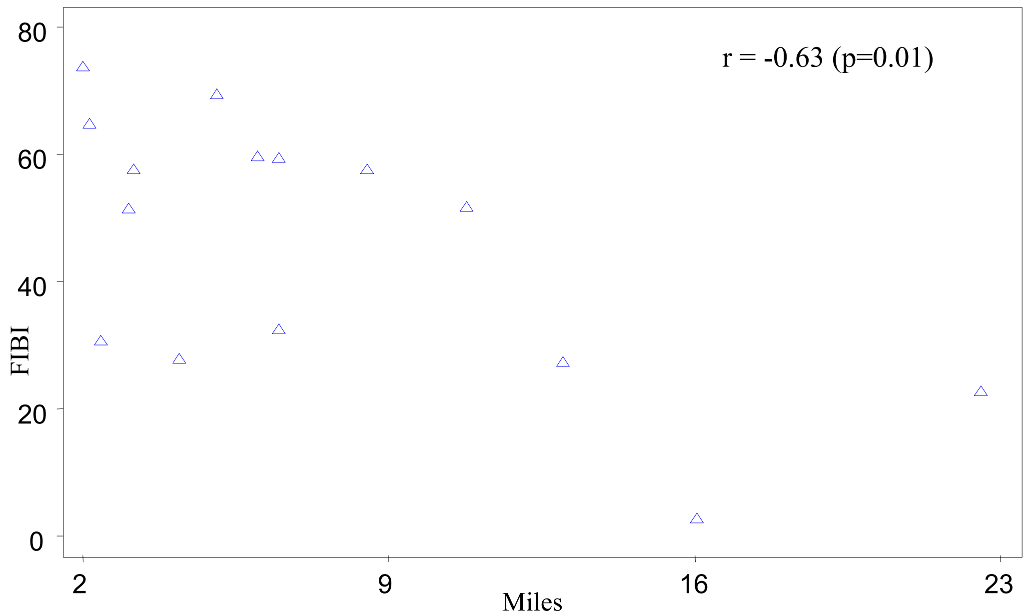
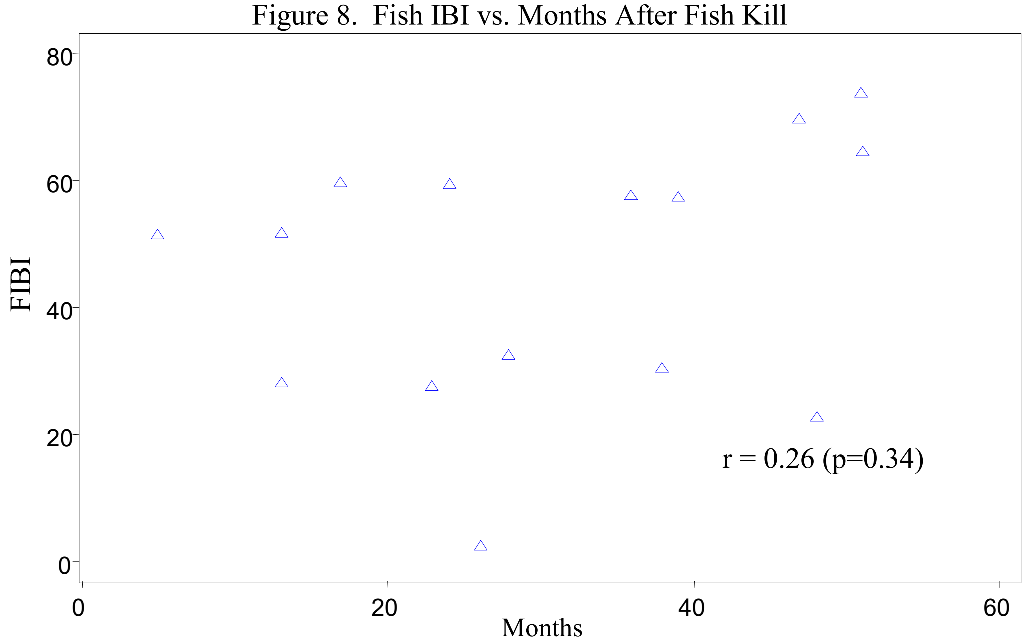


Figure 8. Fish IBI vs. Months After Fish Kill



Species Composition

Several things make it difficult to compare fish presence/absence data from fish kill reports and follow-up sampling. First, there are differences in personnel and sampling procedures. Secondly, as discussed earlier, there are differences in the specificity of fish identifications. There could also be differences in habitat between fish kill assessment sites and follow-up sampling sites that might determine whether a particular species is present or absent. Despite these difficulties, an effort was made to identify follow-up streams that might be missing fish species that were observed during fish kill investigations.

Ten of fifteen streams with sample data from a fish kill segment were missing at least one species or distinct type of fish (Appendix 1). However, eight of these streams also included fish species that were not listed in the fish kill reports. Possible explanations why additional species were found include: 1) the fish kill was incomplete and the species was not affected; 2) the species was missed or grouped with other species during the fish kill investigation; 3) the species migrated into the stream segment after adverse conditions subsided. Typically, fish species that were missing in follow-up sampling are species that were observed in low numbers by fish kill investigators. Obviously, rare species would be more likely to be missed in the limited follow-up sampling that was conducted.

Seven follow-up streams were identified as the most likely to be missing species that were present during fish kills:

Fish Kill Segment (County)	Absent Fish Species
1. No. Fork Maquoketa R. (Dubuque)	carpsucker sp., green sunfish
2. Tipton Creek (Hamilton)	crappie sp., gizzard shad, smallmouth bass, stonecat
3. Sixmile Creek (Sioux)	bullhead sp., goldeye, redhorse sp.
4. No. Buffalo Cr./ Buffalo Cr. (Kossuth)	channel catfish, northern pike
5. Crane Creek (Howard)	carpsucker sp., orangespot sunfish
6. Farmer's Creek (Jackson)	smallmouth bass
7. Floyd River (Sioux)	brassy minnow, orangespot sunfish, redhorse sp.

In several of the streams listed, one or more of the same species also were absent at sample sites located outside the kill segment, which suggests these species are rare or unevenly distributed throughout the stream systems.

The rate at which fish populations colonize a stream area that has been decimated by a natural event or pollution episode is dependent on many factors (Detenback et al. 1992; Ensign et al. 1997). These include but are not limited to: a) existence and proximity of refuge habitat; b) species tendencies to migrate to new habitat; c) life span and age at sexual maturity; d) reproductive strategy. Reported colonization rates among stream fish species range from a few months to several years (Larimore et al. 1958; Ensign et al. 1997). This time frame overlaps the range of recovery times represented by follow-up streams. Therefore, it is certainly possible that some of the missing fish species had not re-established populations in certain fish kill segments by the time follow-up sampling was conducted.

Conclusions

Fish community assessment results from 23 fish kill follow-up streams are summarized in Table 1. As characterized by this study, fish community assessments among follow-up streams range from not impaired to severely impaired. Six streams (26%) showed no evidence of significant impacts from documented fish kills or other sources of pollution in their watersheds. Five streams (22%) had levels of fish abundance and community integrity that were comparable to reference conditions; however, one or more fish species were believed absent from fish kill segments. Fish communities in twelve follow-up streams (52%) were assessed as slightly impaired to severely impaired relative to reference conditions. In streams where unusually low levels of fish abundance and/or community integrity occur, these conditions are believed to be associated with pervasive water quality and/or habitat problems that extend beyond the boundaries of the stream fish kill segments.

The follow-up sampling results obtained in this study provide a limited understanding of recovery from fish kill events, mainly because they represent a snapshot view of stream conditions. To gain a better understanding of the stream recovery process, more detailed and sustained sampling studies are needed. The evaluation of stream recovery was also limited by a lack of baseline (pre-fish kill) sampling data. A strong, sustained biological monitoring program can help provide the foundation needed to measure recovery.

This project only analyzed fish relative abundance and species composition data. Other fisheries indicators, such as biomass (total weight) or age/size composition could provide useful information to evaluate the long-term impacts of fish kills (Don Bonneau, DNR Fisheries Bureau, personal communication). After a fish kill, the distribution of biomass among species, as well as the biomass within age or size classes of the same species are likely to be altered. Large, long-lived fish, for example, probably will not be replaced as quickly as smaller fish that have shorter life cycles. The sampling and assessment methods used in this project are not capable of evaluating these types of impacts.

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Appendix 1. Summary of follow-up fish sampling results: 1999-2001.

Fig. 1 / Tab.2 Ref. No.	Stream Name	County	Location in Relation To Kill Segment (approx. miles)	Dead Fish / 500 ft (Kill Seg.)	Follow-up Sample Fish / 500ft	Reference Site 25th Percentile Fish /500ft	Follow-up FIBI Score	Reference Site FIBI 25th Percentile	Fish Species Absent From Follow-up Sample (comments)
1	Yellow River	Allamakee	Upstream (4.0)	148	305	325	51	59	stonecat (follow-up sample includes many sp. that were not listed in fish kill count)
1	Yellow River	Allamakee	Upstream (1.5)	148	210	325	47	(not applicable –coldwtr. desig.)	
1	Unnamed Trib. Of Yellow R.	Allamakee	Kill Segment	0	35	325	15	(not applicable -general use seg.)	(no fish were observed during fish kill investigation)
1	Yellow River	Allamakee	Kill Segment	148	309	325	51	(not applicable –coldwtr. desig.)	(follow-up sample includes many sp. that were not listed in fish kill count including 1 rainbow trout)
1	Yellow River	Allamakee	Downstream (3.5)	148	350	325	57	(not applicable –coldwtr. desig.)	(follow-up sample includes many sp. that were not listed in fish kill count including brown and rainbow trout)
2	Horton Creek	Bremer	Downstream (1.0)	753	596	178	59	43	
3	Buck Creek	Delaware	Downstream (3.0)	2188	1585	178	60	43	brook stickleback
4	North Fork Maquoketa River	Dubuque	Upstream (2.5)	774	384	178	33	43	carpsucker sp., green sunfish
4	North Fork Maquoketa River	Dubuque	Kill Segment	774	407	317	27	68	carpsucker sp., green sunfish
4	North Fork Maquoketa River	Dubuque	Kill Segment	774	763	178	26	43	carpsucker sp., green sunfish
4	North Fork Maquoketa River	Dubuque	Kill Segment	774	361	178	29	43	carpsucker sp.
5	Tipton Creek	Hamilton/ Hardin	Kill Segment	825	874	285	51	55	stonecat, gizzard shad, smallmouth bass, crappie
5	Tipton Creek	Hamilton/ Hardin	Downstream (11.0)	825	306	285	68	55	crappie, gizzard shad

Fig. 1 / Tab.2 Ref. No.	Stream Name	County	Location In Relation To Kill Segment (approx. miles)	Dead Fish / 500ft (Kill Seg.)	Follow-up Sample Fish / 500ft	Reference Site 25th Percentile Fish /500ft.	Follow-up FIBI Score	Reference Site FIBI 25th Percentile	Fish Species Absent From Follow-up Sample (comments)
6	Heather Branch	Henry	Kill Segment	312	508	239	64	33	bullhead, stonecat (follow-up sample includes many sp. that were not listed in fish kill count)
7	Crane Creek	Howard	Kill Segment	1216	587	178	57	43	orangespot sunfish, carpsucker
7	Crane Creek	Howard	Downstream (7.0)	1216	550	178	64	43	bullhead, carpsucker
8	Prairie Creek	Jackson	Kill Segment	1751	247	217	69	44	green sunfish (follow-up sample includes many sp. that were not listed in fish kill count)
9	Farmers Creek	Jackson	Kill Segment	973	293	259	27	34	smallmouth bass (elevated level of fish disease observed)
10	Silver Creek	Jones	Kill Segment	1012	311	178	59	43	(sp. were not listed in fish kill investig; follow-up sample had good diversity including 8 sensitive sp.)
11	Buffalo Creek	Linn	Upstream (6.0)	87	566	178	66	43	(follow-up sample includes many sp. that were not listed in fish kill count including eight sensitive sp. and sport fish)
11	Buffalo Creek	Linn	Upstream (1.0)	87	320	178	67	43	(follow-up sample includes many sp. that were not listed in fish kill count including eight sensitive sp. and sport fish)
11	Buffalo Creek	Jones	Downstream (7.0)	87	129	178	68	43	(follow-up sample includes many sp. that were not listed in fish kill count including eight sensitive sp. and sport fish)
12	Buffalo Creek	Kossuth	Upstream – confl. (3.5)	2459	96	227	13	32	channel catfish, northern pike, unspecified sunfish
12	North Buffalo Cr.\	Kossuth	Kill Segment	2459	295	227	27	32	channel catfish, northern pike
12	North Buffalo Cr.	Kossuth	Kill Segment	2459	105	227	24	32	channel catfish
12	Buffalo Creek	Kossuth	Kill Segment	2459	299	227	15	32	channel catfish, northern pike
13	Crabapple Creek	Linn	Kill Segment	784	401	178	57	43	stonecat (follow-up sample includes many sp. that were not listed in fish kill count)

Fig. 1 / Tab.2 Ref. No.	Stream Name	County	Location In Relation To Kill Segment (approx. miles)	Dead Fish / 500ft (Kill Seg.)	Follow-up Sample Fish / 500ft	Reference Site 25th Percentile Fish /500ft.	Follow-up FIBI Score	Reference Site FIBI 25th Percentile	Fish Species Absent From Follow-up Sample (comments)
14	Indian Creek	Linn	Upstream (3.5)	1825	822	178	44	43	redhorse, largemouth bass
14	Indian Creek	Linn	Downstream (5.0)	1825	332	178	36	43	largemouth bass, madtoms (follow-up sample includes many sp. that were not listed in fish kill count)
14	Indian Creek	Linn	Downstream (9.0)	1825	151	178	66	43	largemouth bass, madtoms (follow-up sample includes many sp. that were not listed in fish kill count)
15	East Big Creek	Linn	Kill Segment	1043	521	317	73	68	(follow-up sample includes many sp. that were not listed in fish kill count)
15	Big Creek	Linn	Downstream (4.0)	1043	521	178	58	43	(follow-up sample includes many sp. that were not listed in fish kill count)
16	Floyd River	O'Brien	Kill Segment	81	481	396	32	38	redhorse sp. (follow-up sample includes many sp. that were not listed in fish kill count; however, a previous sample (1995) contained orangespot sunfish and brassy minnow which were not present in fish kill count or follow-up sample)
17	Prairie Creek	Palo Alto	Kill Segment	434	1817	227	30	32	(follow-up sample includes many sp. that were not listed in fish kill)
18	Sixmile Creek	Sioux	Upstream (2.5)	7	32	396	10	38	unspecified minnow, bullhead, redhorse, goldeye
18	Sixmile Creek	Sioux	Kill Segment	7	17	396	2	38	bullhead, redhorse, goldeye
19	West Branch Floyd River	Sioux	Downstream (6.5)	151	481	396	22	38	carp, stonecat, stoneroller, golden shiner
20	Deer Creek	Worth	Kill Segment	861	2506	178	59	43	(follow-up sample includes many sp. that were not listed in fish kill count including eight sensitive sp. and sport fish)
20	Deer Creek	Mitchell	Downstream (3.0)	861	885	317	68	68	(follow-up sample includes many sp. that were not listed in fish kill count including ten sensitive sp. and sport fish)

Appendix 2. Fish Index of Biotic Integrity (FIBI) qualitative scoring guidelines.

0-25 (Poor)
Fish abundance is often low. If fish are abundant, the community is dominated by tolerant species and a higher than normal proportion of fish with external physical anomalies is likely to occur. Species richness is low and consists mostly of species that are ubiquitous species that are tolerant of wide-ranging stream water quality and habitat conditions. Sensitive species and habitat specialists are absent or extremely rare.

26-50 (Fair)
Fish abundance is variable, ranging from lower than average numbers to relatively high numbers. If high numbers are present, tolerant species are usually dominant. Sensitive species and habitat specialists are often present, in low numbers and species richness. Fish species richness usually numbers more than ten species. The three most abundant species usually comprise from 50% to 75% of the total number of fish. One to several long-lived fish species and benthic habitat specialists, such as Catostomids (suckers) are present. Top carnivore species are often, but not always present, in low abundance. Species that are able to utilize a wide range of food items including plant, animal and detritus (generalists and omnivores) are usually more common than specialized feeders, such as benthic invertebrate feeding species. Species that require silt-free, rock substrate for spawning or feeding are rare or absent.

51-70 (Good)
Fish (excluding tolerant species) are fairly abundant to very abundant. A moderately high number of fish species are present representing several families. Trophic classes of fish are fairly balanced. Fish with generalized feeding habits are not dominant and specialized feeders and higher trophic levels are well represented. Several long-lived species and benthic invertivore species are present. One to several sensitive species are usually present. Species of intermediate tolerance are the most numerically abundant. Just a few species usually comprise approximately 50% or slightly more of the total number of fish present. Top carnivores are usually present in low numbers. When they are present, often one or more life stages is usually missing. Species that require silt-free, rock substrate for spawning or feeding are present in low proportion of the total number of fish.
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71-100 (Excellent)
Fish (excluding tolerant species) are fairly abundant to abundant. A high level of native species richness is present, including many long-lived, habitat specialist, and sensitive species. Sensitive species and fish species of intermediate pollution tolerance are the most numerically abundant. The three most abundant fish species typically comprise 50% or less of the total number of fish. Top carnivores are represented in appropriate numbers and multiple life stages. Habitat specialists, such as benthic invertivore and simple lithophilous spawning fish are present at near optimal levels. Fish health condition is good; typically less than 1% of the total number of fish exhibit external anomalies associated with disease or stress.