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March 1, 2000

Texas Water Development Board Contract Number 98-483-234

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## EXECUTIVE SUMMARY

Two potential reservoir sites, George Parkhouse I and Marvin Nichols I, were identified by the Texas Water Development Board (1997) on the Sulphur River in Northeast Texas. This study was designed to provide information about the fishes in the affected downstream segments for the Microhabitat Assessment Technique (MAT) (Mathews and Bao 1991) for flow assessment by the Texas Water Development Board. The flow assessment is focused on the relationships between physical habitat availability and use of the habitats by fish during targeted flow regimes and seasons. Published studies of fish surveys of the Sulphur River can be found in Bonn and Inman (1955), Carroll et al. (1977), and Turner (1978). A comprehensive list of fish species known from museum records for the Sulphur River basin can be found in Travis et al. (1994).

The goals of this study were: 1) assess and map habitats, 2) measure ambient water quality parameters, 3) report the abundance of fishes of each species collected in each habitat at each of three sample sites for each reservoir site, 4) evaluate the relative health of sites to each other, using a modified Index of Biological Integrity (Karr et al. 1986) that we developed for comparisons among sampled reaches, and 5) identify instream habitat types based on relative abundance of fishes across all hydraulic-structural microhabitats in sampled reaches.

Comments on the draft final report by reviewers were incorporated in the main body of this final report. While the draft final report was in review, we had the opportunity on January 22-24, 2000 to obtain a sample for the winter low-flow range. This allowed us to make more extensive measurements of depth and velocity in those hydraulic habitats (riffles and runs) that were less abundant at other flow ranges. The results and interpretation of those data are presented in the Appendix.

## ACKNOWLEDGEMENTS

We thank Nikkoal J. Dictson, Jonathan B. Goff, Brian D. Healy, E. Todd Lantz, R. Trent Martin, Michael S. Robertson, Stephen G. Sutton, Diann A. Stroman and Perry F. Trial for assistance in the field. We also thank staff from the Texas Water Development Board: Ray Mathews and Gary Powell for guidance and Mark Wentzel for providing flow ranges for sampling and assistance with discharge monitoring. Finally, special thanks are extended to Jack Williams, Texas Department of Transportation, for help with road access from the Hwy 37 bridge.

## INTRODUCTION

Two potential reservoir sites, George Parkhouse I and Marvin Nichols I, were identified by the Texas Water Development Board (1997) on the Sulphur River in Northeast Texas. This study was designed to provide information about the fishes in the affected downstream segments for the Microhabitat Assessment Technique (MAT) (Mathews and Bao 1991) for flow assessment by the Texas Water Development Board. The flow assessment is focused on the relationships between physical habitat availability and use of the habitats by fish during targeted flow regimes and seasons. Published studies of fish surveys of the Sulphur River can be found in Bonn and Inman (1955), Carroll et al. (1977), and Turner (1978). A comprehensive list of fish species known from museum records for the Sulphur River basin can be found in Turner et al. (1994).

The goals of this study were to: 1) assess and map habitats, 2) measure ambient water quality parameters, 3) report the number of each fish species collected in each habitat at each of three sample sites for each reservoir site, 4) assess stream health using an Index of Biological Integrity (Karr et al. 1986), and 5) identify habitat groups based on fish species.

## STUDY AREA

The Sulphur River, located in Northeast Texas, begins as three forks: the North Sulphur River, the Middle Sulphur River, and the South Sulphur River. The North and South Sulphur rivers join to form the mainstem Sulphur River. Streamflow is generally from West to East and drains approximately 3600 square miles (Bonn and Inman 1955). The Sulphur joins the Red River in Arkansas. The upper 60% of the basin is in the Blackland Prairie region and contains clay and semipermeable soils. Sampling sites were in the lower portion of this region. Landuse is primarily rangeland and crop agriculture. The lower 40% of the basin is in the East Texas Timberlands region and contains sandy soils. Landuse in the lower area is primarily forest and commercial wood products. There are two multi-purpose reservoirs operated by the U.S. Army Corps of Engineers; Jim Chapman Lake (formerly known as Cooper Lake) on the South Sulphur River and Wright-Patman Lake on the mainstem Sulphur River near Texarkana, TX.

Three sites were selected for fish and habitat sampling for the proposed George Parkhouse I Reservoir. These sites were generally straight with steep banks and levees due to historic channelization by the U.S. Army Corps of Engineers, U.S. Natural Resources Conservation Service, and private individuals (E. Kangas, U.S. Army Corps of Engineers - Ft. Worth, Texas, personal communication). Site 1 was located on the South Sulphur River with a length of approximately 182 m and a representative width of 15 m. Sites 2 and 3 were on the mainstem Sulphur River. Site 2 was approximately 536 m long with a representative width of 38 m. Site 3 was approximately 850 m long with a representative width of 30 m. A supplemental site (7) was sampled on the North Sulphur River. Site 7 was approximately 600 m long with a representative width of 27 m. Access to sites 1-3 and 7 was from the streambank at the State Hwy 37 bridge approximately 3.2 km (2 miles) north of Hagansport, TX.

Three sites on the mainstem Sulphur River were selected for fish and habitat sampling for the proposed Marvin Nichols I Reservoir. These sites had steep banks with meanders and had not been channelized. All three sites were on the mainstem Sulphur River. Site 4 was approximately 228 m long with a representative width of 20 m. Site 5 was approximately 200 m long with a representative width of 20 m. Site 6 was approximately 161 m long with a representative width of 15 m. Access to sites 4-6 was from the boatramp at the U.S. 259 bridge approximately 1.6 km (1 mile) north of Insterstate 30.

## METHODS AND MATERIALS

### Seasons and flows

Two seasonal intervals were selected for sampling; a summer season (April-October) with lower flows and warmer water temperatures, and a winter season (November-March) with higher flows and cooler water temperatures. To distribute fish community assessment across the normal to low flow conditions in the river, flow ranges based on percentile flows were provided by the Texas Water Development Board. For each proposed reservoir, sampling was targeted for the following three flow regimes in each season: 50th-30th percentile (high), 30th-15th percentile (middle), and < 15th percentile (low). Summer flow ranges were 500-64 cfs high, 64-16 cfs middle, and < 16 cfs low. Winter season flow ranges were 1190-340 cfs high, 340-33 cfs middle, and < 33 cfs low.

### Habitat assessment and identification

Latitude and longitude for each site was either estimated from U.S. Geological Survey (USGS) topographic maps (7.5 min series, 1:24000) or recorded using a Global Positioning System (GPS) (Table 1). Maps were sketched and representative habitats were photographed for each site during the study. Twenty habitat types were distinguished based on their occurrence at least once during the study period. A habitat type was characterized by a mesohabitat based on hydraulic characteristics and a microhabitat based on physical characteristics. Mesohabitats included riffles, runs, pools, and backwaters. Microhabitats included bank snags, channel snags, snag complexes, undercut banks, rootwads, debris dams, edge, vegetation, and tree. Three additional microhabitat categories were created: edge, vegetation, and tree. Edge microhabitat was bare streambank. Vegetation microhabitat was riparian plants such as willow (*Calex* sp.) or tree branches which, when submerged at high flows, created complex habitat. Tree microhabitat was submerged, live tree trunks. Typically, only woody habitats that appeared relatively permanent were selected for sampling.

### Fish collection

All representative habitat types present at a site were sampled for fish, using a variety of gear, including seines, gillnets, and electrofishers. All sampling was conducted during daylight hours. Straight seines (5-mm mesh) were 1.2 m deep and 2.4 m, 3.0 m, and 6.1 m long as appropriate for the habitat sampled. Seining effort continued until no additional species were collected in three consecutive hauls and no new habitats were encountered. One 38.1-m long experimental gillnet that consisted of five panels each 7.6 m long x 1.8 m deep with 2.5, 3.8, 5.1, 6.3, and 7.6-cm bar mesh, was set perpendicular to the current in pools. Gillnets were allowed to fish up to 8 hours while other work was being performed.

Table 1. Latitude and longitude coordinates for sampling sites on the Sulphur River.

| Site | River | Upstream boundary | Downstream boundary |
|---|---|---|---|
| 1 | South Sulphur | N 33E 23' 41.39" | N 33E 23' 40.68" |
| | | W 95E 22' 16.68" | W 95E 22' 09.63" |
| 2 | Sulphur | N 33E 23' 14.93" | N 33E 23' 07.15" |
| | | W 95E 20 56.99" | W 95E 20' 38.33" |
| 3 | Sulphur | N 33E 23' 03.33" | N 33E 22' 45.31" |
| | | W 95E 19' 47.41" | W 95E 19' 22.32" |
| 4 | Sulphur | N 33E 19' 00.81" | N 33E 19' 02.22" |
| | | W 94E 44' 04.34" | W 94E 43' 55.61" |
| 5[a] | Sulphur | N 33E 18' 28" | N 33E 18' 29" |
| | | W 94E 43' 28" | W 94E 43' 27" |
| 6 | Sulphur | N 33E 18' 29.25" | N 33E18' 24.02" |
| | | W 94E 43' 15.00" | W 94E 43' 14.23" |
| 7[a] | North Sulphur | N 33E 25' 18" | N 33E 25' 13" |
| | | W 95E 23' 46" | W 95E 23' 27" |

[a]Estimated.

Two electrofishing units were used; a Coffelt Mark 10 backpack unit powered by a Honda 350EX generator and a 4.9-m aluminum jon-boat powered by a 15 horsepower outboard motor. The boat used for electrofishing had a Wisconsin ring attached to a fixed boom, a 5000 watt Honda generator, and a Smith-Root Model 1.5-KVA control box. Direct current (DC) output on each unit was set at 200-350 V and 5-8 A depending on conductivity. Because depth was primarily greater than 2 m at most sites, boat electrofishing was the primary sampling method and was typically conducted in an upstream direction. Individual habitats (at least 5-m apart) were electrofished separately for habitat-specific data collection.

Fishes greater than 50 mm were identified, weighed, (nearest 1 g), measured for total length (nearest 1 mm), and released in the field. Small and uncommon fishes were preserved in 10% formalin and returned to the lab for identification and enumeration. At least one specimen of each fish species (except spotted gar, bigmouth buffalo, and smallmouth buffalo) was preserved in 70% EtOH and deposited in the Texas Cooperative Wildlife Collection (TCWC) at Texas A&M University.

**Physicochemical parameters**

Dissolved oxygen, temperature, conductivity, and percent oxygen saturation were measured at the water surface with a YSI Model 85 multiparameter meter at each study site for all collection dates. pH was measured at each site using a Hach digital probe or pH paper. Mean daily discharges (cfs) were obtained from USGS gage number 07343200 (Sulphur River Nr Talco, TX). A representative depth and velocity measurement was taken at each habitat type at the time it was sampled. Depth to the nearest 0.1 m was measured using either a Hondex digital depth sounder or a graduated wading rod. Velocity was measured at 0.6 depth with a Marsh-McBirney Model 2000 digital flowmeter.

**Index of Biological Integrity**

Karr et al. (1986) proposed an Index of Biological Integrity (IBI) that used fish community attributes to assess stream health. Because watershed characteristics and fish communities from the Sulphur River differ from those for midwestern headwater streams originally used by Karr et al. (1986), we modified the metrics. Of the 12 original metrics, three were omitted and three were modified. The modifications generally followed the format of those developed for the Brazos-Navasota watershed (Texas) reported by Winemiller and Gelwick (1999). Original metric 10, number of individuals in sample, was omitted because this data was sensitive to the species by area relationship and the number of samples. Metric 11, proportion of individuals as hybrids, was omitted due to the inherent difficulty in accurately identifying hybrids (Karr et al. 1986). Metric 12, proportion of individuals with disease or other anomaly, was omitted because few reliable data exist for setting criteria for this metric (Karr et al. 1986). For metric 2, number of darter species, freckled madtom (*Noturus nocturnus*) was added because it fills a similar trophic niche. For metric 6, proportion of individuals as green sunfish, mosquitofish (*Gambusia affinis*) was substituted because they are a tolerant, rapid colonizer and also because green sunfish were uncommon in collections. For metric 8, proportion of individuals as insectivorous cyprinids, invertivores of all families were substituted again because cyprinid species were less common overall. Assignment of trophic status and intolerance/tolerance was based on Linam and Kleinsasser (1993). Because data for suitable reference streams comparable to the Sulphur River were not yet available (R. Kleinsasser, Texas Parks and Wildlife Department - Austin, Texas, personal communication) and because only seven sites were sampled at restricted locations on the river, ranks were assigned to each metric for each site rather than a true IBI score that is normally relativized to a suite of least disturbed reference sites for such evaluations (Karr et al. 1986). Thus, sites were evaluated relative to only each other.

**Habitat groups and indicator species**

Because fish species collected in low abundances cannot be characterized accurately, species making up < 1% of the total individuals of all species collected were omitted from this analysis. Habitats used in the analysis were those in which at least one species had been collected. Data were standardized by relativizing abundance across species for each habitat type and cluster analysis was run using the software package PC-ORD (McCune and Mefford 1997). Thus, habitats were clustered based on species relative abundances. Indicator species analysis (Dufrêne and Legendre 1997) provided by PC-ORD was used to determine what species could be indicators of the habitat groups identified in the cluster analysis.

## RESULTS AND CONCLUSIONS

**Physicochemical**

Mean daily discharges varied during the study period with a low of 7.1 cfs and a high of 9040 cfs (Figure 1). Ambient water quality parameters for the summer season are given in Table 2 and for the winter season in Table 3. For all sites, conductivity ranged from 50.4-811.1 µS/cm and pH ranged from 7.0 to 8.4. Dissolved oxygen ranged from 3.55-14.62 mg/L and the corresponding percent oxygen saturation ranged from 49.9-197.6. Water temperature ranged from 25.4-34.1 °C. Part of the variation in oxygen and temperature measurements depended on cloud cover and time of day during sampling. Depths ranged from 0.1-4.3 m and velocities ranged from 0-0.54 m/s at the habitats (Tables 4-10). Generally, velocities associated with pool mesohabitats were slower (< 0.2 m/s) than those associated with riffle and run mesohabitats (> 0.3 m/s). The velocity measurements in this report reflect the value at the time for a representative example of a habitat type in which fish were collected during a particular flow condition and season. This should be taken into consideration when interpreting our results and the flow models developed at a later time by the Texas Water Development Board.

Sketch maps of sample sites are given in Figures 2, 5, 24, 46, 59, 73, 82 and accompanied by photographs (Figures 3-4, 6-23, 25-45, 47-58, 60-72, 74-81, 83-92). The alpha-numeric code for each habitat type identified (Table 11) during fish collections includes a letter that identifies the individual microhabitat at the site and a number for the habitat type code.

**Fish species and microhabitat utilization**

Table 11 lists the species and habitat codes used in bubble graphs of fish species collected by habitat type (Figures 93-127). Figures 93-119 are individual bubble graphs for a site sampled during a particular season and a particular flow range. Figures 120-122 are composite bubble graphs for George Parkhouse I and Figures 123-125 are composite bubble graphs for Marvin Nichols I. Figures 126-127 are composite bubble graphs for both reservoirs based on season. Codes, for species names and habitat types, are indicated on the axes. A total of 2584 individuals representing 36 species and 12 families were collected from 20 habitat types. Red shiners were most abundant (48%) followed by Mississippi silvery minnows (12%) and mosquitofish (6%). We note that for two large-river fish groups (gar, Lepisosteidae, and buffalo fishes, *Ictiobus*), all species known to occur in Texas were included in our collections.

## Index of Biological Integrity

Results for the 10 IBI metrics for the seven sites are given in Table 12. The range of the possible total value for IBI metrics was that for the possible sum of the ranks (10-70). Site 3 had the highest sum of the ranks (56.5) and therefore the highest percentage (81%) of the maximum score. Sites 7, 4, and 6 had the lowest sums of the ranks and therefore the lowest percentages of the maximum score (47%, 46%, and 40% respectively).

The mean of scores for the upstream sites 1, 2, and 3 (within the channelized area to be influenced by George Parkhouse I) was 69.3% (63.8% if site 7 was included in that average). The mean of scores for the downstream sites 4, 5, and 6 (to be influenced by Marvin Nichols I) was 48.3%. This is an interesting result given that the habitat of the upstream sites would appear to be strongly degraded by channelization. Thus, it may be that the metrics which were most sensitive to generally recognized biological criteria (e.g., number of sucker species, percentage of tolerant species) were not necessarily correlated to those of habitat degredation. This may also be a consequence of having no established reference sites at this time. However, the difference between scores for the two groups of sites was not statistically significant (ANOVA, $F = 0.25$, $P = 0.64$). Therefore, results of the IBI analysis should be interpreted as only a relative index within the Sulphur River until more comprehensive IBI assessments can be done that include reference sites for large rivers in this region of Texas.

## Habitat groups and fish species indicators

The cluster analysis distinguished 4 habitat groups with which more than 1 species was associated. Riffle-channel snag habitat contained only red shiner and occurred only once so indicator values could not be evaluated. Table 13 gives indicator values for fish species associated with habitat groups. Group 4 had species with the highest indicator values and contained some of the most structurally complex habitats, i.e., snag complex and vegetation. Freshwater drum and centrarchids (bluegill, orangespotted sunfish, longear sunfish, and white crappie) dominated this group. This is reasonable given that sunfish (Centrarchidae) are characteristically associated with slower water velocities and complex structure.

Group 2 consisted of pool-rootwad, backwater, and backwater-bank snag habitats and contained the second largest number of species occurrences. Backwater habitats, having lower velocities, are refuges for many species of fish and are often nursery areas. Group 1 had few species associated with it except red shiners which were dominant in the run mesohabitat that occurred only once and only at site 4. Bank snags, channel snags, and trees are relatively simple habitats structurally compared to rootwads, snag complexes, and vegetation.

Although distinguished in the cluster analysis, group 3 (riffle-snag complex, riffle-debris dam, riffle-edge) was poorly differentiated by fish occurrences for any species. This is likely in large part due to the low occurrence of these habitat types across the sample sites. The fast velocities and complex hydraulics found in habitat types in this group likely limit their use primarily to that of corridors, or as delivery systems for drifting invertebrate prey for invertivores stationed downstream of them. Generally, more species were associated with structurally complex habitats with slower velocities. This is reasonable given the predominance of pool mesohabitat in the Sulphur River.

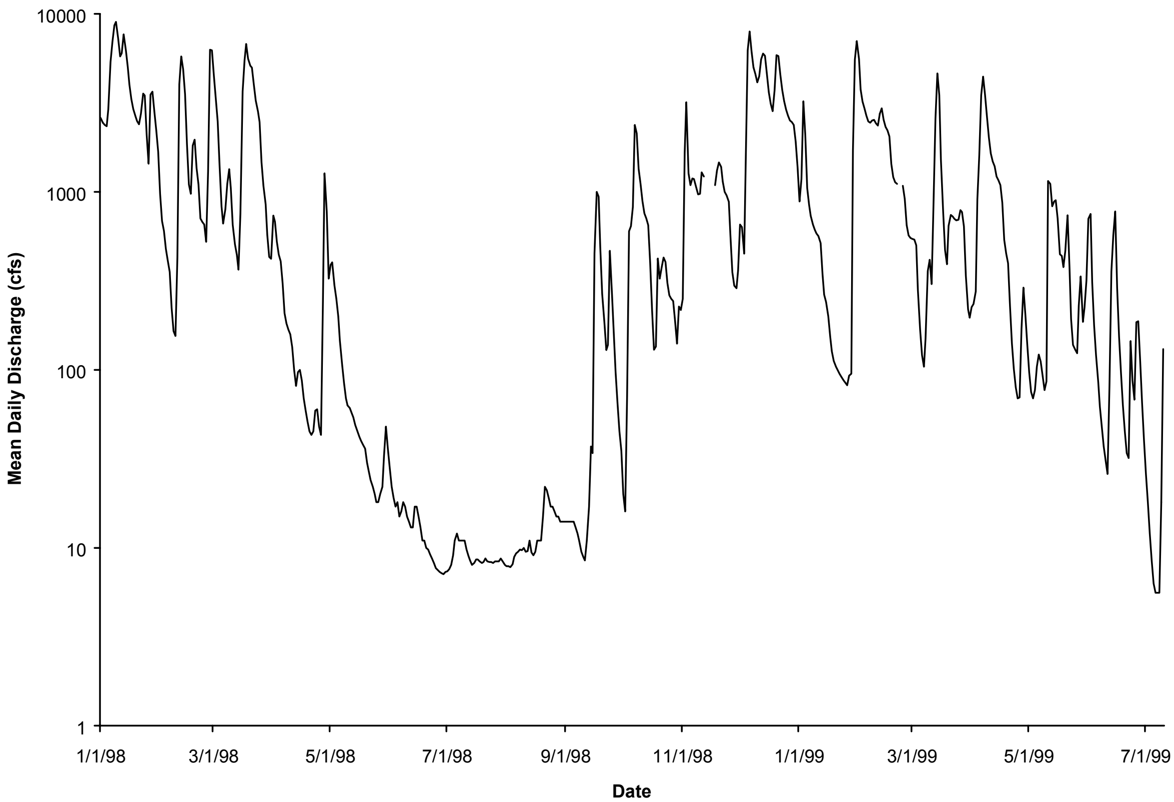


Figure 1. Mean daily discharge recorded during the study period, 1 January 1998 – 1 July 1999, at USGS gauge 07343200 on the Sulphur River.

Table 2. Physicochemical parameters for sites in the Sulphur River during the summer season, April - October.

| Site | Date | Time (24 hr) | Flow (cfs) | pH | Temperature (EC) | Conductivity (ΦS/cm) | DO (mg/L) | % $O_2$ Saturation |
|---|---|---|---|---|---|---|---|---|
| 1 | 30 July 1998 | 1045-1645[a] | 8.6-8.6 | 8.2 | N/A[b] | N/A[b] | N/A[b] | N/A[b] |
| | 9 June 1999 | 1436-1731 | 35-35 | 7.0 | 32.9 | 533.0 | 10.43 | 155.8 |
| | 17 June 1999 | 1012-1154 | 158-153 | 7.0 | 27.5 | 353.8 | 3.55 | 20.1 |
| 2 | 31 July 1998 | 1002-1645 | 8.1-8.1 | 8.0 | 31.1 | 160.0 | 3.95 | 52.8 |
| | 10 June 1999 | 1345-1542 | 30-28 | 7.0 | 32.6 | 541.0 | 10.32 | 140.1 |
| | 17 June 1999 | 0938-1515 | 160-143 | 7.0 | 29.9 | 380.3 | 8.42 | 100.3 |
| 3 | 31 July 1998 | 0926-1440 | 8.6-8.1 | 8.2 | 31.4 | 50.4 | 4.25 | 57.1 |
| | 10 June 1999 | 0942-1629 | 30-28 | 7.0 | 31.8 | 504.0 | 14.62 | 197.6 |
| | 18 June 1999 | 0945-1350 | 100-92 | 7.0 | 28.0 | 373.9 | 5.15 | 71.7 |
| 4 | 1 Aug 1998 | 0854-1306 | 8.1-8.1 | 8.2 | 30.5 | 811.1 | 4.10 | 66.3 |
| | 25 May 1999 | 1049-1415 | 130-132 | 7.0 | 25.4 | 281.4 | 6.45 | 74.1 |
| | 9 June 1999 | 0821-1043 | 38-38 | 7.0 | 29.2 | 389.1 | 5.22 | 66.2 |

Table 2. Continued.

| Site | Date | Time (24 hr) | Flow (cfs) | pH | Temperature (EC) | Conductivity (ΦS/cm) | DO (mg/L) | % $O_2$ Saturation |
|---|---|---|---|---|---|---|---|---|
| 5 | 1 Aug 1998 | 1442-1632 | 8.1-8.1 | 8.4 | 34.1 | 874.0 | 5.80 | 83.4 |
| | 8 June 1999 | 1520-1740 | 46-43 | 7.0 | 30.2 | 385.4 | 5.18 | 63.1 |
| | 16 June 1999 | 1530-1855 | 240-221 | 7.0 | 27.1 | 340.5 | 5.32 | 66.1 |
| 6 | 2 Aug 1998 | 0847-1220 | 8.1-8.1 | 8.2 | 30.3 | 816.0 | 3.7 | 49.3 |
| | 25 May 1999 | 1009-1737 | 127-132 | 7.0 | 26.0 | 285.4 | 6.54 | 80.6 |
| | 8 June 1999 | 1257-1509 | 48-46 | 7.0 | 30.1 | 381.3 | 5.14 | 67.7 |
| 7 | 19 June 1999 | 1007-1250 | 6.9-6.9 | 7.0 | 29.4 | 468.4 | 10.20 | 132.8 |

[a]Estimated.
[b]Not measured due to instrument malfunction.

Table 3. Physicochemical parameters for sites in the Sulphur River during the winter season, November - March.

| Site | Date | Time (24 hr) | Flow (cfs) | pH | Temperature (EC) | Conductivity (ΦS/cm) | DO (mg/L) | % $O_2$ Saturation |
|---|---|---|---|---|---|---|---|---|
| 1 | 26 Mar 1999 | 1120-1736 | 800-819 | 7.0 | 13.2 | 131.2 | 10.65 | 100.5 |
| 2 | 27 Mar 1999 | 0958-1307 | 780-768 | 7.0 | 13.3 | 166.4 | 9.45 | 92.1 |
| 3 | 27 Mar 1999 | 1144-1717 | 768-760 | 7.0 | 13.5 | 161.8 | 9.61 | 91.8 |
| 4 | 22 Nov 1998 | 0589-1604 | 1170-1100 | 7.9 | 14.4 | 179.0 | 8.61 | 83.2 |
| | 14 Jan 1999 | 0815-1045[a] | 267-262 | 7.0 | 7.3 | 172.8 | 11.04 | 92.6 |
| 5 | 23 Nov 1998 | 0822-1326 | 1010-994 | 8.1 | 14.4 | 181.8 | 8.96 | 82.0 |
| | 13 Jan 1999 | 0913-1524 | 350-319 | 7.2 | 7.6 | 164.6 | 11.40 | 246.4 |
| 6 | 14 Jan 1999 | 1113-1548 | 264-258 | 7.0 | 7.0 | 169.2 | 11.62 | 93.4 |

[a]Estimated.

Table 4. Depths (m) and velocities (m/s) at site 1 habitats in the Sulphur River during winter and summer sampling seasons, 1998-1999. "-" indicates a habitat that was absent from the site during sampling. "N/M" indicates no measurement.

| | Summer season | | | | | | Winter season | |
|---|---|---|---|---|---|---|---|---|
| | High flow range | | Middle flow range | | Low flow range | | High flow range | |
| Habitat | Depth | Velocity | Depth | Velocity | Depth | Velocity | Depth | Velocity |
| Riffle | - | - | - | - | - | - | - | - |
| Riffle - bank snag | - | - | - | - | - | - | - | - |
| Riffle - channel snag | - | - | - | - | 0.5 | 0.45 | - | - |
| Riffle - snag complex | - | - | - | - | - | - | - | - |
| Riffle - debris dam | - | - | - | - | - | - | - | - |
| Riffle - edge | - | - | - | - | - | - | - | - |
| Run | - | - | - | - | - | - | - | - |
| Pool | 1.5 | 0.03 | 1.1 | 0 | - | - | 2.8 | 0.54 |
| Pool - bank snag | 0.9 | 0.01 | 1.5 | 0 | 0.8 | 0.01 | - | - |
| Pool - channel snag | - | - | 0.6 | 0 | 1.2 | 0.06 | - | - |
| Pool - snag complex | - | - | - | - | 0.2 | 0 | - | - |
| Pool - undercut bank | - | - | - | - | - | - | - | - |
| Pool - rootwad | 1.0 | 0.04 | 0.8 | 0 | 0.3 | 0.01 | - | - |
| Pool - debris dam | - | - | - | - | - | - | - | - |
| Pool - edge | 0.4 | 0.03 | 0.5 | 0 | - | - | 1.4 | 0.19 |
| Pool - vegetation | 0.6 | 0.03 | - | - | - | - | 0.7 | 0.10 |
| Pool - tree | - | - | - | - | - | - | 2.0 | 0.35 |
| Backwater | - | - | - | - | N/M | N/M | - | - |
| Backwater - bank snag | - | - | - | - | - | - | - | - |
| Backwater - channel snag | - | - | - | - | - | - | - | - |

Table 5. Depths (m) and velocities (m/s) at site 2 habitats in the Sulphur River during winter and summer sampling seasons, 1998-1999. "-" indicates a habitat that was absent from the site during sampling. "N/M" indicates no measurement.

| | Summer season | | | | | | Winter season | |
|---|---|---|---|---|---|---|---|---|
| | High flow range | | Middle flow range | | Low flow range | | High flow range | |
| Habitat | Depth | Velocity | Depth | Velocity | Depth | Velocity | Depth | Velocity |
| Riffle | - | - | - | - | - | - | - | - |
| Riffle - bank snag | - | - | - | - | - | - | - | - |
| Riffle - channel snag | - | - | - | - | - | - | - | - |
| Riffle - snag complex | - | - | - | - | - | - | - | - |
| Riffle - debris dam | - | - | - | - | - | - | - | - |
| Riffle - edge | - | - | - | - | - | - | - | - |
| Run | - | - | - | - | - | - | - | - |
| Pool | N/M | N/M | N/M | N/M | N/M | N/M | N/M | N/M |
| Pool - bank snag | 1.8 | 0.03 | 1.9 | 0.01 | - | - | - | - |
| Pool - channel snag | 1.7 | 0.04 | 1.6 | 0.02 | - | - | - | - |
| Pool - snag complex | - | - | - | - | - | - | - | - |
| Pool - undercut bank | 0.6 | 0.02 | - | - | - | - | - | - |
| Pool - rootwad | 2.1 | 0.02 | 1.4 | 0.02 | 0.6 | 0.01 | 0.1 | 0.01 |
| Pool - debris dam | - | - | - | - | - | - | - | - |
| Pool - edge | 0.5 | 0.02 | 1.0 | 0 | 0.9 | 0.01 | 0.8 | 0.06 |
| Pool - vegetation | - | - | - | - | - | - | 1.4 | 0.06 |
| Pool - tree | - | - | - | - | - | - | - | - |
| Backwater | - | - | - | - | - | - | - | - |
| Backwater - bank snag | - | - | - | - | - | - | - | - |
| Backwater - channel snag | - | - | - | - | - | - | - | - |

Table 6. Depths (m) and velocities (m/s) at site 3 habitats in the Sulphur River during winter and summer sampling seasons, 1998-1999. "-" indicates a habitat that was absent from the site during sampling. "N/M" indicates no measurement.

| | Summer season | | | | | | Winter season | |
|---|---|---|---|---|---|---|---|---|
| | High flow range | | Middle flow range | | Low flow range | | High flow range | |
| Habitat | Depth | Velocity | Depth | Velocity | Depth | Velocity | Depth | Velocity |
| Riffle | - | - | - | - | - | - | - | - |
| Riffle - bank snag | - | - | - | - | - | - | - | - |
| Riffle - channel snag | - | - | - | - | - | - | - | - |
| Riffle - snag complex | - | - | - | - | - | - | - | - |
| Riffle - debris dam | - | - | - | - | - | - | - | - |
| Riffle - edge | - | - | - | - | - | - | - | - |
| Run | - | - | - | - | - | - | - | - |
| Pool | 3.4 | 0.04 | N/M | N/M | 0.5 | 0.03 | N/M | N/M |
| Pool - bank snag | N/M | N/M | 3.2 | 0 | - | - | 1.3 | 0.02 |
| Pool - channel snag | 4.2 | 0.02 | 4.2 | 0.03 | - | - | 1.8 | 0.15 |
| Pool - snag complex | 1.5 | 0.03 | 4.3 | 0.03 | - | - | - | - |
| Pool - undercut bank | - | - | - | - | - | - | - | - |
| Pool - rootwad | 1.3 | 0.02 | 1.5 | 0.01 | - | - | - | - |
| Pool - debris dam | - | - | - | - | - | - | - | - |
| Pool - edge | 0.7 | 0 | 0.3 | 0.02 | 0.6 | 0.03 | 1.0 | 0.06 |
| Pool - vegetation | 1.2 | 0 | - | - | - | - | 1.5 | 0.03 |
| Pool - tree | - | - | - | - | - | - | 1.5 | 0.13 |
| Backwater | - | - | 1.5 | 0 | - | - | - | - |
| Backwater - bank snag | 1.0 | 0.01 | - | - | - | - | - | - |
| Backwater - channel snag | - | - | - | - | - | - | - | - |

Table 7. Depths (m) and velocities (m/s) at site 4 habitats in the Sulphur River during winter and summer sampling seasons, 1998-1999. “-“ indicates a habitat that was absent from the site during sampling. “N/M” indicates no measurement.

| | Summer season | | | | | | Winter season | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | High flow range | | Middle flow range | | Low flow range | | High flow range | | Middle flow range | |
| Habitat | Depth | Velocity | Depth | Velocity | Depth | Velocity | Depth | Velocity | Depth | Velocity |
| Riffle | - | - | - | - | - | - | 2.4 | 0.32 | N/M | N/M |
| Riffle - bank snag | - | - | - | - | - | - | 1.8 | 0.32 | - | - |
| Riffle - channel snag | - | - | - | - | - | - | - | - | - | - |
| Riffle - snag complex | - | - | - | - | 0.5 | 0.16 | - | - | - | - |
| Riffle - debris dam | - | - | 0.4 | 0.30 | - | - | - | - | - | - |
| Riffle - edge | 0.7 | 0.31 | - | - | - | - | - | - | - | - |
| Run | - | - | 0.7 | 0.45 | 0.4 | 0.32 | - | - | 1.3 | 0.81 |
| Pool | N/M | N/M | N/M | N/M | N/M | N/M | N/M | N/M | - | - |
| Pool - bank snag | - | - | 0.5 | 0.04 | 0.6 | 0.03 | - | - | - | - |
| Pool - channel snag | 1.7 | 0.23 | 1.3 | 0.17 | 0.8 | 0.06 | 2.3 | 0.11 | - | - |
| Pool - snag complex | - | - | 0.6 | 0.01 | N/M | N/M | - | - | - | - |
| Pool - undercut bank | - | - | - | - | - | - | - | - | - | - |
| Pool - rootwad | - | - | - | - | - | - | 1.3 | 0.05 | - | - |
| Pool - debris dam | - | - | - | - | - | - | - | - | - | - |
| Pool - edge | 0.2 | 0.09 | 1.1 | 0.21 | - | - | 1.6 | 0.28 | 1.4 | 0.18 |
| Pool - vegetation | - | - | - | - | - | - | 2.4 | 0.32 | 0.6 | 0.02 |
| Pool - tree | - | - | - | - | - | - | - | - | - | - |
| Backwater | - | - | 1.2 | 0 | 0.7 | 0.01 | - | - | - | - |
| Backwater - bank snag | - | - | N/M | N/M | - | - | - | - | - | - |
| Backwater - channel snag | - | - | - | - | - | - | - | - | - | - |

Table 8. Depths (m) and velocities (m/s) at site 5 habitats in the Sulphur River during winter and summer sampling seasons, 1998-1999. "-" indicates a habitat that was absent from the site during sampling. "N/M" indicates no measurement.

| | Summer season | | | | | | Winter season | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | High flow range | | Middle flow range | | Low flow range | | High flow range | | Middle flow range | |
| Habitat | Depth | Velocity | Depth | Velocity | Depth | Velocity | Depth | Velocity | Depth | Velocity |
| Riffle | - | - | - | - | - | - | - | - | - | - |
| Riffle - bank snag | - | - | - | - | - | - | 1.8 | 0.35 | - | - |
| Riffle - channel snag | - | - | - | - | - | - | - | - | - | - |
| Riffle - snag complex | - | - | - | - | - | - | - | - | - | - |
| Riffle - debris dam | - | - | - | - | - | - | - | - | - | - |
| Riffle - edge | - | - | - | - | - | - | - | - | - | - |
| Run | - | - | - | - | - | - | - | - | - | - |
| Pool | N/M | N/M | N/M | N/M | 0.5 | 0.06 | N/M | N/M | N/M | N/M |
| Pool - bank snag | 0.6 | 0.21 | 1.3 | 0.08 | - | - | - | - | 0.6 | 0.02 |
| Pool - channel snag | 3.0 | 0.43 | 1.0 | 0.11 | - | - | - | - | 2.0 | 0 |
| Pool - snag complex | - | - | 0.4 | 0.03 | - | - | - | - | 2.1 | 0.10 |
| Pool - undercut bank | - | - | - | - | - | - | - | - | - | - |
| Pool - rootwad | 0.2 | 0 | 0.2 | 0.05 | - | - | - | - | 0.9 | 0.03 |
| Pool - debris dam | 2.1 | 0.13 | - | - | - | - | - | - | - | - |
| Pool - edge | 1.6 | 0.17 | 0.7 | 0.26 | N/M | N/M | 1.3 | 0.01 | 1.3 | 0.21 |
| Pool - vegetation | 0.6 | 0.04 | - | - | - | - | 0.8 | 0.04 | - | - |
| Pool - tree | 1.5 | 0.24 | - | - | - | - | 1.1 | 0.25 | - | - |
| Backwater | - | - | - | - | - | - | - | | 0.4 | 0 |
| Backwater - bank snag | - | - | - | - | - | - | - | - | - | - |
| Backwater - channel snag | - | - | - | - | - | - | - | - | - | - |

Table 9. Depths (m) and velocities (m/s) at site 6 habitats in the Sulphur River during winter and summer sampling seasons, 1998-1999. "-" indicates a habitat that was absent from the site during sampling. "N/M" indicates no measurement.

| | Summer season | | | | | | Winter season | |
|---|---|---|---|---|---|---|---|---|
| | High flow range | | Middle flow range | | Low flow range | | Middle flow range | |
| Habitat | Depth | Velocity | Depth | Velocity | Depth | Velocity | Depth | Velocity |
| Riffle | - | - | - | - | - | - | - | - |
| Riffle - bank snag | - | - | - | - | - | - | - | - |
| Riffle - channel snag | - | - | - | - | - | - | - | - |
| Riffle - snag complex | - | - | - | - | 0.2 | 0.40 | - | - |
| Riffle - debris dam | - | - | - | - | - | - | - | - |
| Riffle - edge | - | - | - | - | - | - | - | - |
| Run | - | - | - | - | - | - | - | - |
| Pool | N/M | N/M | N/M | N/M | 0.9 | 0.01 | N/M | N/M |
| Pool - bank snag | 0.9 | 0.04 | 1.8 | 0.04 | 0.9 | 0.02 | 1.0 | 0.17 |
| Pool - channel snag | 1.5 | 0.13 | 0.5 | 0.07 | 0.7 | 0.05 | - | - |
| Pool - snag complex | - | - | - | - | - | - | - | - |
| Pool - undercut bank | - | - | - | - | - | - | - | - |
| Pool - rootwad | - | - | - | - | - | - | - | - |
| Pool - debris dam | - | - | - | - | - | - | - | - |
| Pool - edge | 0.9 | 0.01 | 0.3 | 0 | N/M | N/M | 1.9 | 0.45 |
| Pool - vegetation | 0.9 | 0.15 | - | - | - | - | 0.9 | 0.04 |
| Pool - tree | - | - | - | - | - | - | - | - |
| Backwater | - | - | - | - | N/M | N/M | - | - |
| Backwater - bank snag | - | - | - | - | - | - | - | - |
| Backwater - channel snag | - | - | - | - | - | - | - | - |

Table 10. Depths (m) and velocities (m/s) at site 7 habitats in the Sulphur River during the summer-high flow range. "-" indicates a habitat that was absent from the site during sampling.

| Habitat | Depth | Velocity |
|---|---|---|
| Riffle | - | - |
| Riffle-bank snag | - | - |
| Riffle-channel snag | - | - |
| Riffle-snag complex | - | - |
| Riffle-debris dam | - | - |
| Riffle-edge | - | - |
| Run | - | - |
| Pool | 1.0 | 0.01 |
| Pool-bank snag | 1.0 | 0.02 |
| Pool-channel snag | 0.9 | 0.01 |
| Pool-snag complex | 0.4 | 0.02 |
| Pool-undercut bank | 0.4 | 0.02 |
| Pool-rootwad | 0.2 | 0.01 |
| Pool-debris dam | - | - |
| Pool-edge | - | - |
| Pool-vegetation | - | - |
| Pool-tree | - | - |
| Backwater | - | - |
| Backwater-bank snag | - | - |
| Backwater-channel snag | - | - |

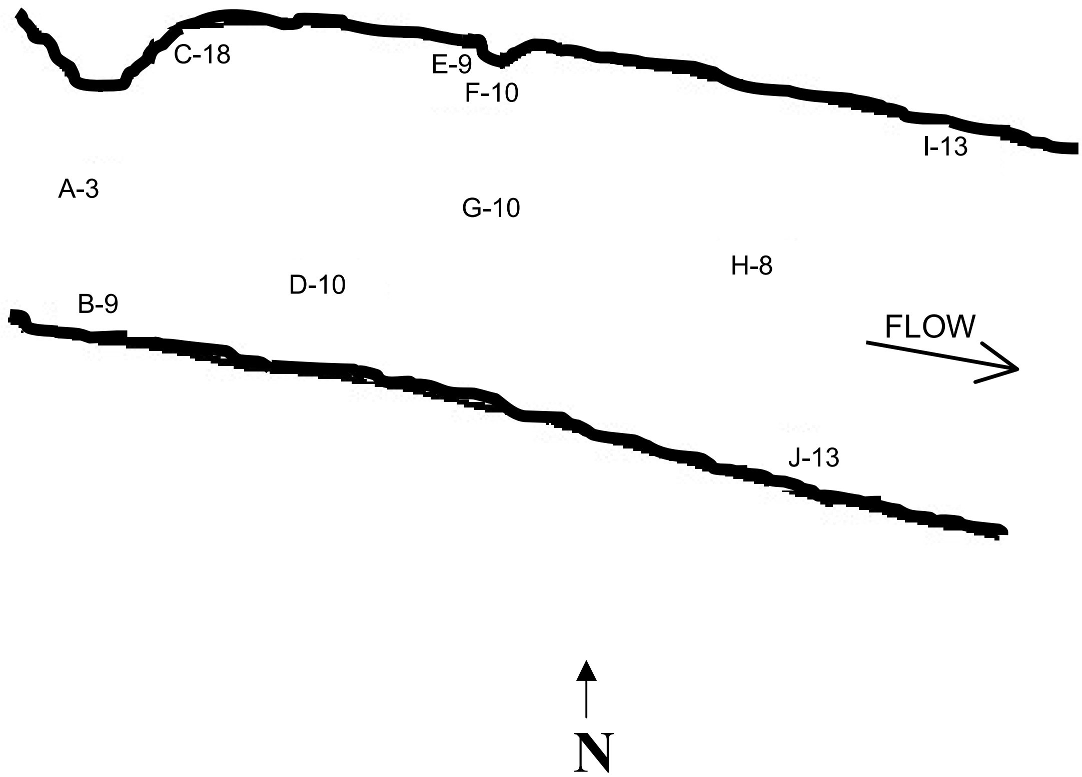


Figure 2. Sketch map of site 1. Letters refer to the order in which habitats were encountered moving downstream within the site. Numbers refer to habitat codes in Table 11.

Figure 3.  Site 1.  B-9 left in foreground, A-3 center in background.  Upstream view.

Figure 4.  Site 1.  F-10 on right.  Upstream view.

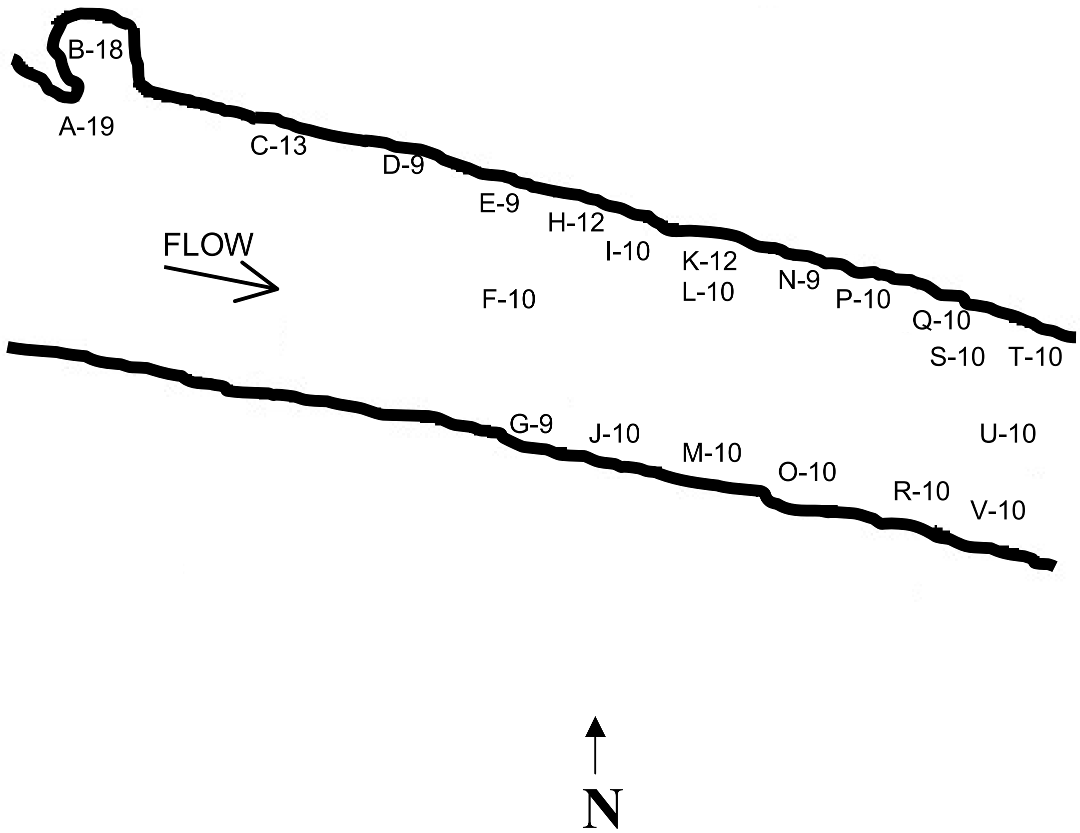


Figure 5. Sketch map of site 2. Letters refer to the order in which habitats were encountered moving downstream within the site. Numbers refer to habitat codes in Table 11.

Figure 6.  Site 2.  A-19 on left, B-18 on right.  Upstream view.

Figure 7.  Site 2. C-13.

Figure 8.  Site 2.  D-9.

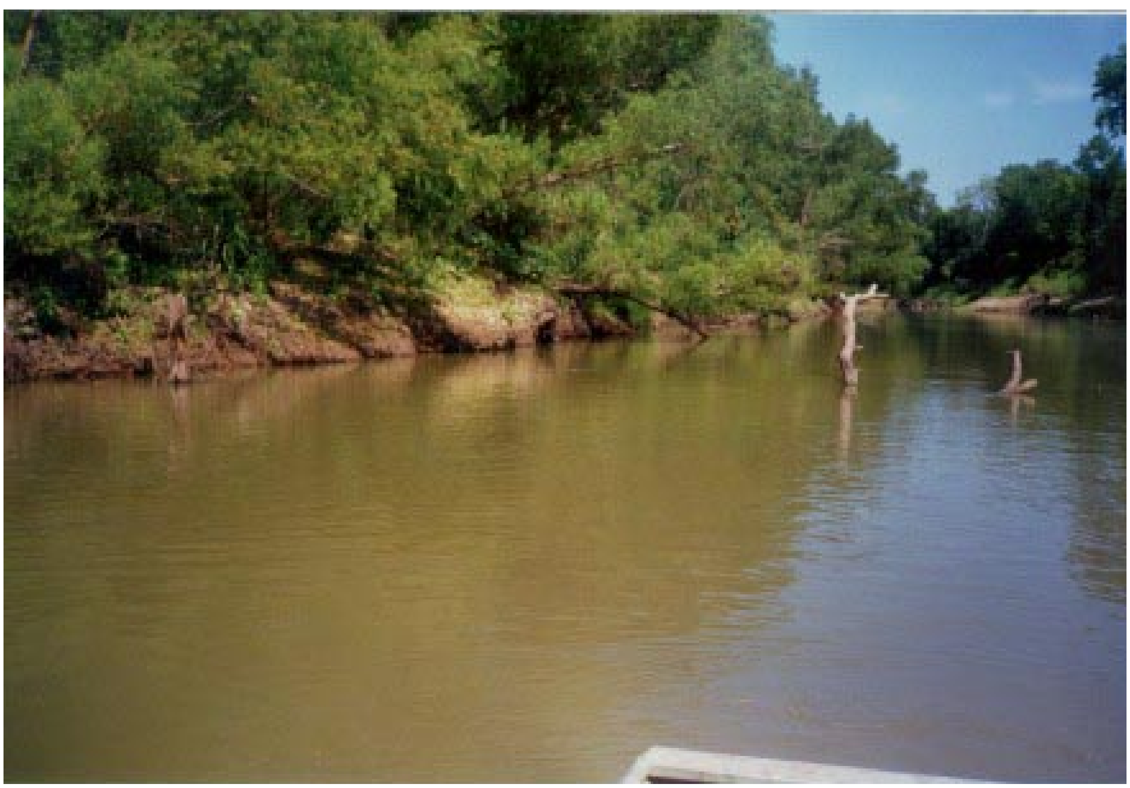

Figure 9.  Site 2.  E-9 on left, F-10 on right.  Downstream view.

Figure 10. Site 2. G-9.

Figure 11. Site 2. H-12.

Figure 12. Site 2. I-10.

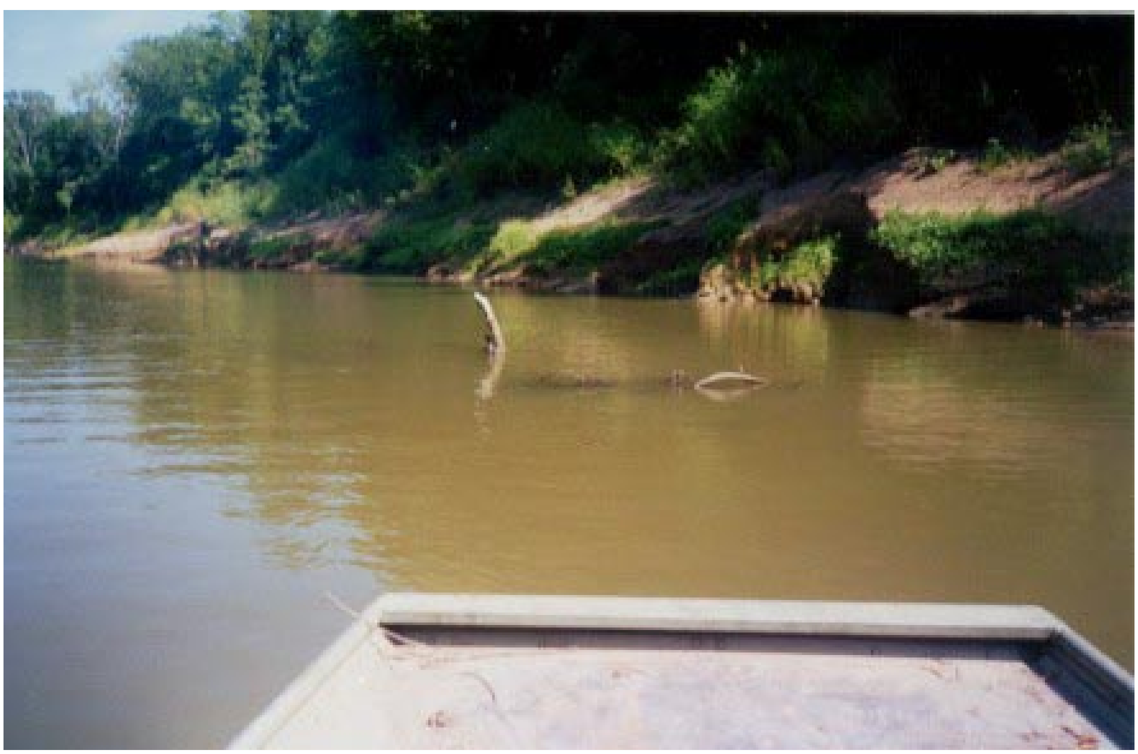

Figure 13. Site 2. J-10. Downstream view.

Figure 14. Site 2. K-12 on right, L-10 on left.

Figure 15. Site 2. M-10.

Figure 16.  Site 2.  N-9.

Figure 17.  Site 2.  O-10.

Figure 18.  Site 2.  P-10.

Figure 19.  Site 2.  Q-10.

Figure 20. Site 2. S-10. Downstream view.

Figure 21. Site 2. T-10.

Figure 22.  Site 2.  U-10.

Figure 23.  Site 2.  V-10.

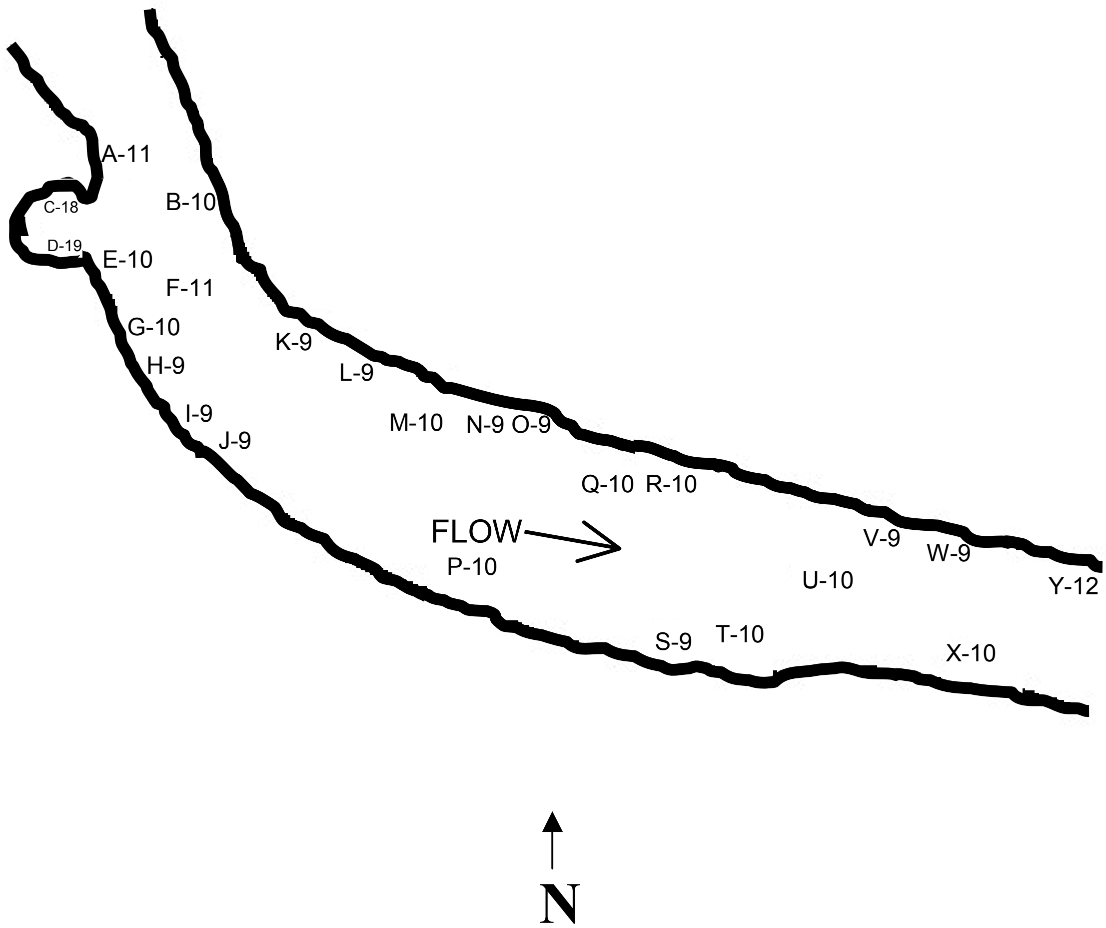


Figure 24. Sketch map of site 3. Letters refer to the order in which habitats were encountered moving downstream within the site. Numbers refer to habitat codes in Table 11.

Figure 25. Site 3. D-19, C-18, and A-11 from left to right. Upstream view.

Figure 26. Site 3. B-10.

Figure 27. Site 3. E-10.

Figure 28. Site 3. F-11.

Figure 29.  Site 3.  G-10.

Figure 30.  Site 3.  H-9.

Figure 31.  Site 3.  I-9.

Figure 32.  Site 3.  J-9.

Figure 33. Site 3. K-9. Downstream view.

Figure 34. Site 3. L-9.

Figure 35.  Site 3. O-9.

Figure 36.  Site 3.  P-10.  Downstream view.

Figure 37. Site 3. Q-10.

Figure 38. Site 3. R-10.

Figure 39. Site 3. S-9.

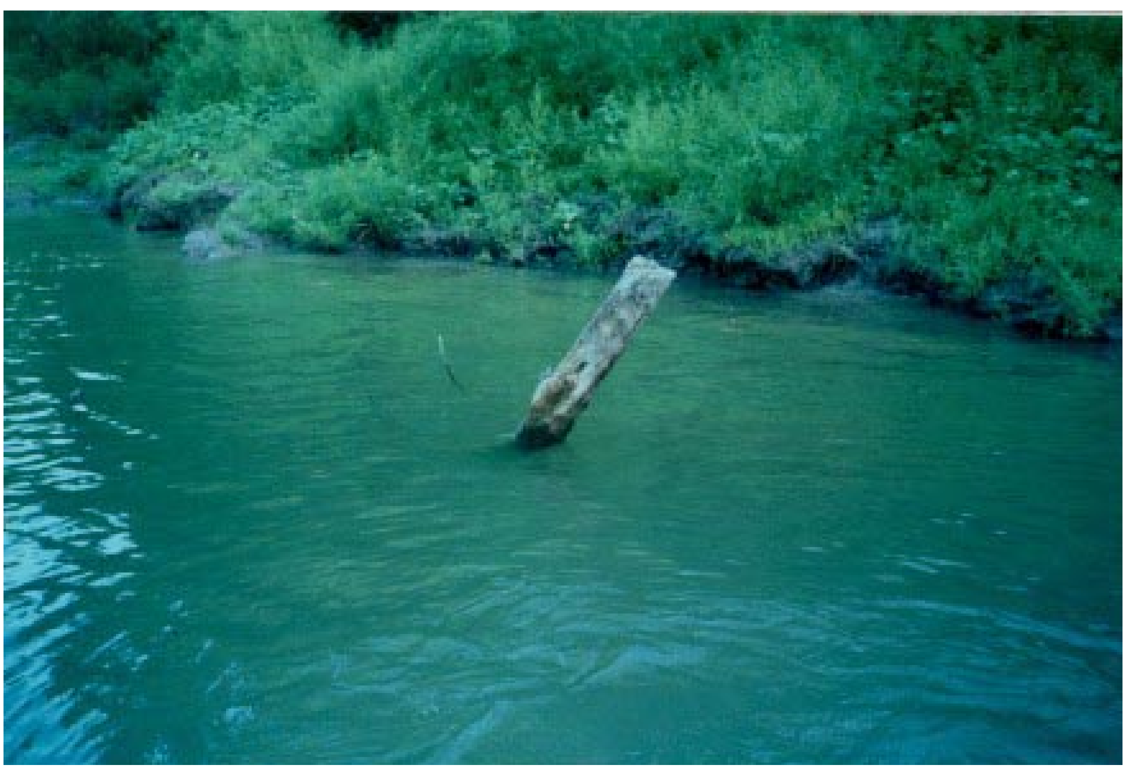

Figure 40. Site 3. T-10.

Figure 41. Site 3. U-10.

Figure 42. Site 3. V-9.

Figure 43.  Site 3.  W-9.

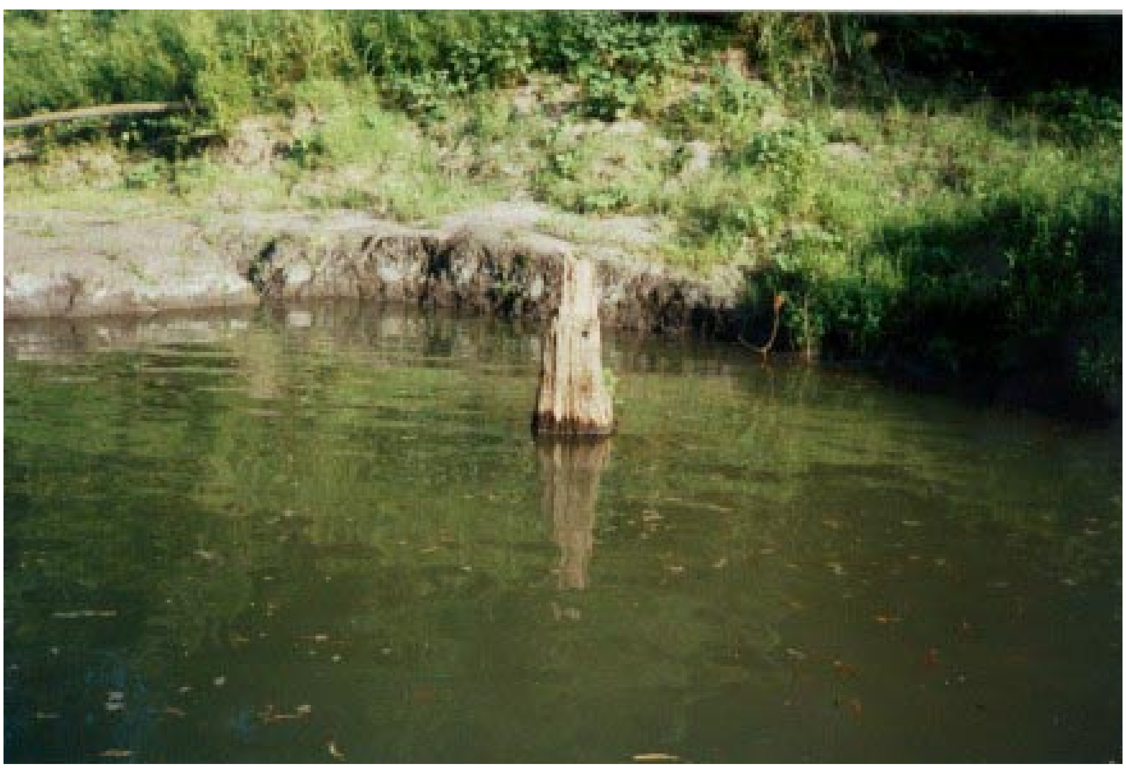

Figure 44.  Site 3.  X-10.

Figure 45. Site 3. Y-12.

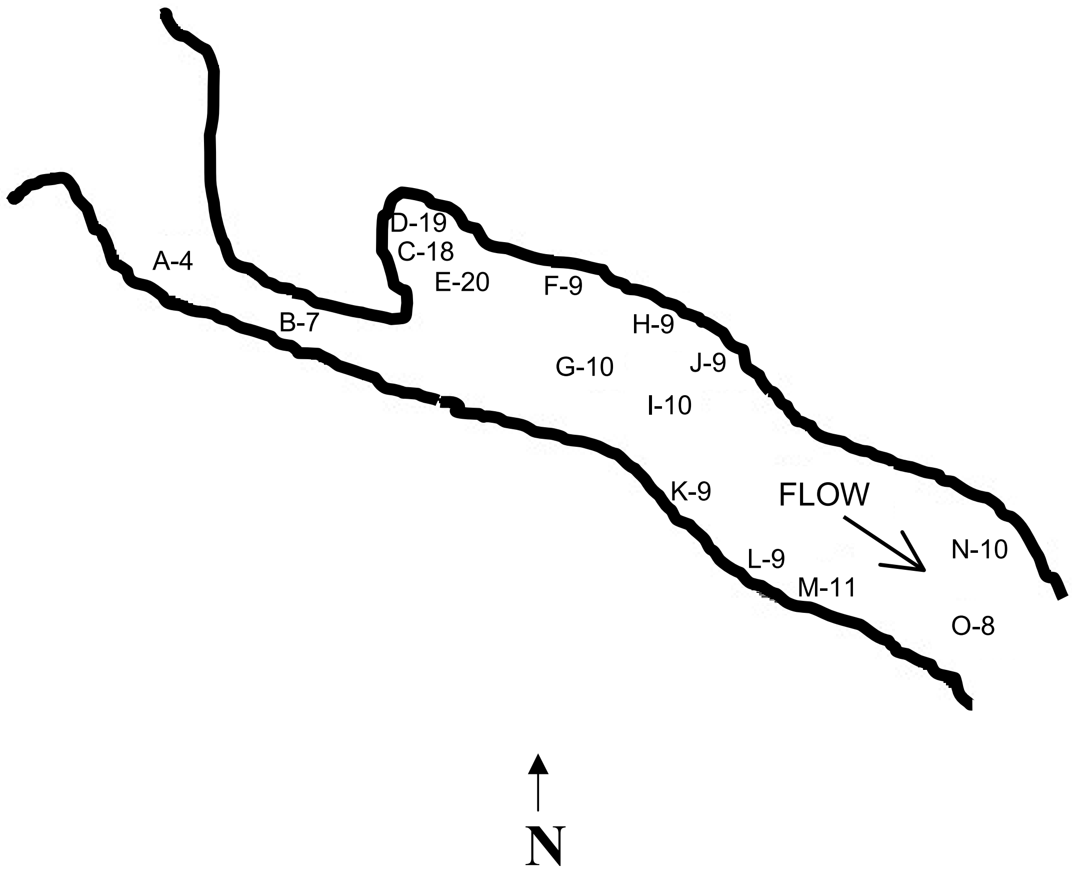


Figure 46. Sketch map of site 4. Letters refer to the order in which habitats were encountered moving downstream within the site. Numbers refer to habitat codes in Table 11.

Figure 47. Site 4. A-4.

Figure 48. Site 4. B-7.

Figure 49. Site 4. C-18, D-19, and E-20 from left to right.

Figure 50. Site 4. F-9 on left and G-10 on far right.

Figure 51. Site 4. H-9.

Figure 52. Site 4. I-10.

Figure 53.  Site 4.  J_9.  Downstream view.

Figure 54.  Site 4.  K-9.  Downstream view.

Figure 55. Site 4. L-9. Upstream view.

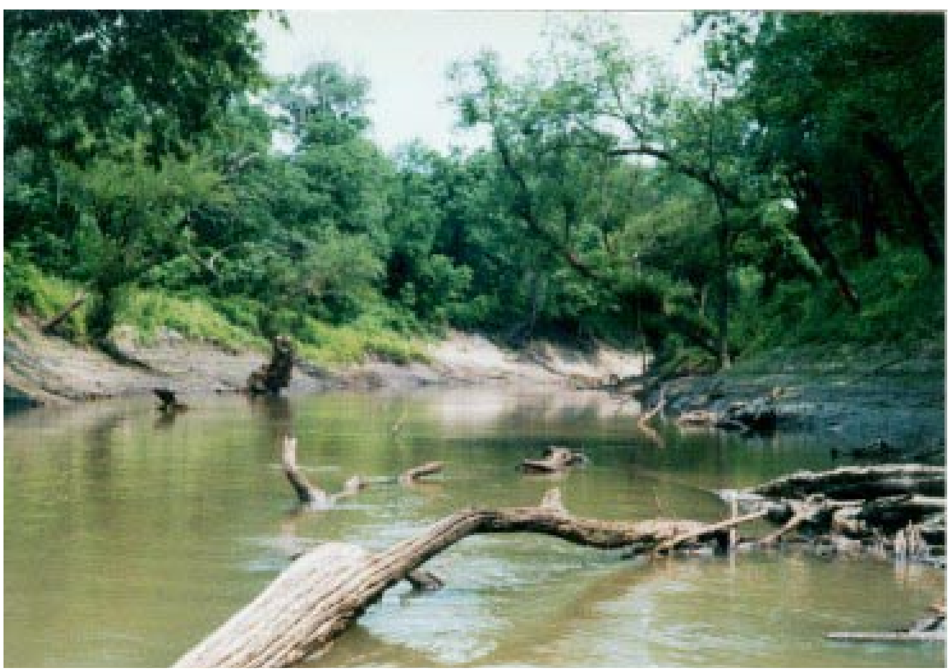

Figure 56. Site 4. M-11. Downstream view.

Figure 57. Site 4. N-10.

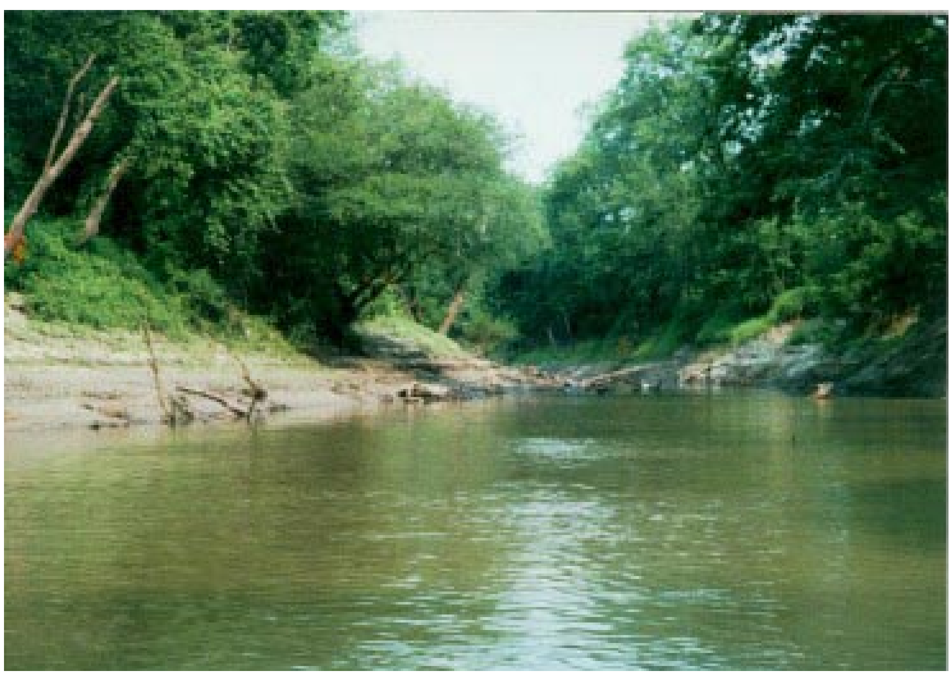

Figure 58. Site 4. O-8. Upstream view.

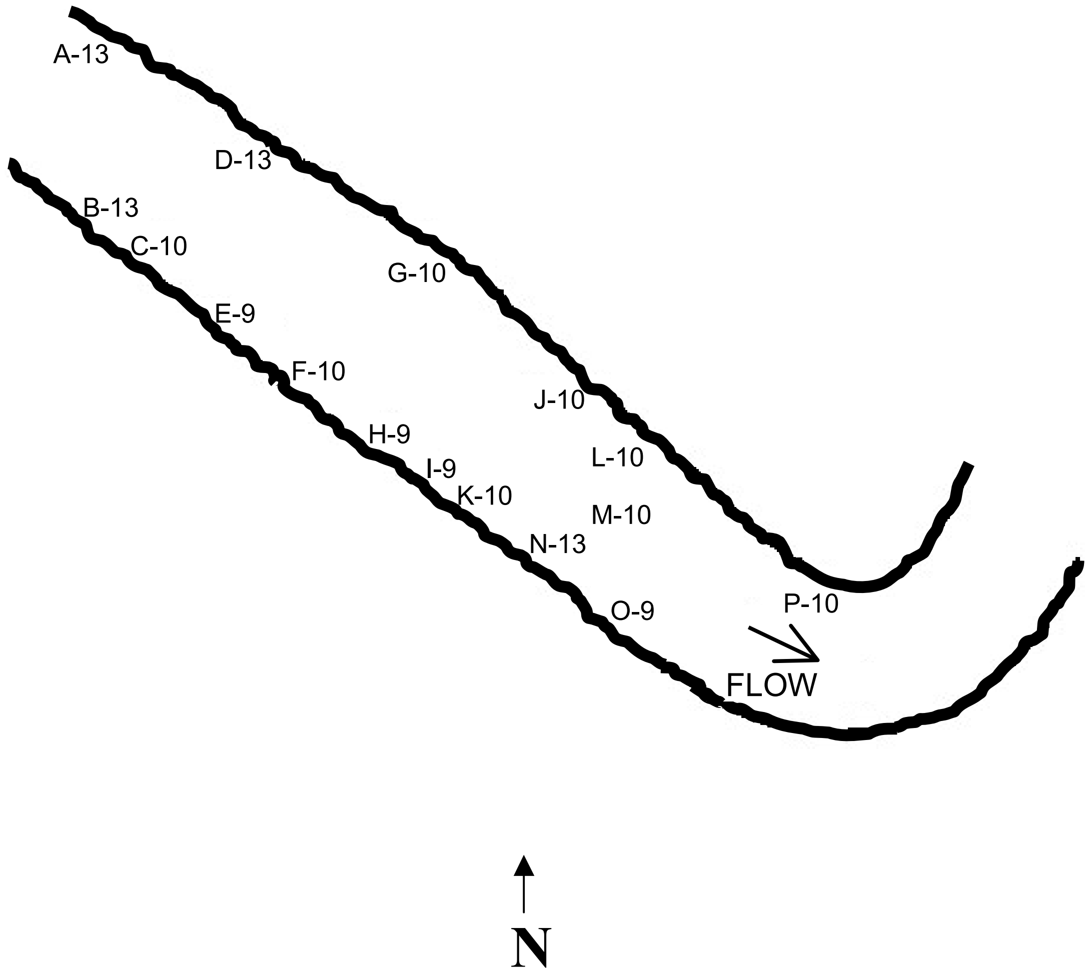


Figure 59. Sketch map of site 5. Letters refer to the order in which habitats were encountered moving downstream within the site. Numbers refer to habitat codes in Table 11.

Figure 60. Site 5. A-13.

Figure 61. Site 5. B-13.

Figure 62.  Site 5.  C-10.

Figure 63.  Site 5.  D-13.

Figure 64.  Site 5.  E-9.  Downstream view.

Figure 65.  Site 5.  F-10.

Figure 66. Site 5.  G-10.

Figure 67.  Site 5.  H-9.

Figure 68. Site 5. I-9.

Figure 69. Site 5. J-10.

Figure 70. Site 5. K-10.

Figure 71. Site 5. L-10 in left foreground, M-10 in center. Downstream view.

Figure 72.  Site 5.  N-13.

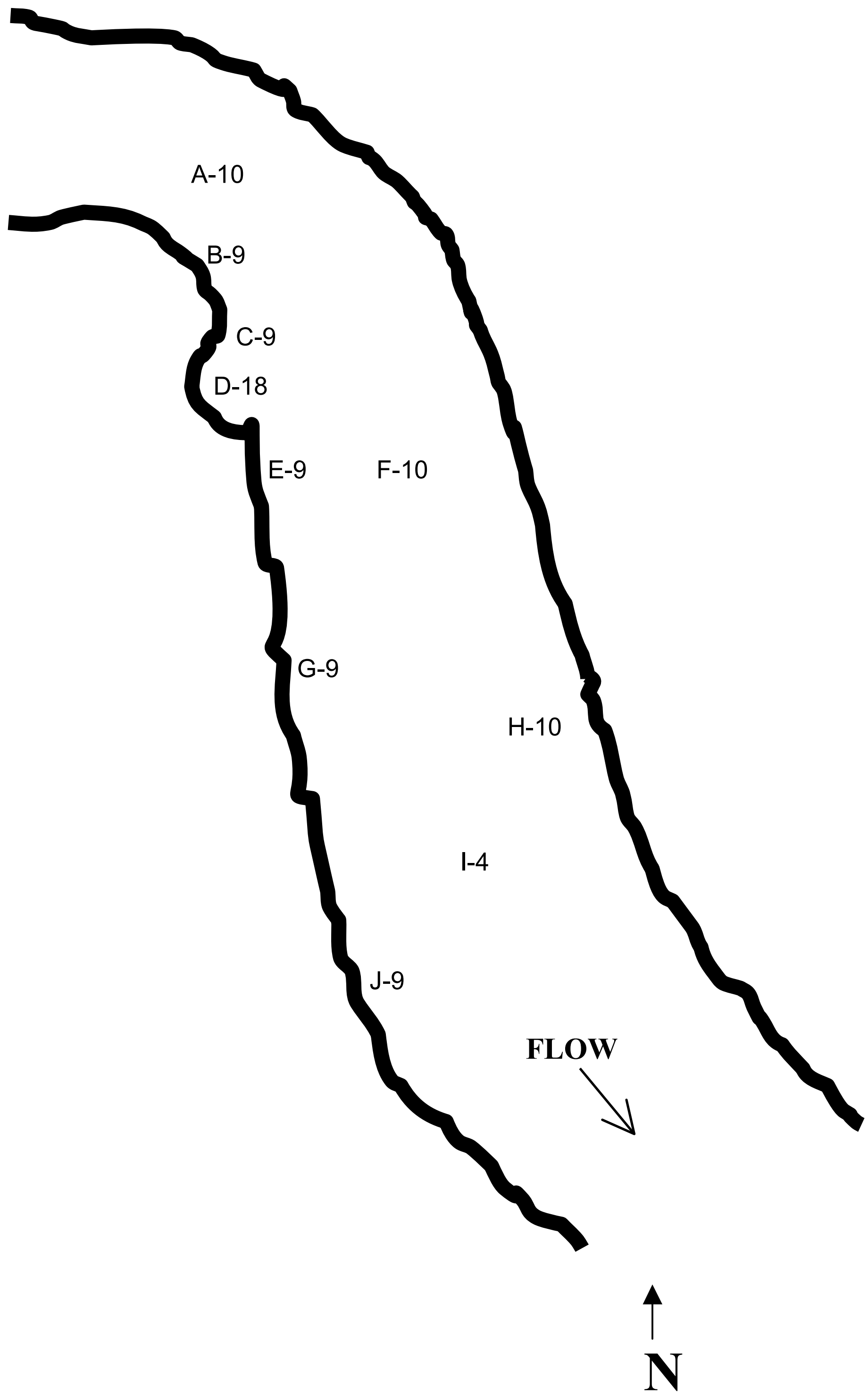


Figure 73. Sketch map of site 6. Letters refer to the order in which habitats were encountered moving downstream within the site. Numbers refer to habitat codes in Table 11.

Figure 74.  Site 6.  A-10.

Figure 75.  Site 6.  B-9.  Upstream view.

Figure 76. Site 6. C-9 on on right and D-18 on left.

Figure 77. Site 6. E-9 on right and F-10 on left. Downsteam view.

Figure 78. Site 6. G-9. Downstream view.

Figure 79. Site 6. H-10.

Figure 80. Site 6. I-4.

Figure 81. Site 6. J-9. Downstream view.

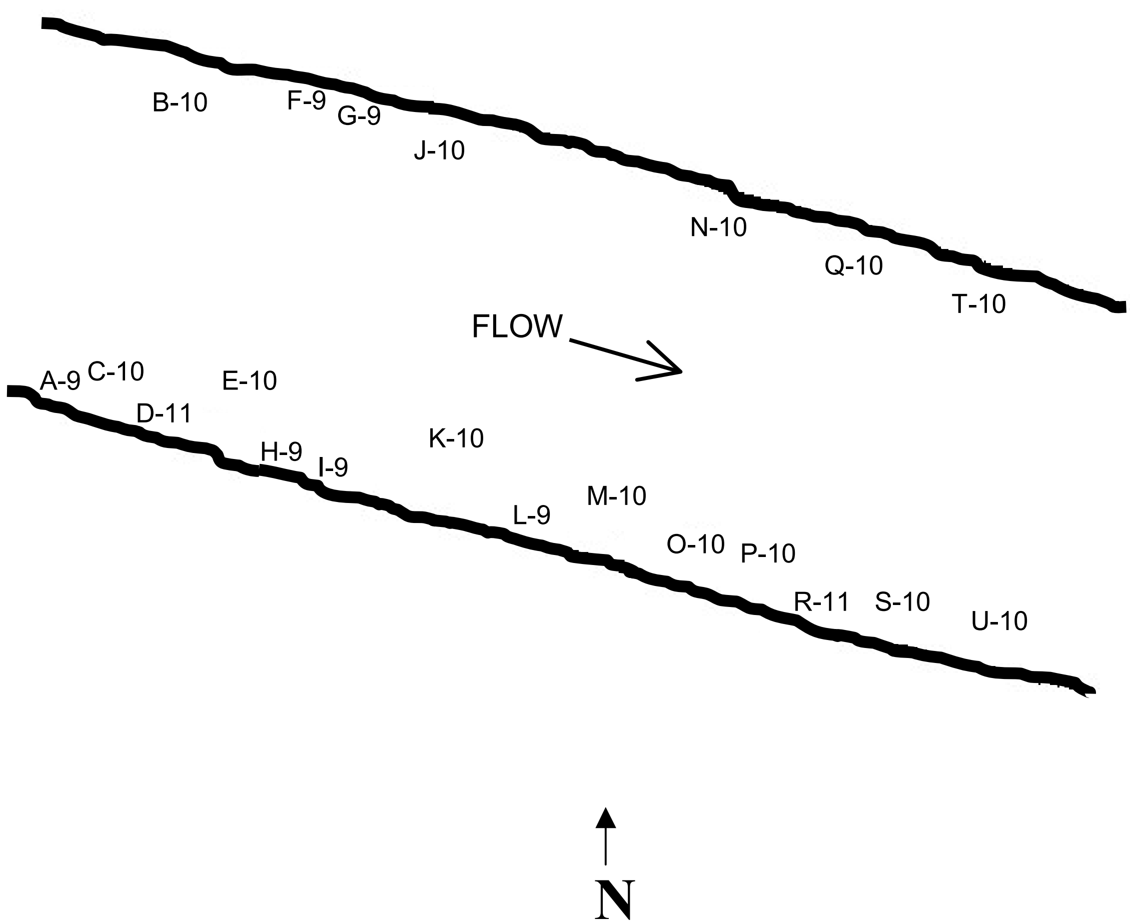


Figure 82. Sketch map of site 7. Letters refer to the order in which habitats were encountered moving downstream within the site. Numbers refer to habitat codes in Table 11.

Figure 83. Site 7. Upstream boundary. A-9. Upstream view.

Figure 84. Site 7. B-10. Downstream view.

Figure 85. Site 7. C –10. Downstream view.

Figure 86. Site 7. D-11. Downstream view.

Figure 87. Site 7. F-9 with tape and G-9 on right. Upstream view.

Figure 88.  Site 7.  K-10.

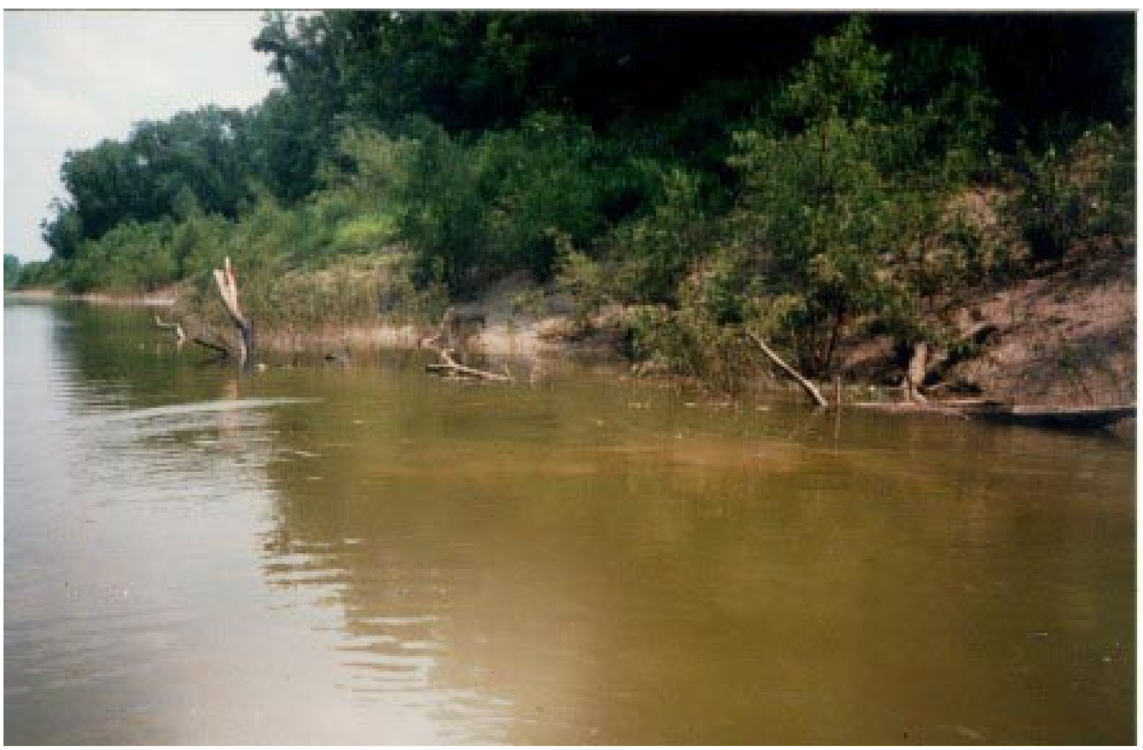

Figure 89.  Site 7.  R-11.  Downstream view.

Figure 90. Representative photographs of edge microhabitat.

Figure 91. Representative photographs of edge microhabitat.

Figure 92. Representative photographs of tree microhabitat.

Table 11. Species and habitat codes for bubble graphs.

| Code | Species | Common name | Habitat |
|---|---|---|---|
| 1 | *Atractosteus spatula* | Alligator gar | Riffle |
| 2 | *Lepisosteus oculatus* | Spotted gar | Riffle - bank snag |
| 3 | *Lepisosteus osseus* | Longnose gar | Riffle - channel snag |
| 4 | *Lepisosteus platostomus* | Shortnose gar | Riffle - snag complex |
| 5 | *Dorosoma cepedianum* | Gizzard shad | Riffle - debris dam |
| 6 | *Dorosoma petenense* | Threadfin shad | Riffle - edge |
| 7 | *Cyprinella lutrensis* | Red shiner | Run |
| 8 | *Cyprinus carpio* | Common carp | Pool |
| 9 | *Hybognathus nuchalis* | Mississippi silvery minnow | Pool - bank snag |
| 10 | *Notemigonus crysoleucas* | Golden shiner | Pool - channel snag |
| 11 | *Notropis atherinoides* | Emerald shiner | Pool - snag complex |
| 12 | *Pimephales vigilax* | Bullhead minnow | Pool - undercut bank |
| 13 | *Carpiodes carpio* | River carpsucker | Pool - rootwad |
| 14 | *Ictiobus bubalus* | Smallmouth buffalo | Pool - debris dam |
| 15 | *Ictiobus cyprinellus* | Bigmouth buffalo | Pool - edge |
| 16 | *Ictiobus niger* | Black buffalo | Pool - vegetation |
| 17 | *Ictalurus furcatus* | Blue catfish | Pool - tree |
| 18 | *Ictalurus punctatus* | Channel catfish | Backwater |
| 19 | *Noturus nocturnus* | Freckled madtom | Backwater - bank snag |
| 20 | *Pylodictis olivaris* | Flathead catfish | Backwater - channel snag |
| 21 | *Fundulus notatus* | Blackstripe topminnow | |
| 22 | *Gambusia affinis* | Mosquitofish | |
| 23 | *Labidesthes sicculus* | Brook silverside | |
| 24 | *Aplodinotus grunniens* | Freshwater drum | |

Table 11. Continued.

| Code | Species | Common name | Habitat |
|---|---|---|---|
| 25 | *Aphredoderus sayanus* | Pirate perch | |
| 26 | *Morone chrysops* | White bass | |
| 27 | *Morone saxatilis* | Striped bass | |
| 28 | *Micropterus salmoides* | Largemouth bass | |
| 29 | *Lepomis cyanellus* | Green sunfish | |
| 30 | *Lepomis gulosus* | Warmouth | |
| 31 | *Lepomis humilis* | Orangespotted sunfish | |
| 32 | *Lepomis macrochirus* | Bluegill | |
| 33 | *Lepomis marginatus* | Dollar sunfish | |
| 34 | *Lepomis megalotis* | Longear sunfish | |
| 35 | *Lepomis* sp.[a] | | |
| 36 | *Pomoxis annularis* | White crappie | |
| 37 | *Pomoxis nigromaculatus* | Black crappie | |

[a] Fish < 50 mm total length.

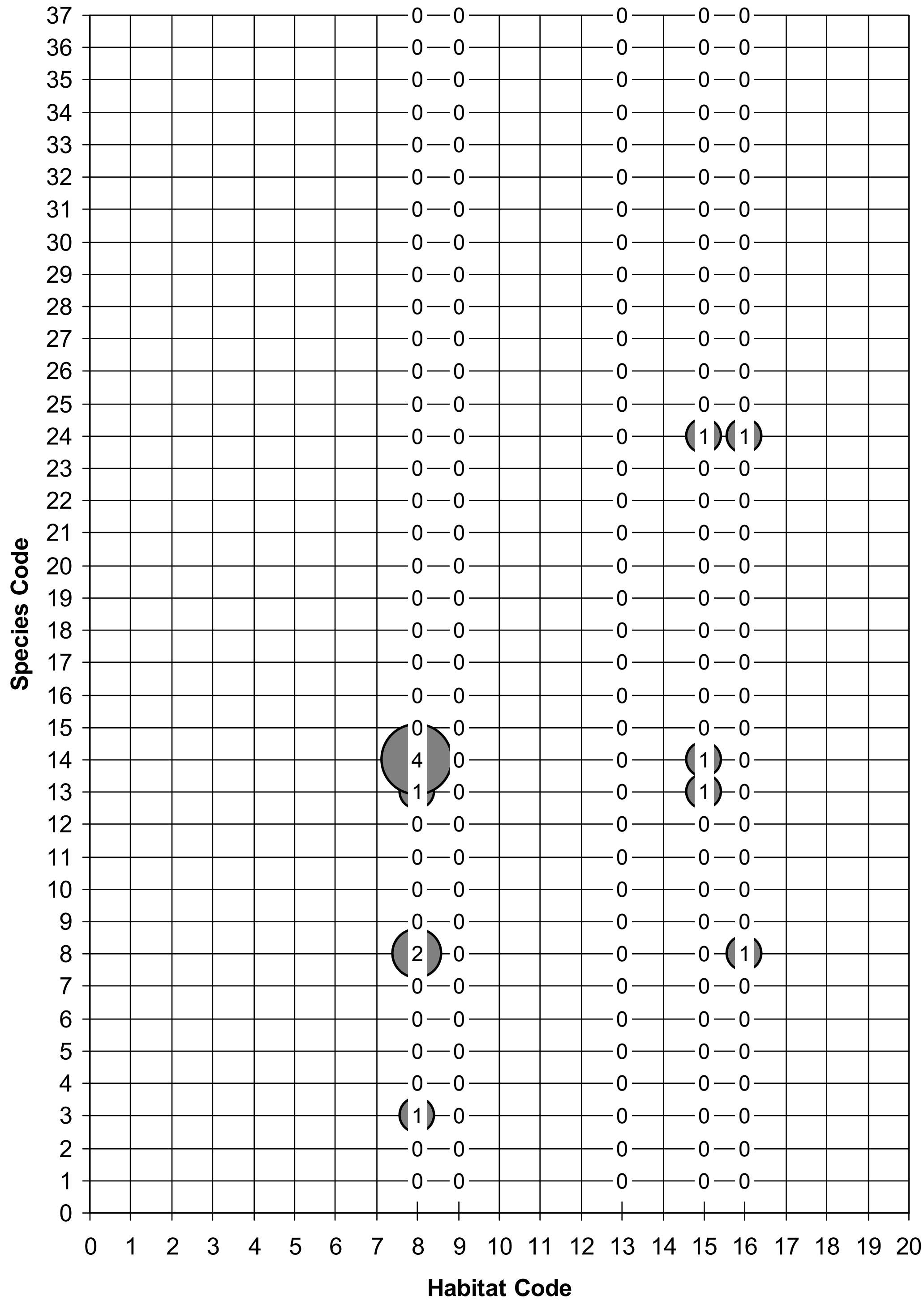


Figure 93. Total number of fishes collected from site 1 in the South Sulphur River on 17 June 1999 during the summer-high flow range (500-64 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

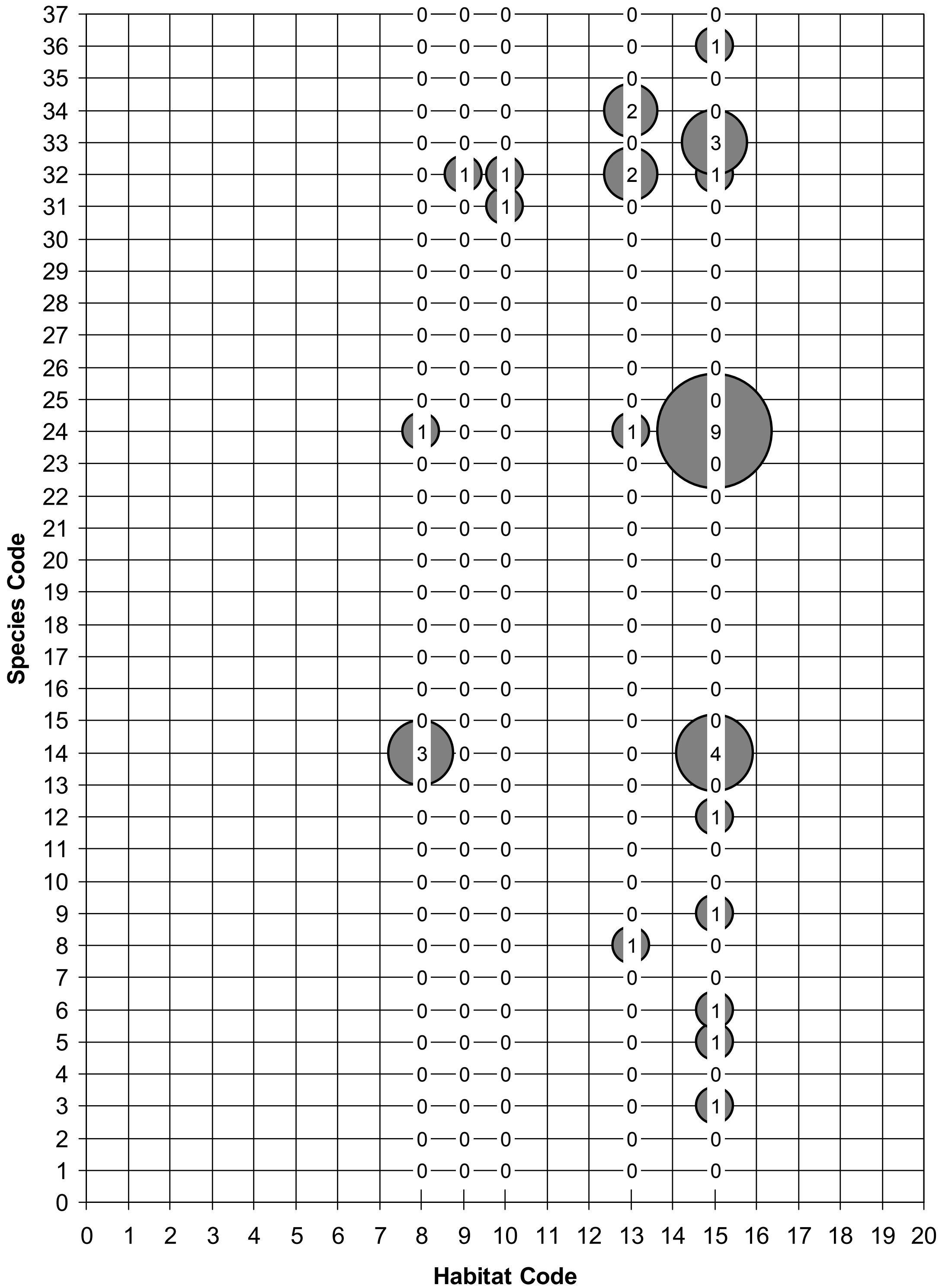


Figure 94. Total number of fishes collected from site 1 in the South Sulphur River on 9 June 1999 during the summer-middle flow range (64-16 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

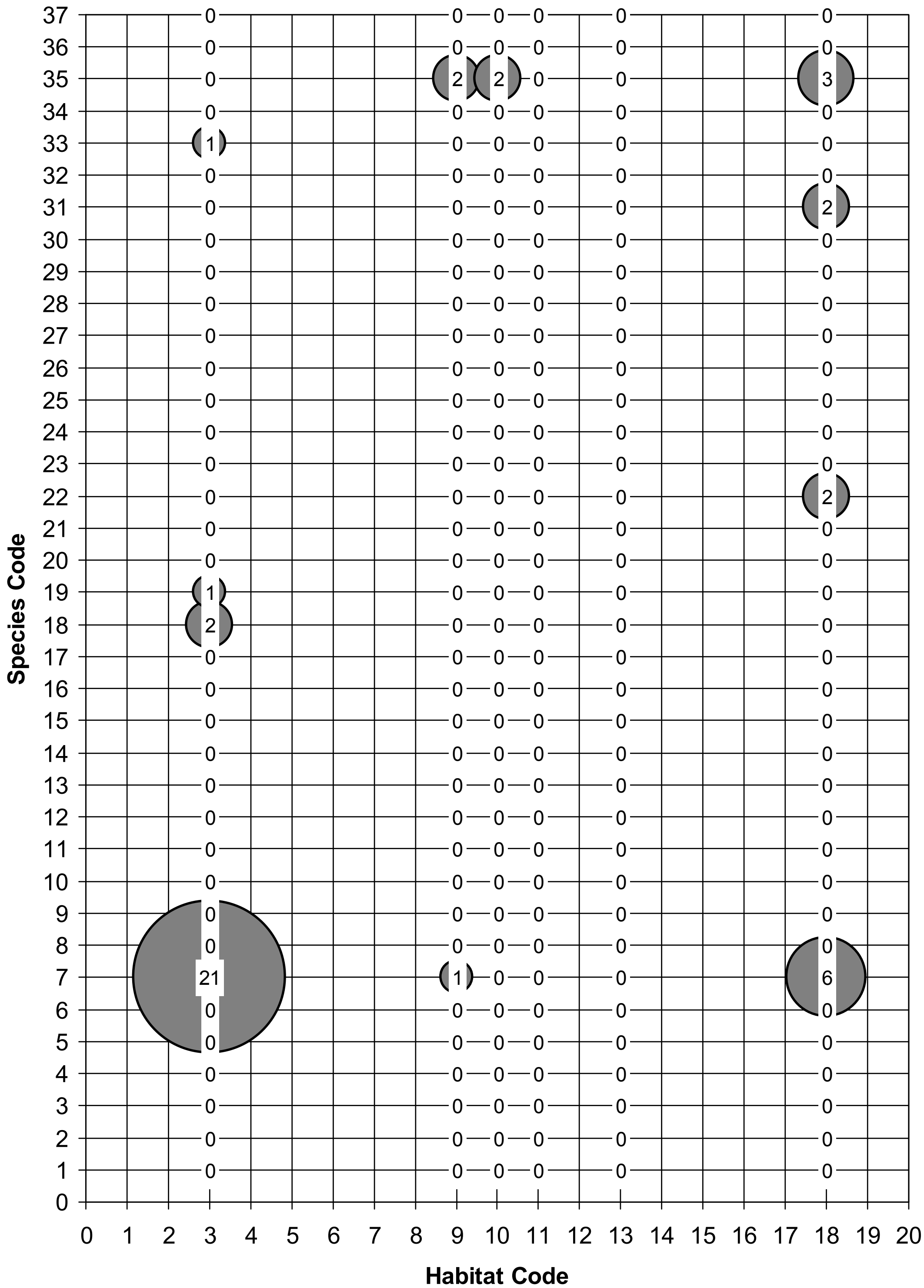


Figure 95. Total number of fishes collected from site 1 in the South Sulphur River on 30 July 1998 during the summer-low flow range (<16 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

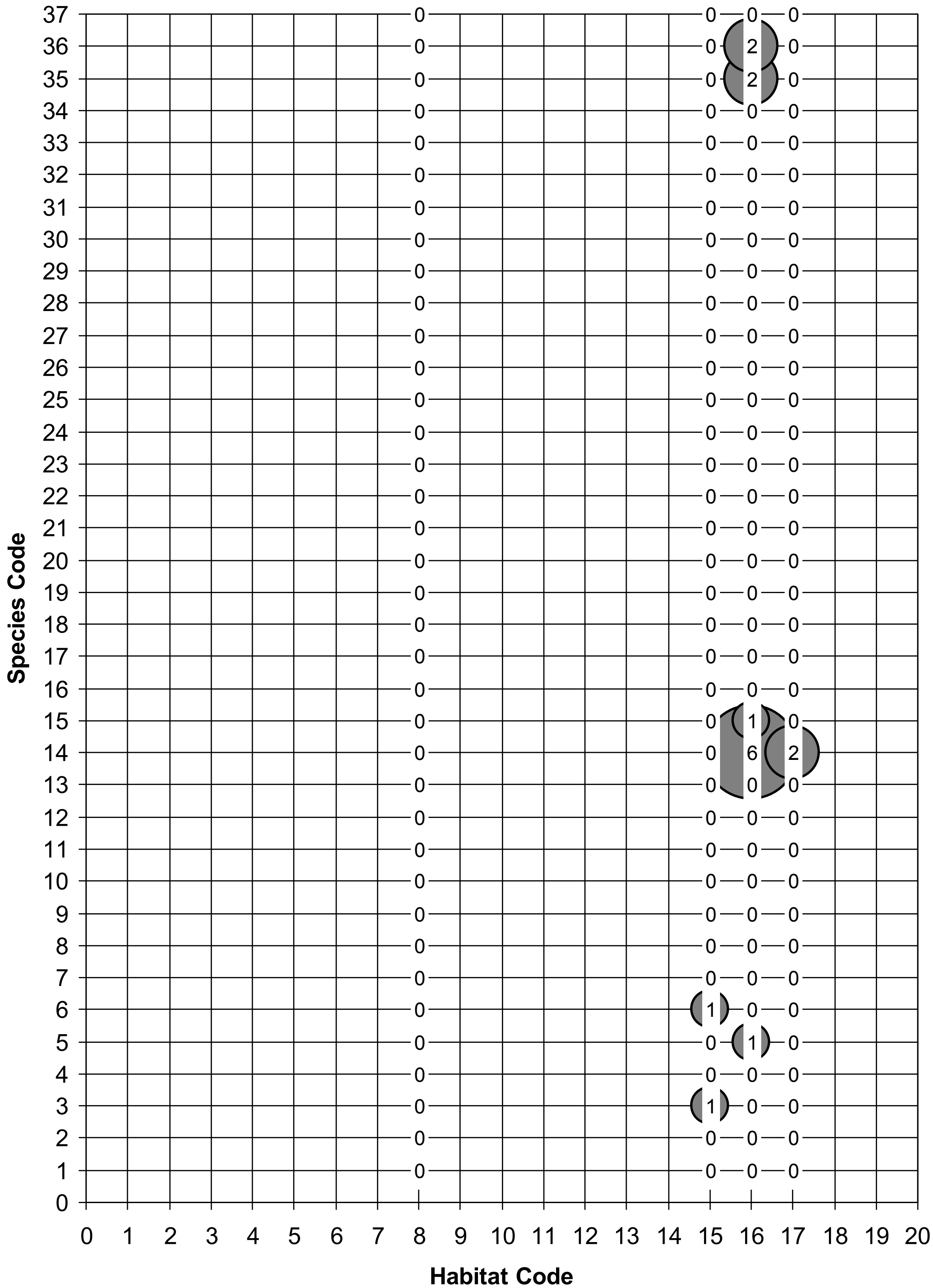


Figure 96. Total number of fishes collected from site 1 in the South Sulphur River on 26 March 1999 during the winter-high flow range (1190-340 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

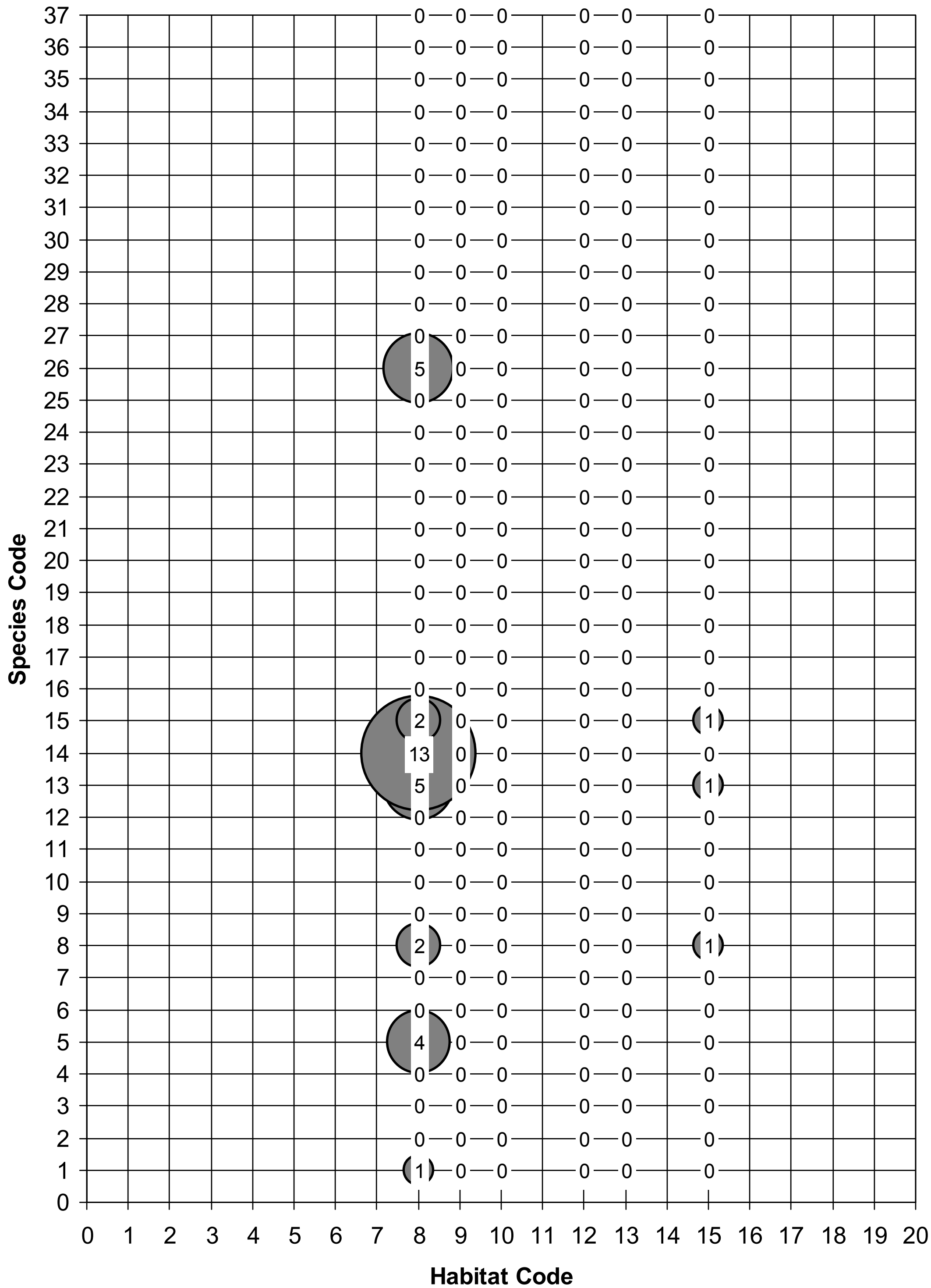


Figure 97. Total number of fishes collected from site 2 in the Sulphur River on 17 June 1999 during the summer-high flow range (500-64 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

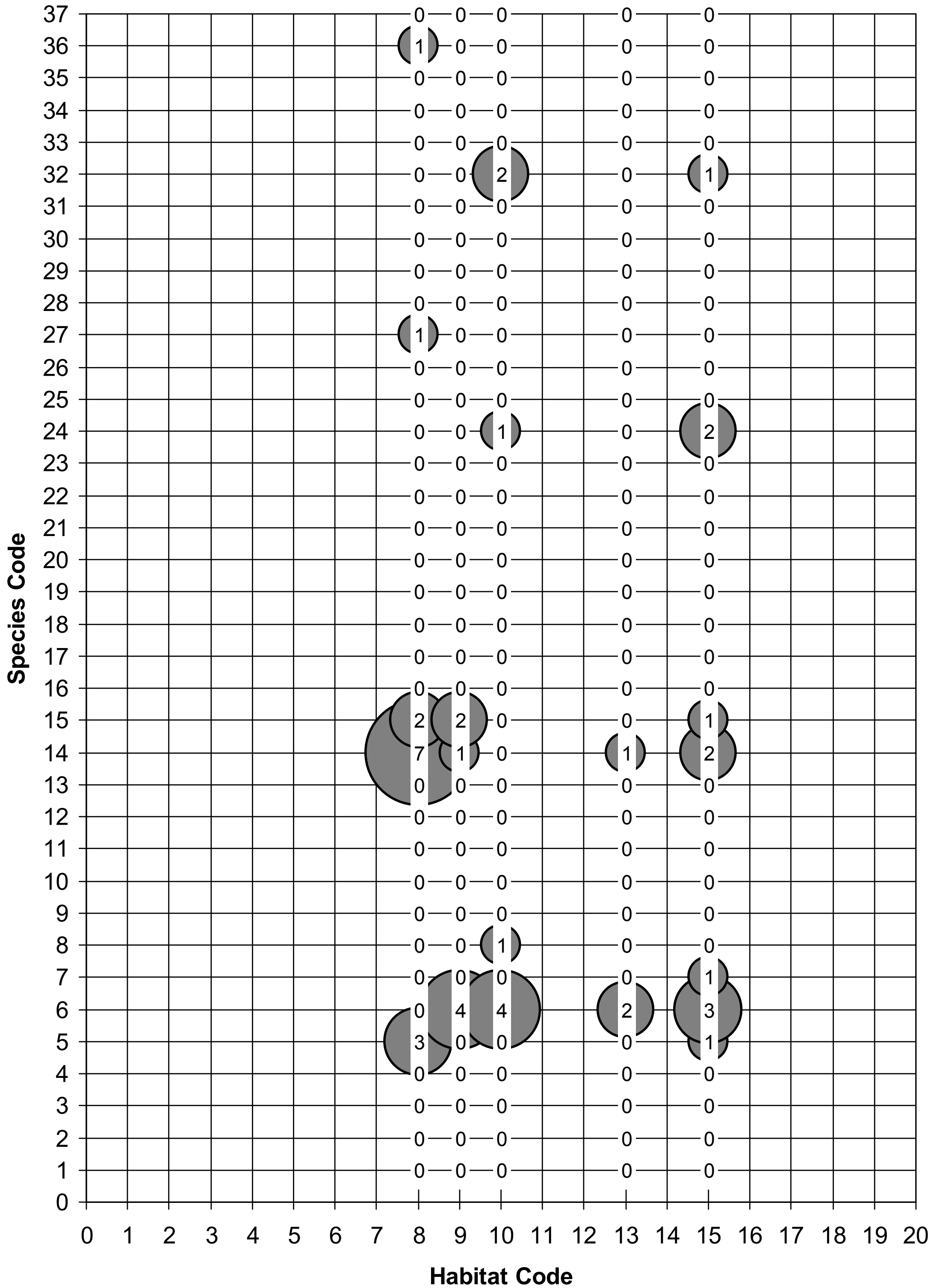


Figure 98. Total number of fishes collected from site 2 in the Sulphur River on 10 June 1999 during the summer-middle flow range (64-16 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

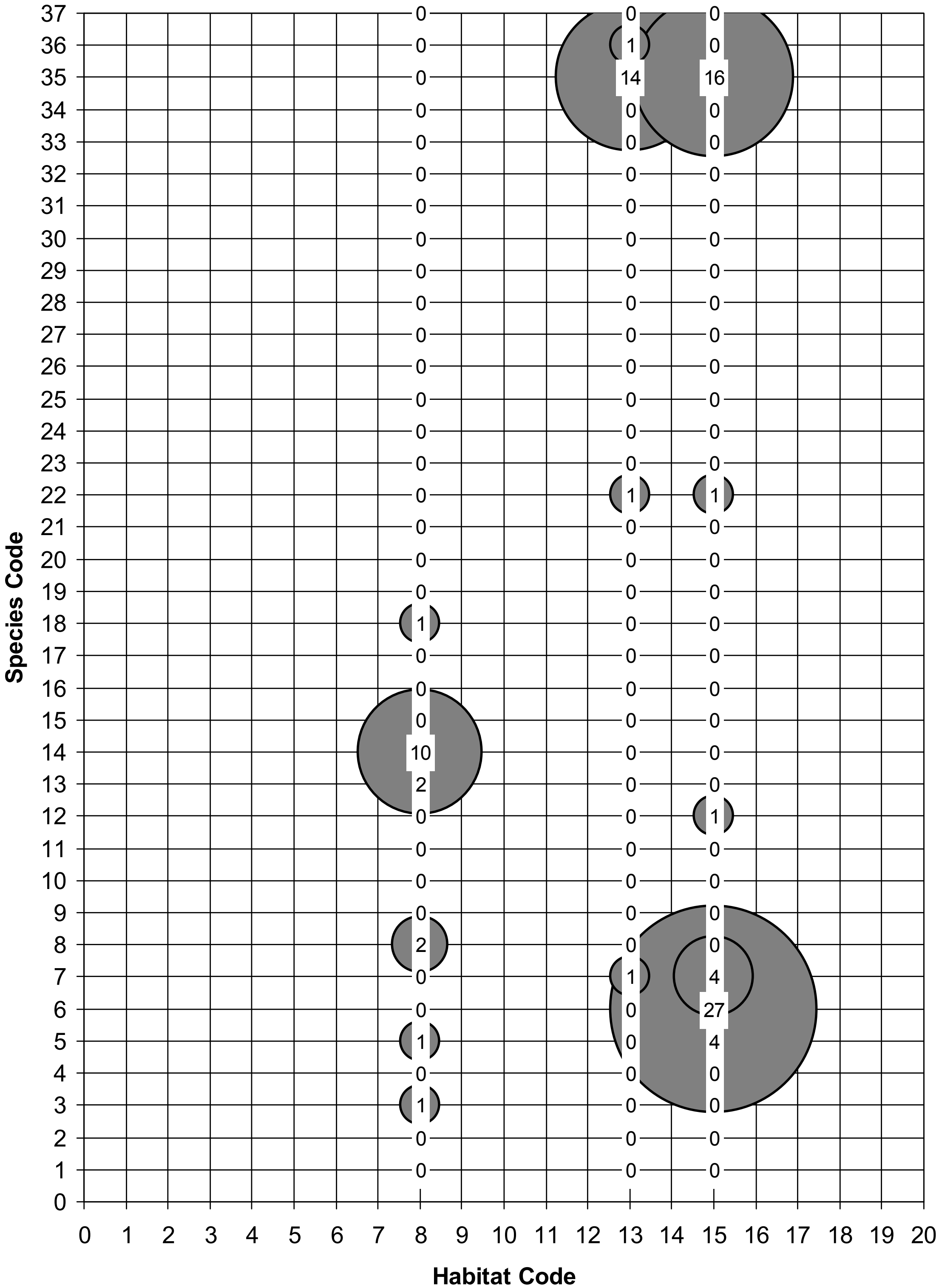


Figure 99. Total number of fishes collected from site 2 in the Sulphur River on 31 July 1998 during the summer-low flow range (<16 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

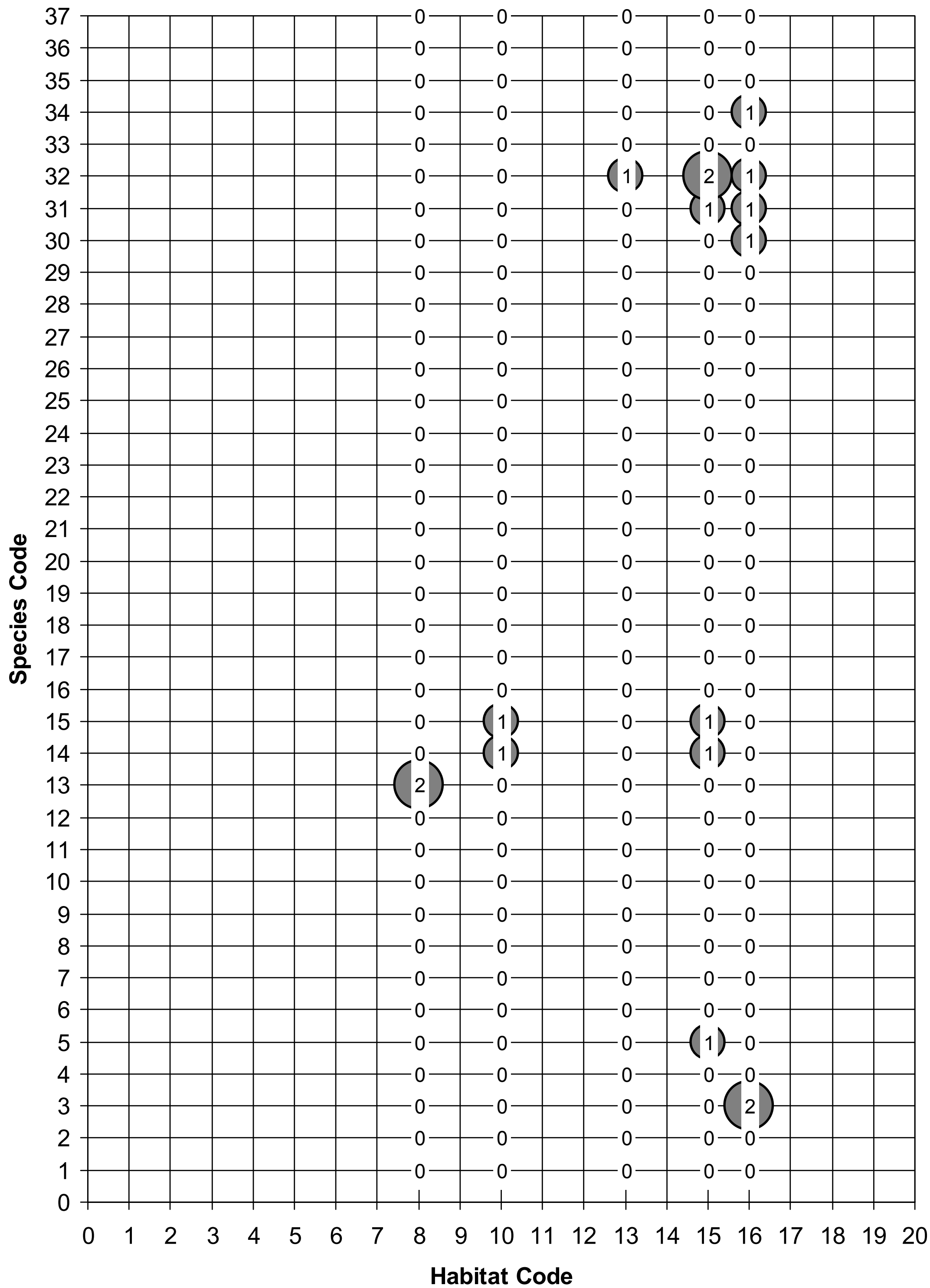


Figure 100. Total number of fishes collected from site 2 in the Sulphur River on 27 March 1999 during the winter-high flow range (1190-340 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

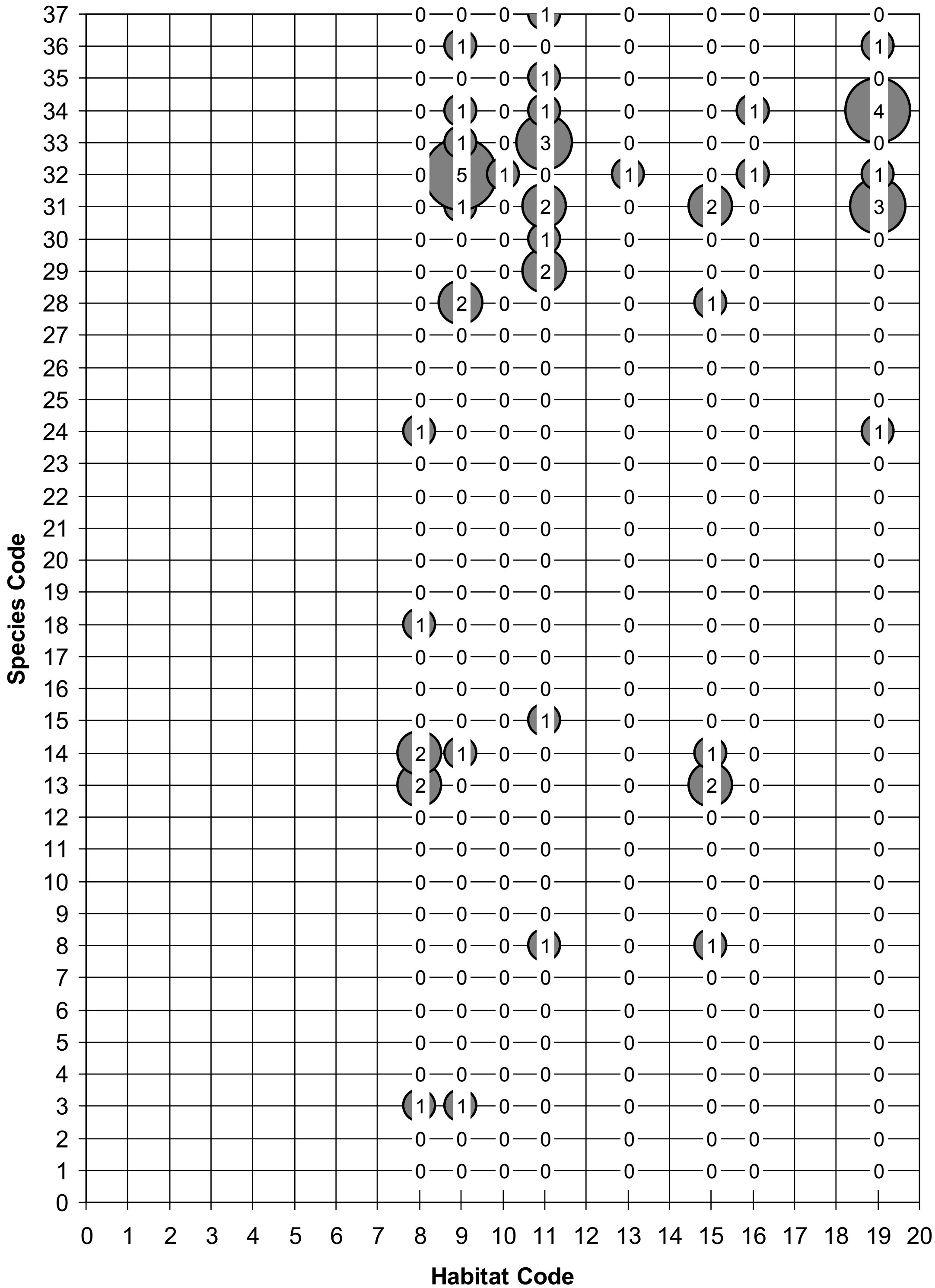


Figure 101. Total number of fishes collected from site 3 in the Sulphur River on 18 June 1999 during the summer-high flow range (500-64 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

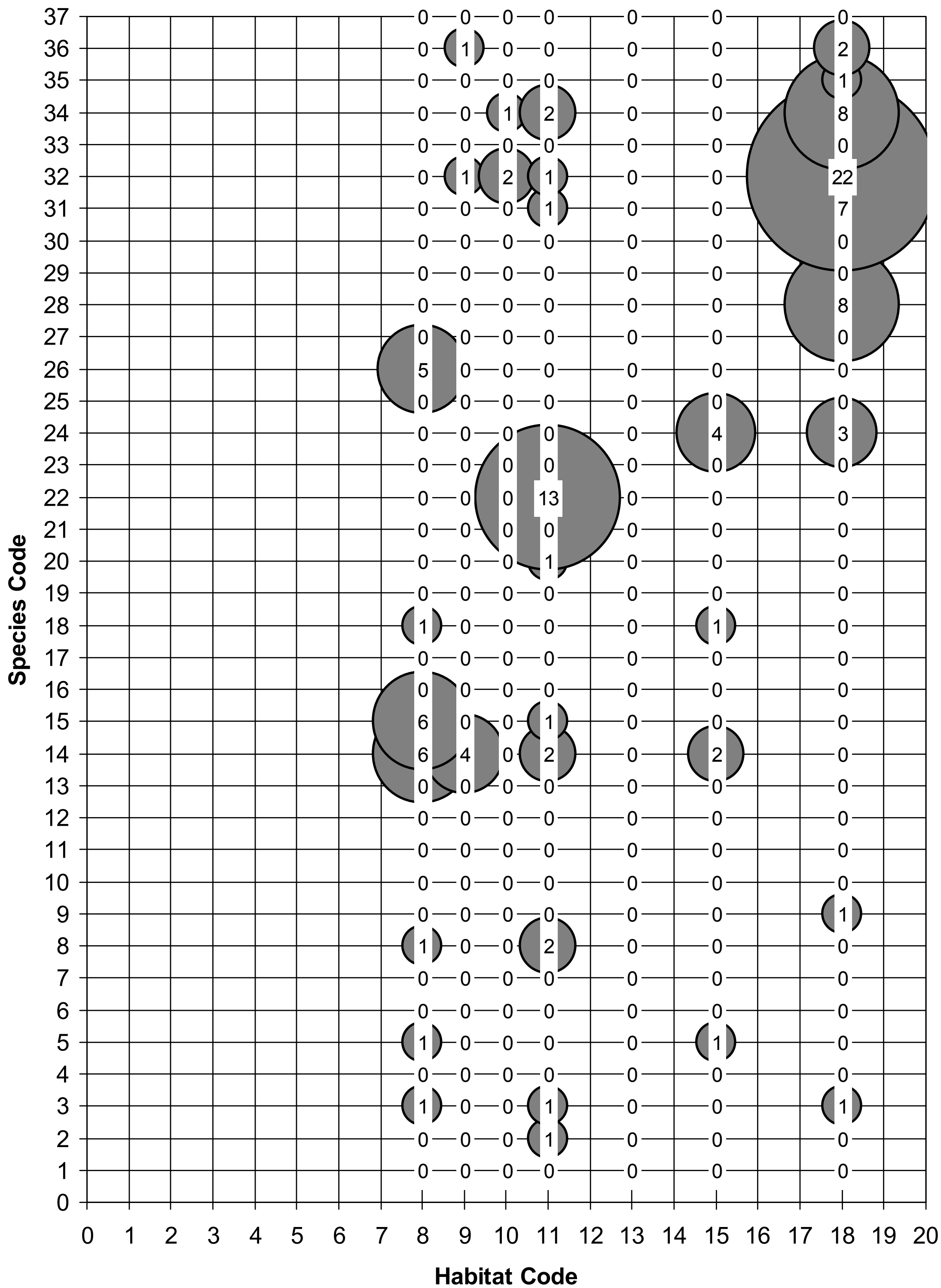


Figure 102. Total number of fishes collected from site 3 in the Sulphur River on 10 June 1999 during the summer-middle flow range (64-16 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

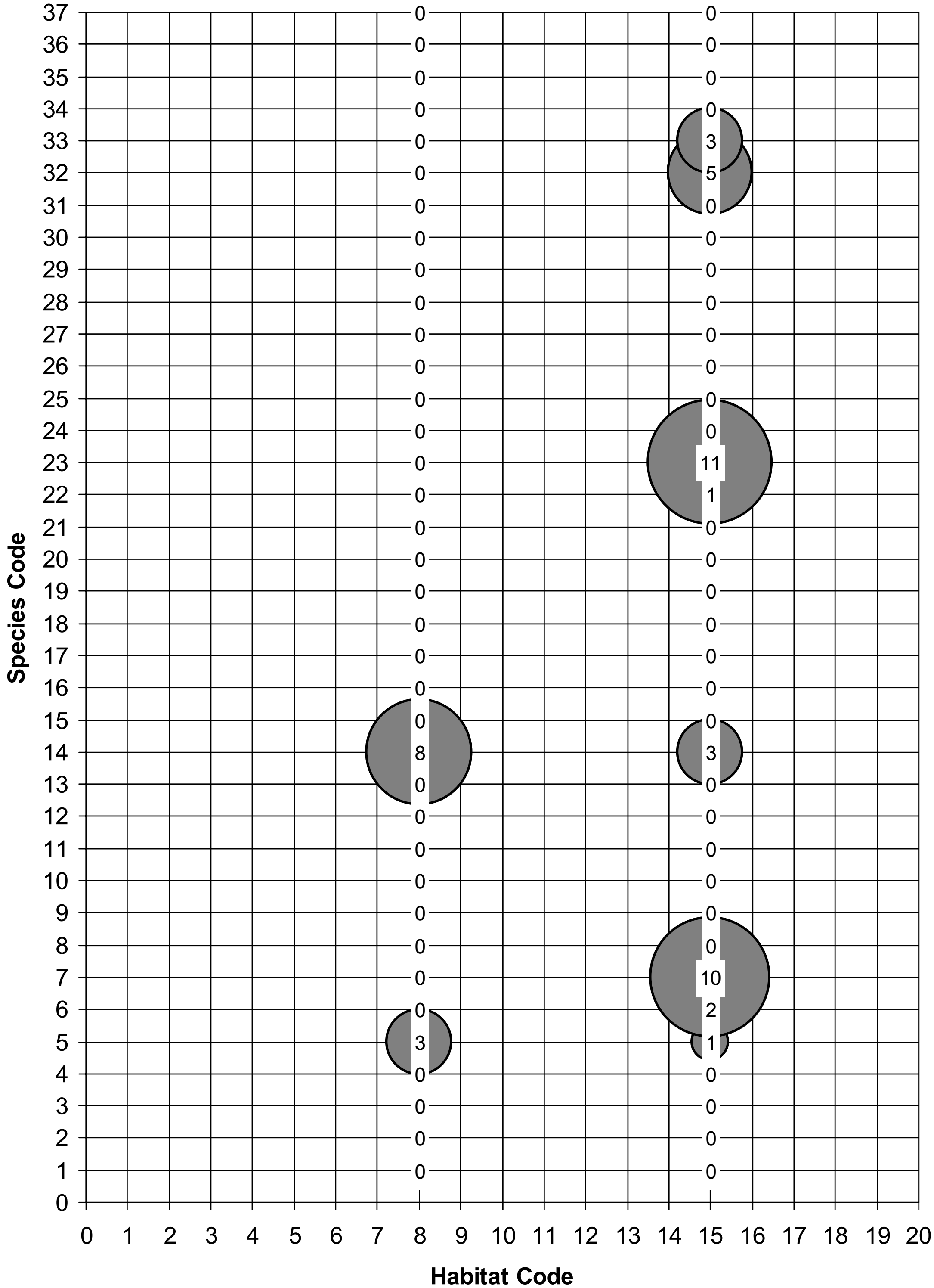


Figure 103. Total number of fishes collected from site 3 in the Sulphur River on 31 July 1998 during the summer-low flow range (<16 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

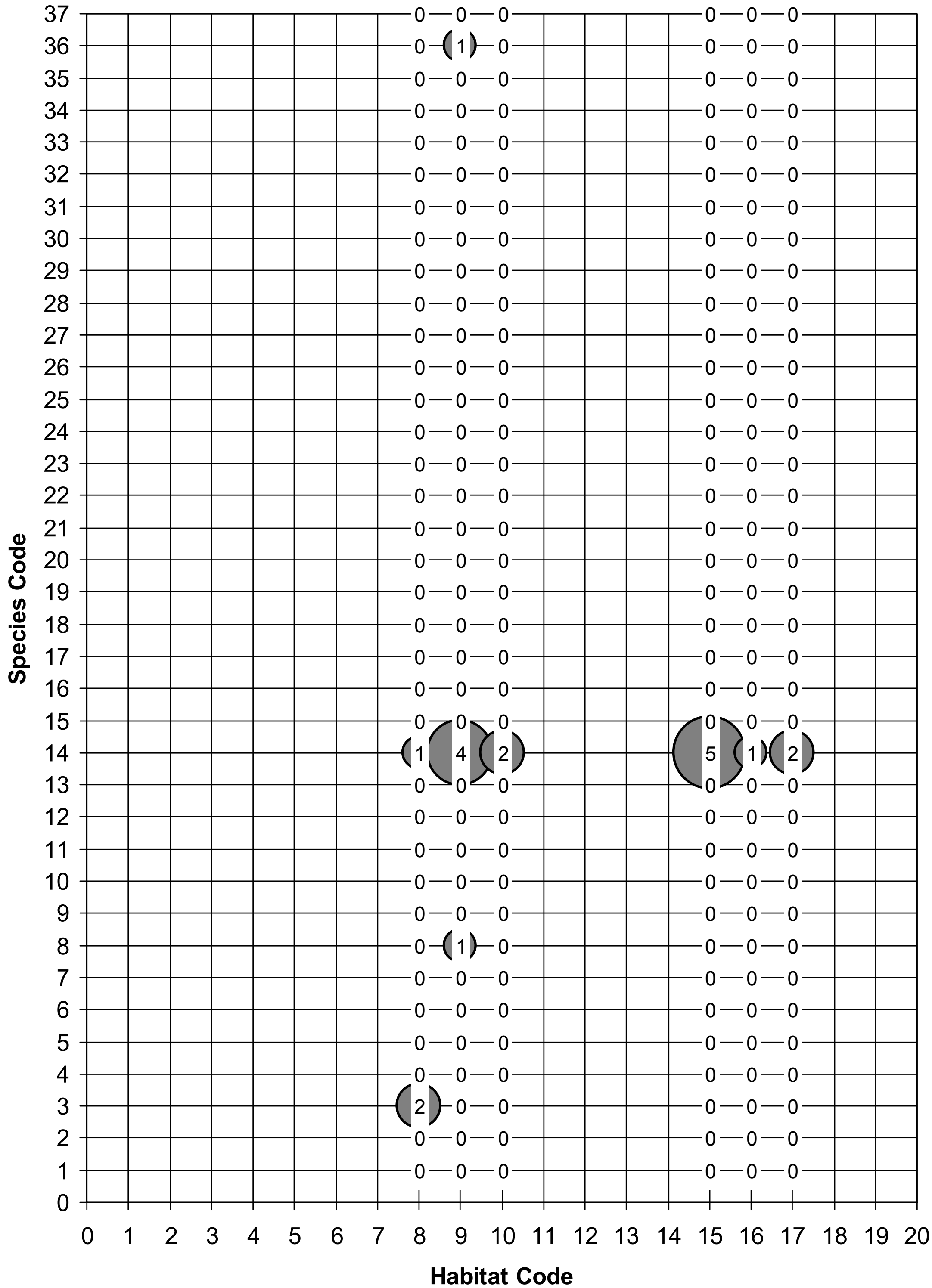


Figure 104. Total number of fishes collected from site 3 in the Sulphur River on 27 March 1999 during the winter-high flow range (1190-340 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

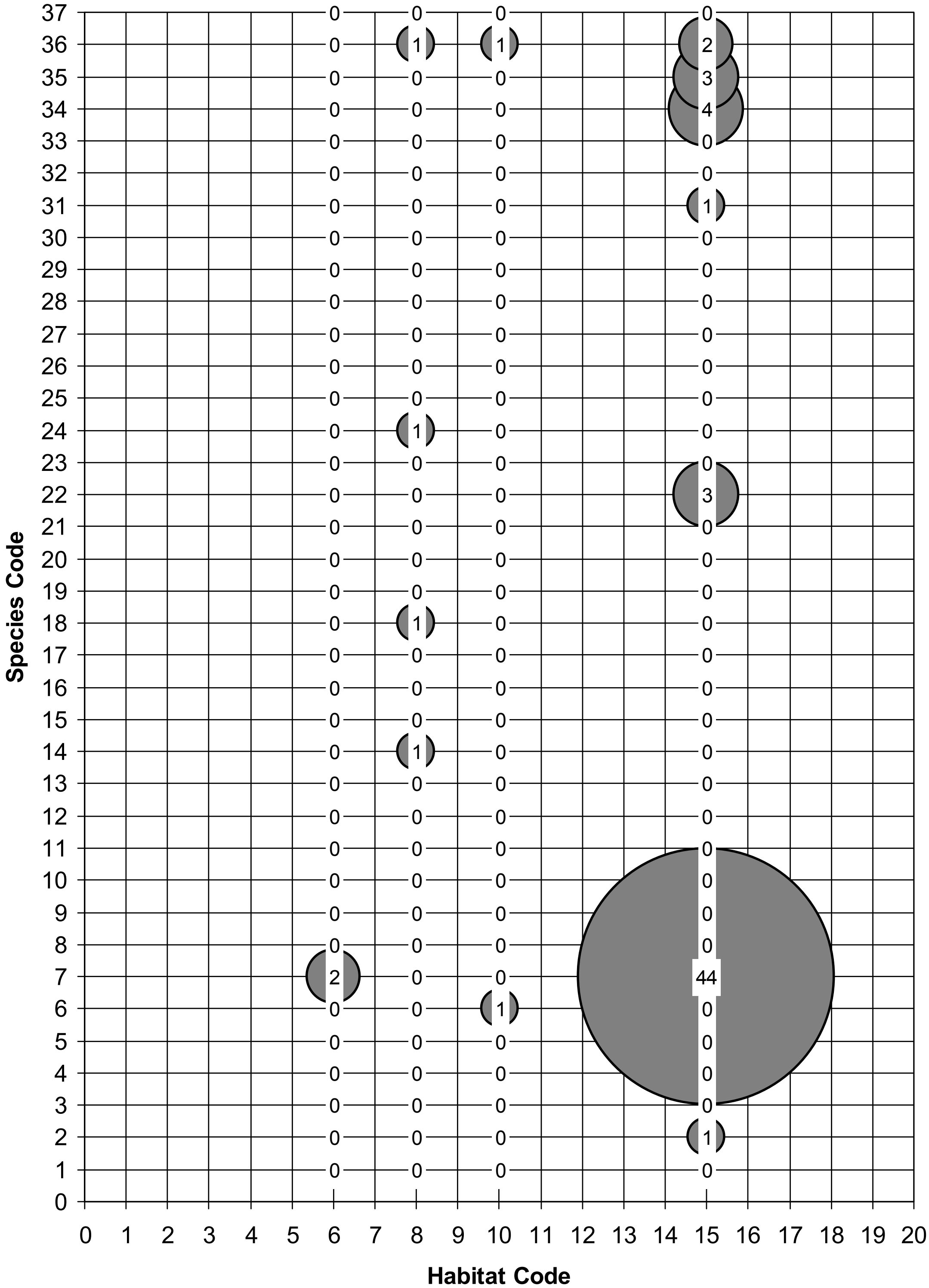


Figure 105. Total number of fishes collected from site 4 in the Sulphur River on 25 May 1999 during the summer-high flow range (500-64 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

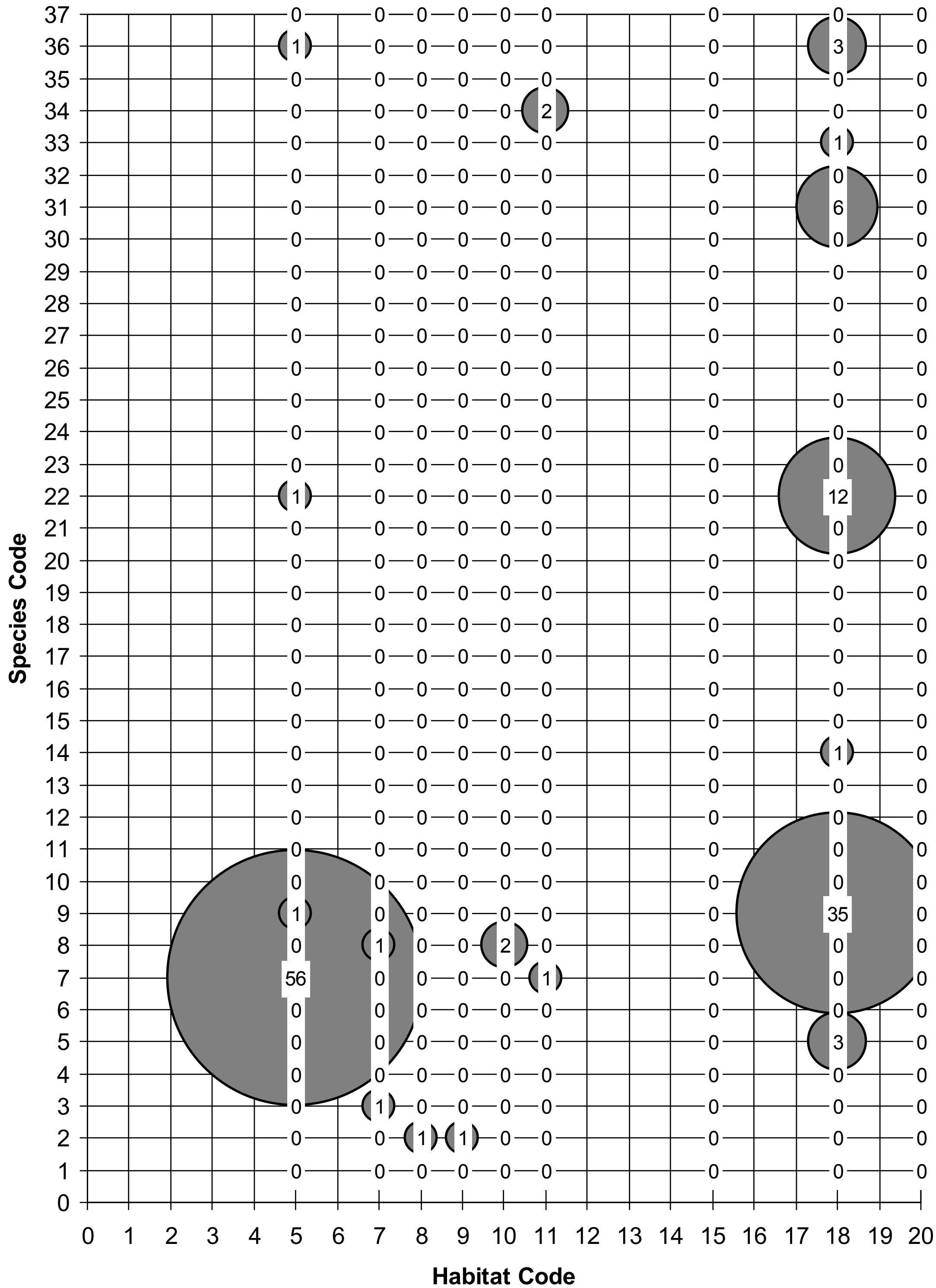


Figure 106. Total number of fishes collected from site 4 in the Sulphur River on 9 June 1999 during the summer-middle flow range (64-16 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

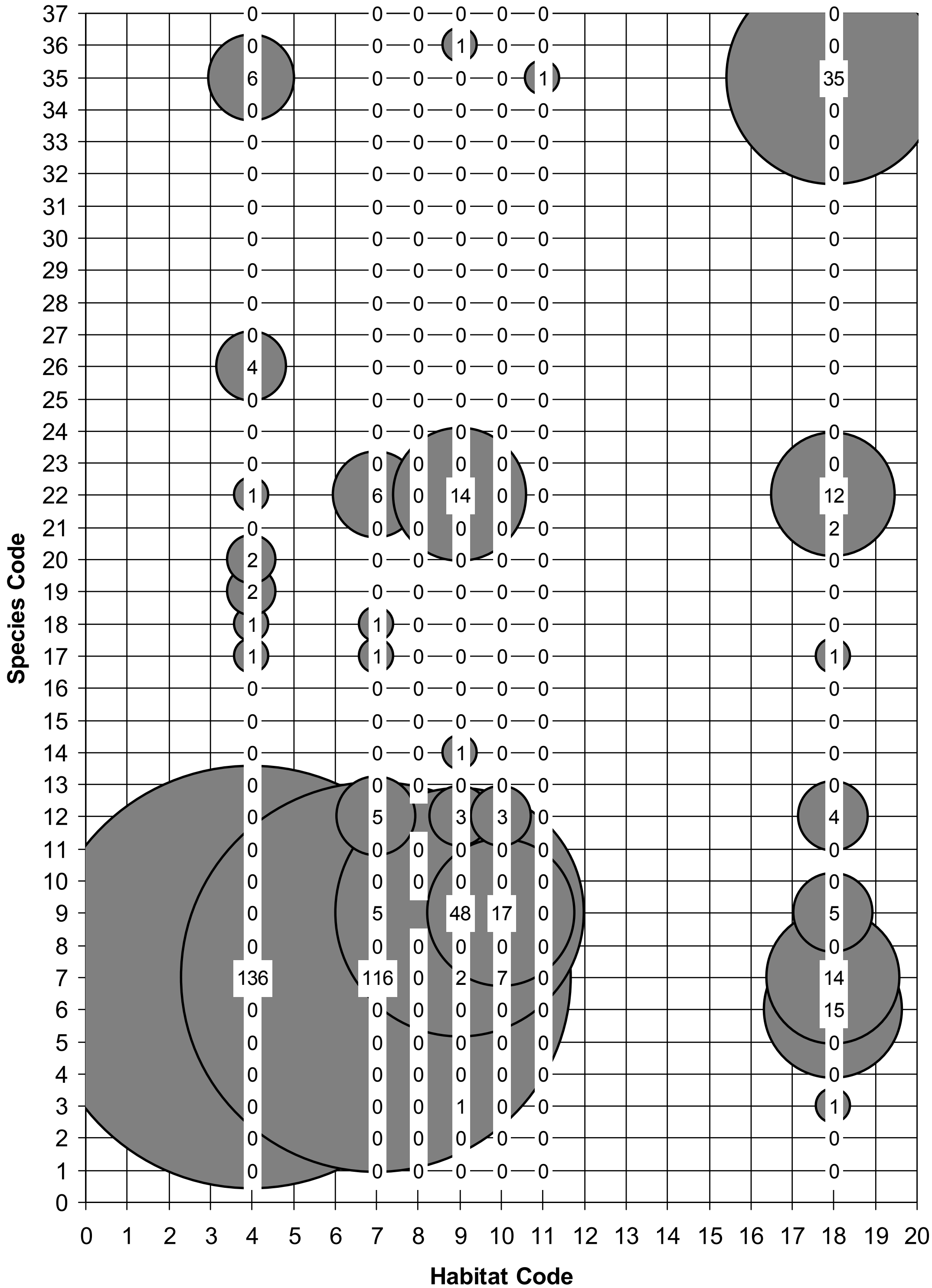


Figure 107. Total number of fishes collected from site 4 in the Sulphur River on 1 August 1998 during the summer-low flow range (<16 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

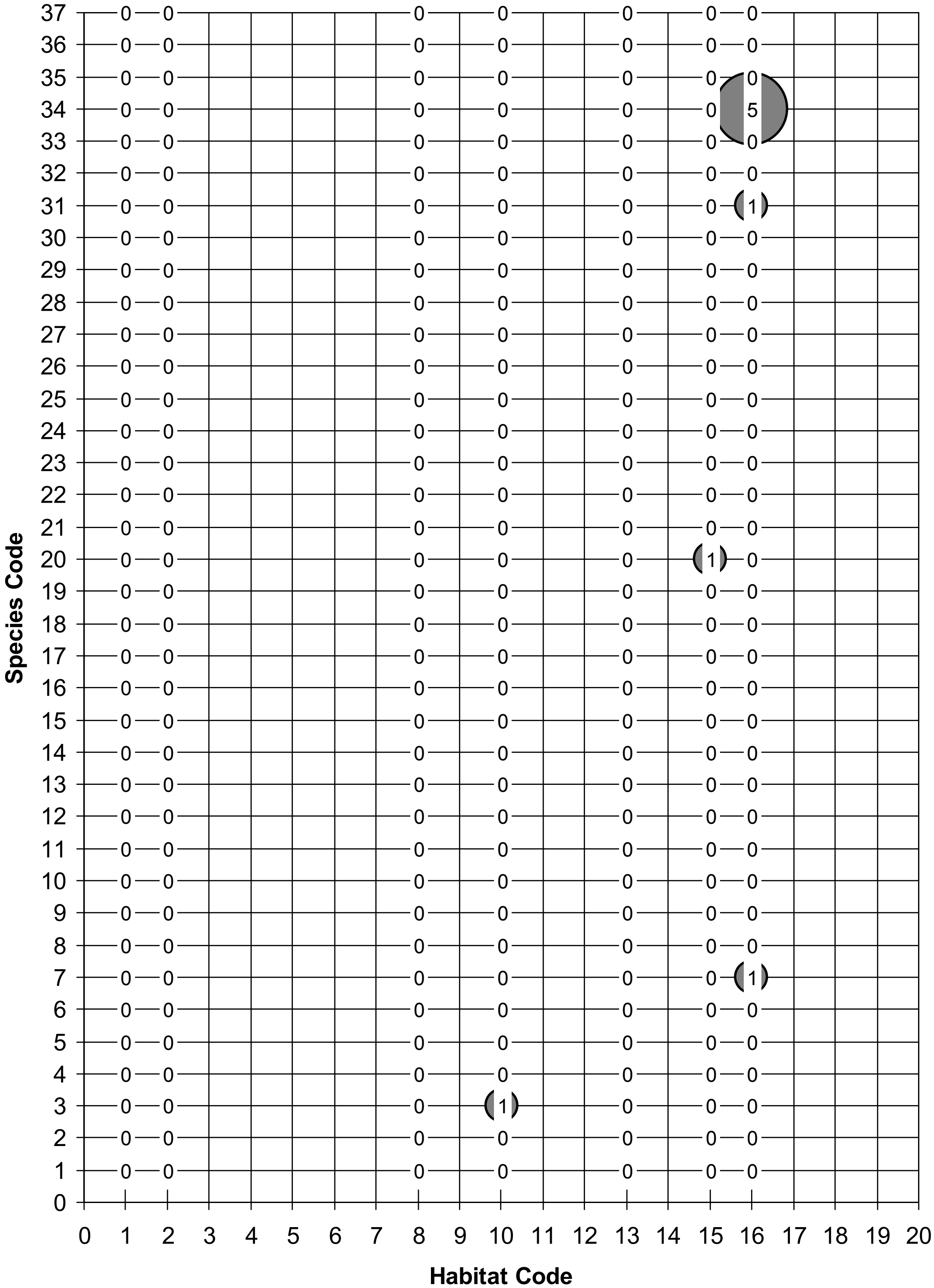


Figure 108. Total number of fishes collected from site 4 in the Sulphur River on 22 November 1998 during the winter-high flow range (1190-340 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

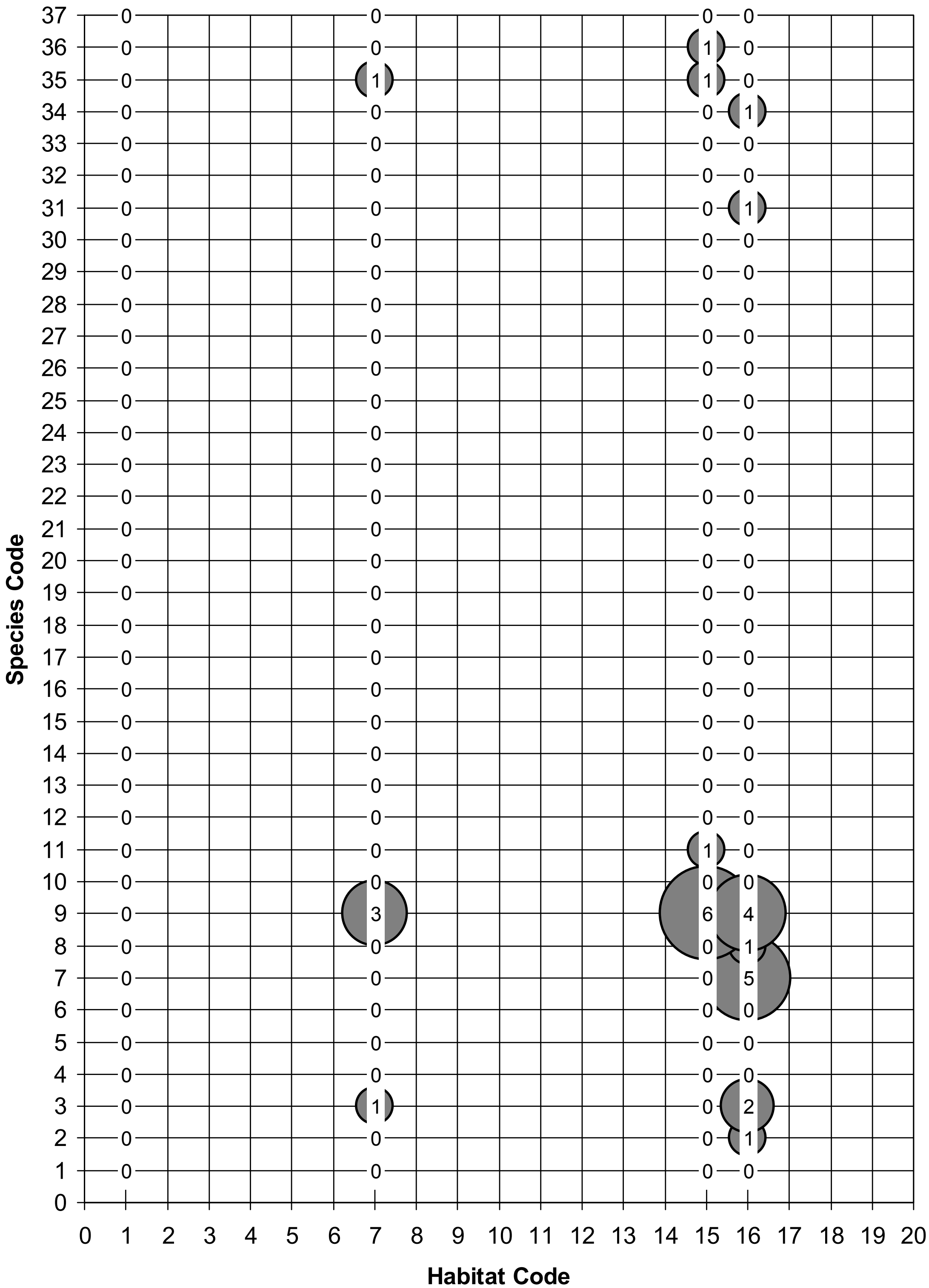


Figure 109. Total number of fishes collected from site 4 in the Sulphur River on 14 January 1999 during the winter-middle flow range (340-33 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

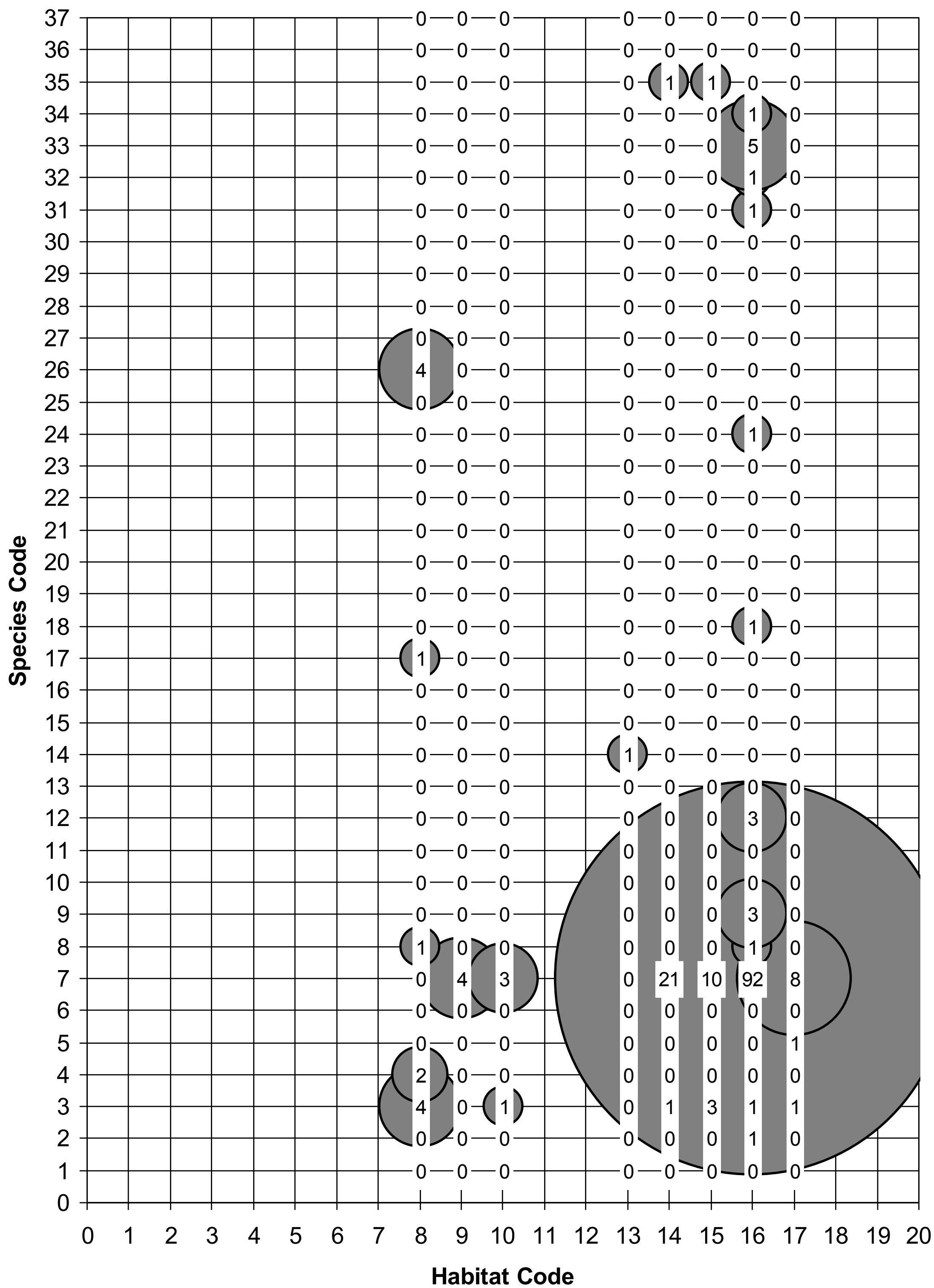


Figure 110. Total number of fishes collected from site 5 in the Sulphur River on 16 June 1999 during the summer-high flow range (500-64 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

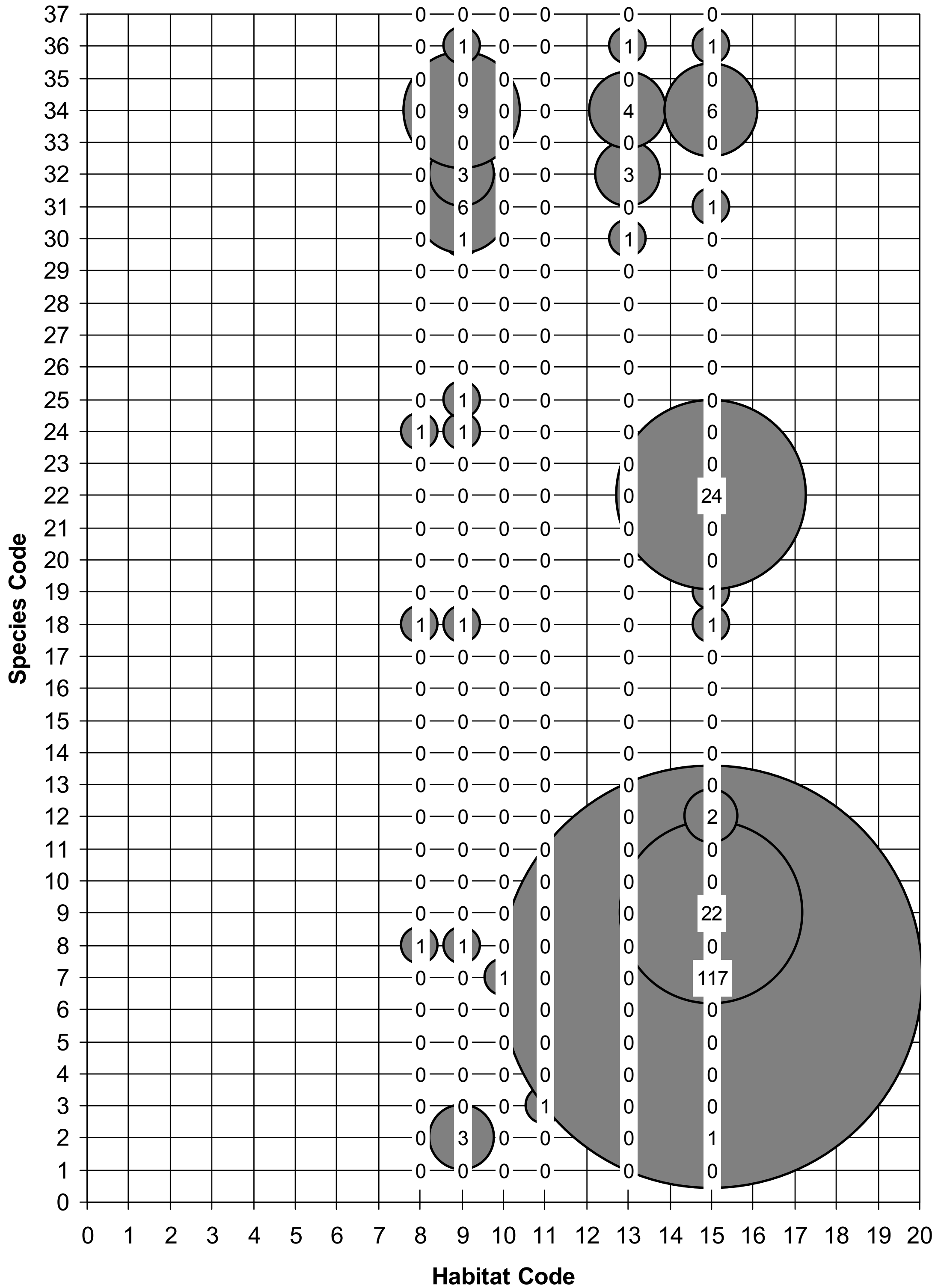


Figure 111. Total number of fishes collected from site 5 in the Sulphur River on 8 June 1999 during the summer-middle flow range (64-16 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

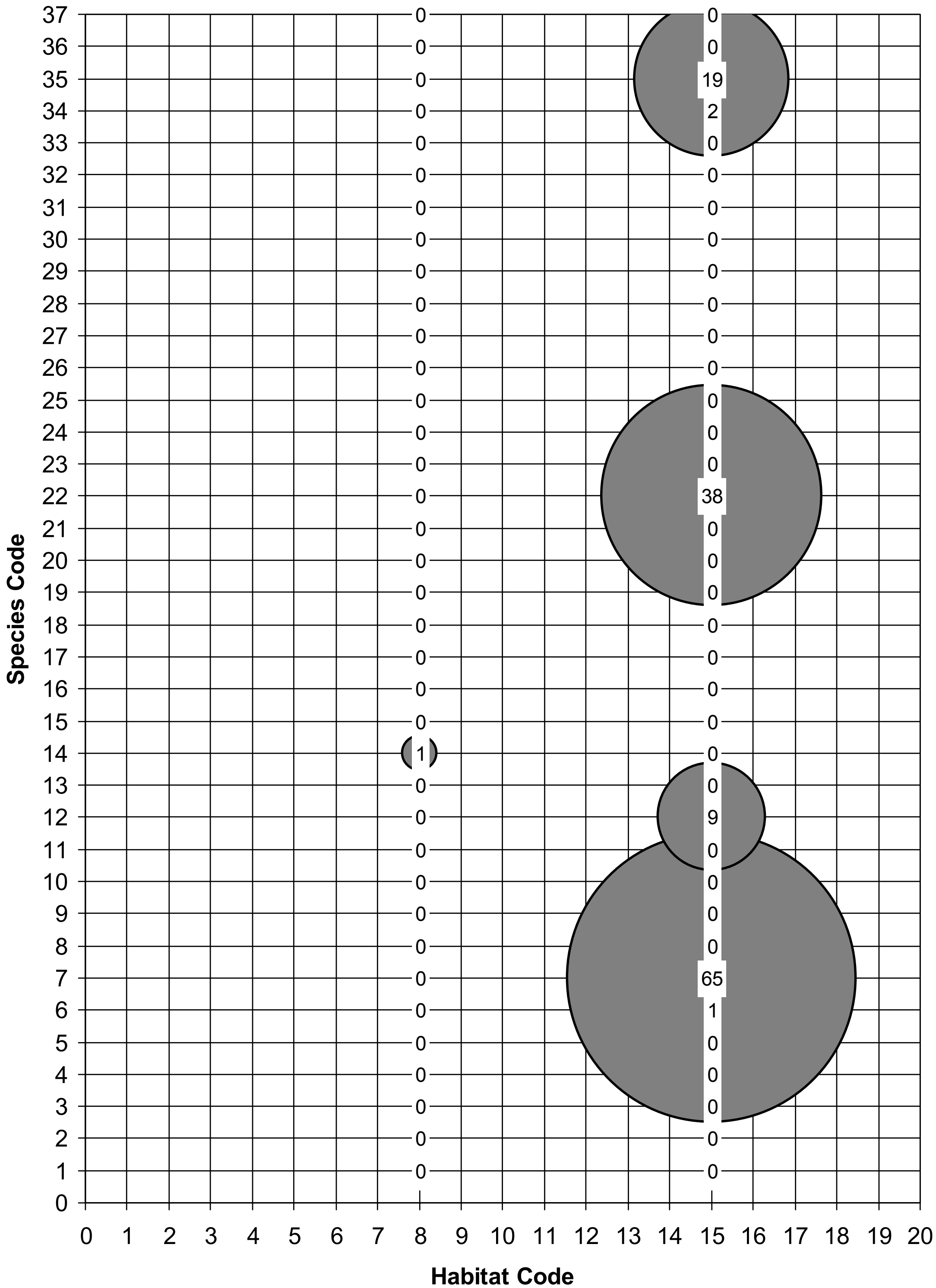


Figure 112. Total number of fishes collected from site 5 in the Sulphur River on 1 August 1998 during the summer-low flow range (<16 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

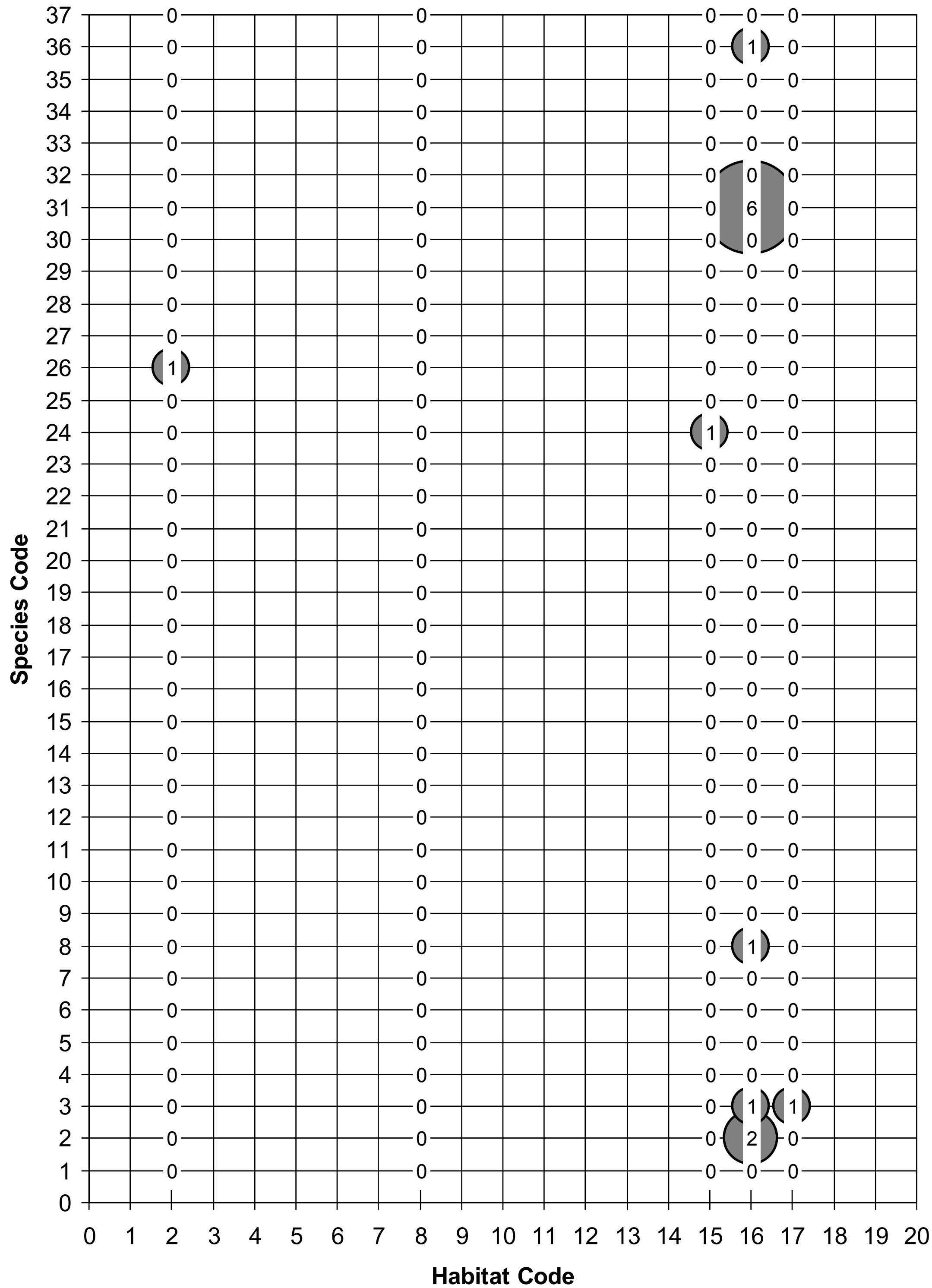

Figure 113. Total number of fishes collected from site 5 in the Sulphur River on 23 November 1998 during the winter-high flow range (1190-340 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

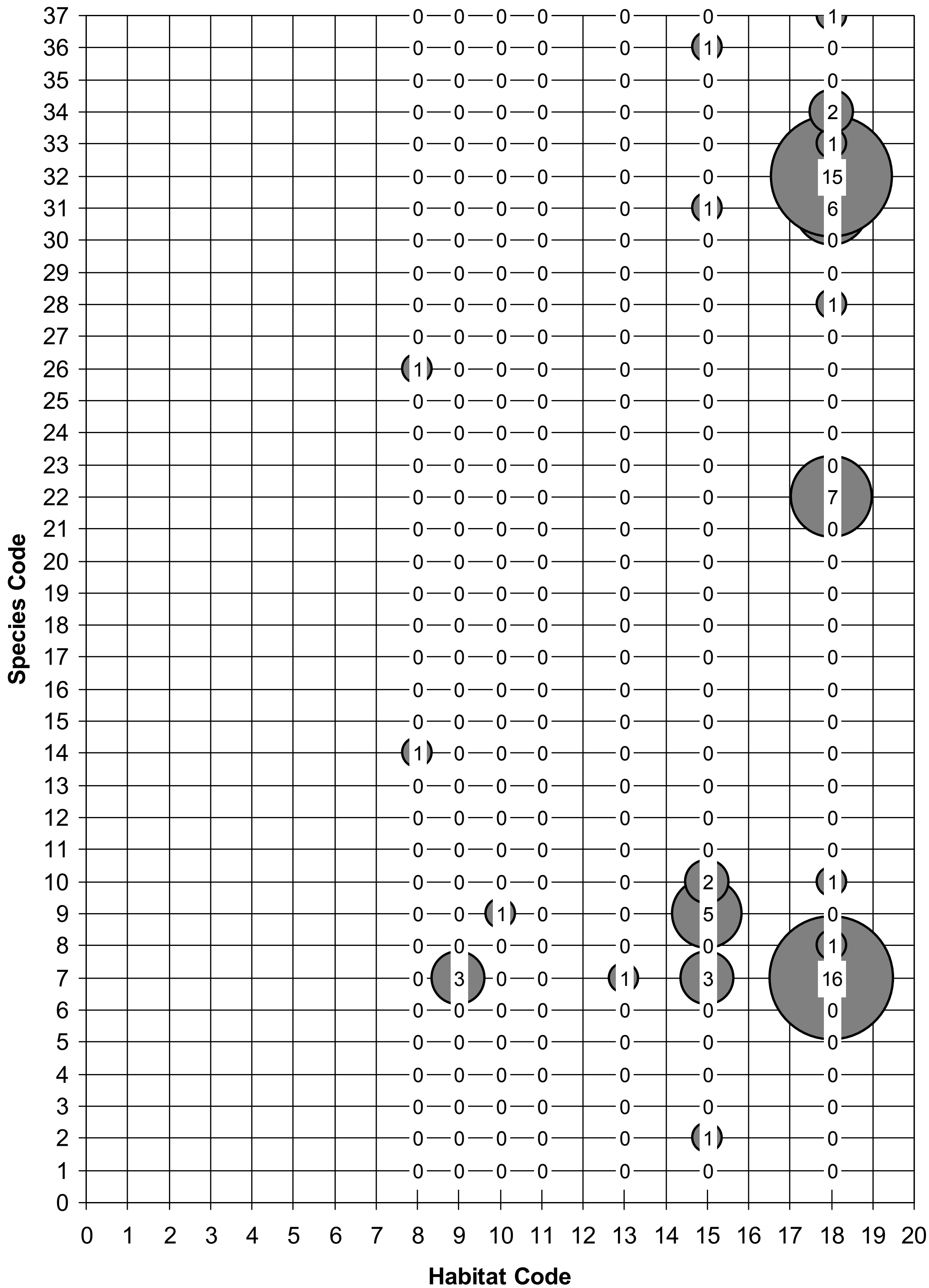


Figure 114. Total number of fishes collected from site 5 in the Sulphur River on 13 January 1999 during the winter-middle flow range (340-33 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

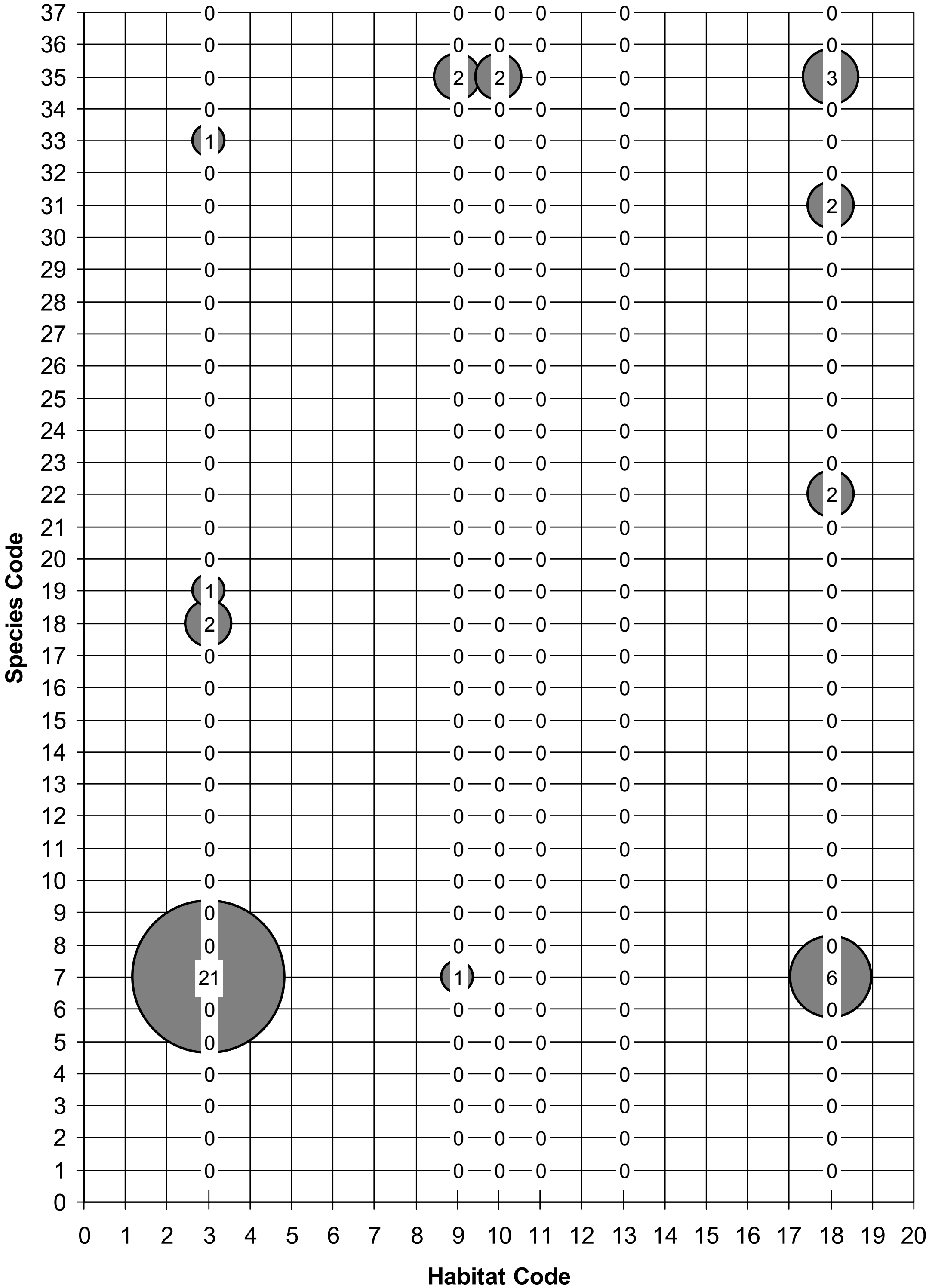


Figure 115. Total number of fishes collected from site 6 in the Sulphur River on 25 May 1999 during the summer-high flow range (500-64 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

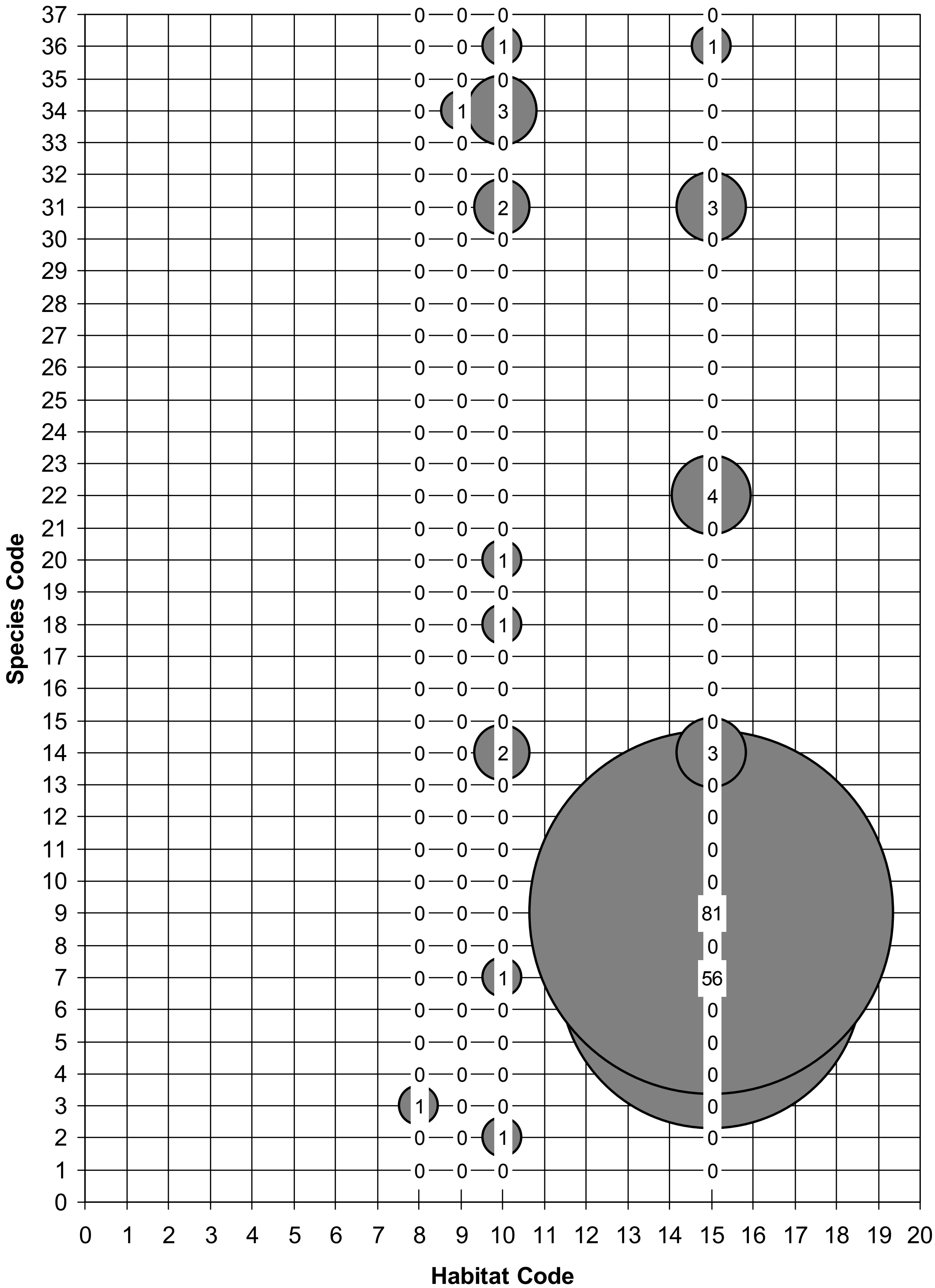


Figure 116. Total number of fishes collected from site 6 in the Sulphur River on 8 June 1999 during the summer-middle flow range (64-16 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

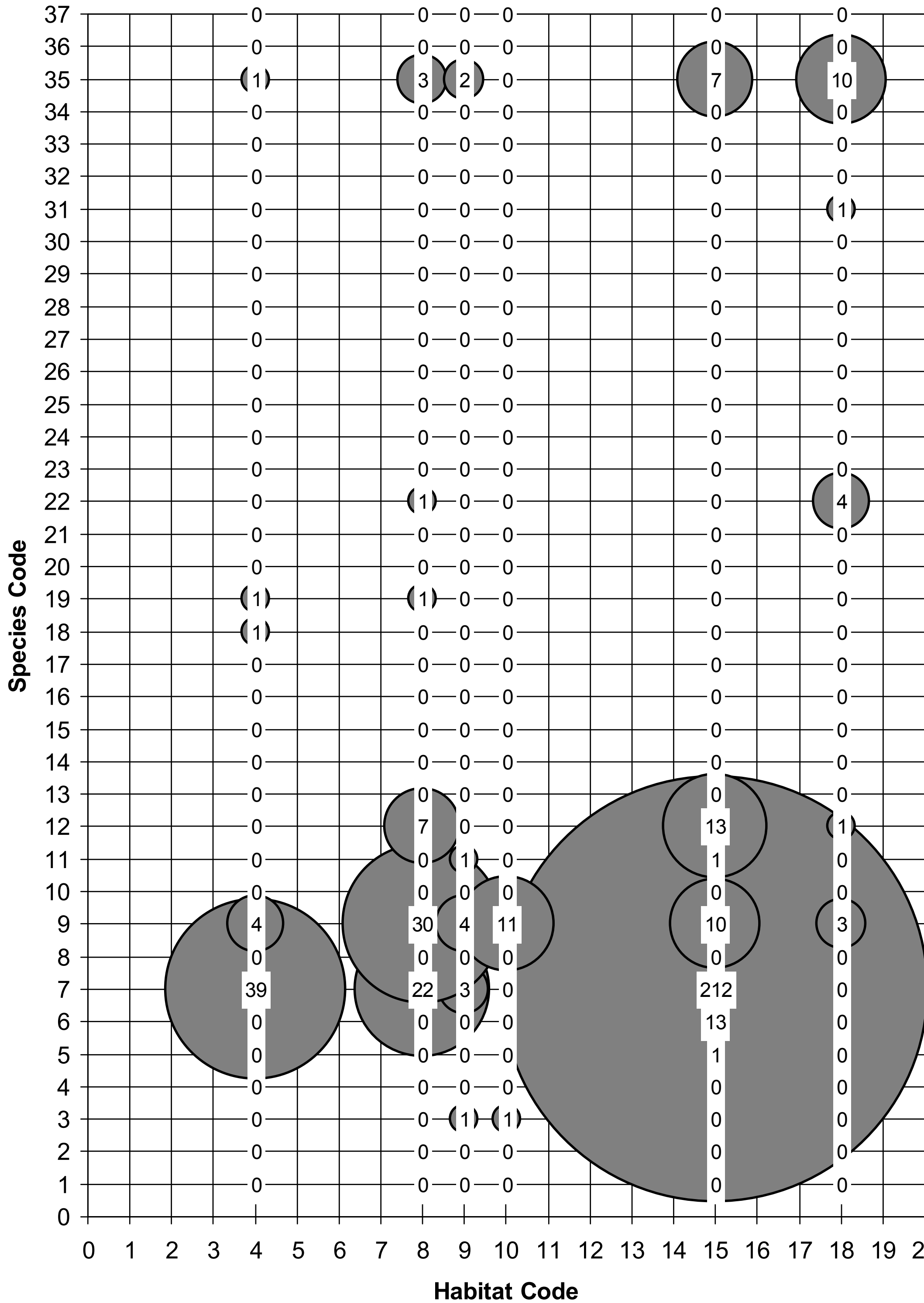


Figure 117. Total number of fishes collected from site 6 in the Sulphur River on 2 August 1998 during the summer-low flow range (<16 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

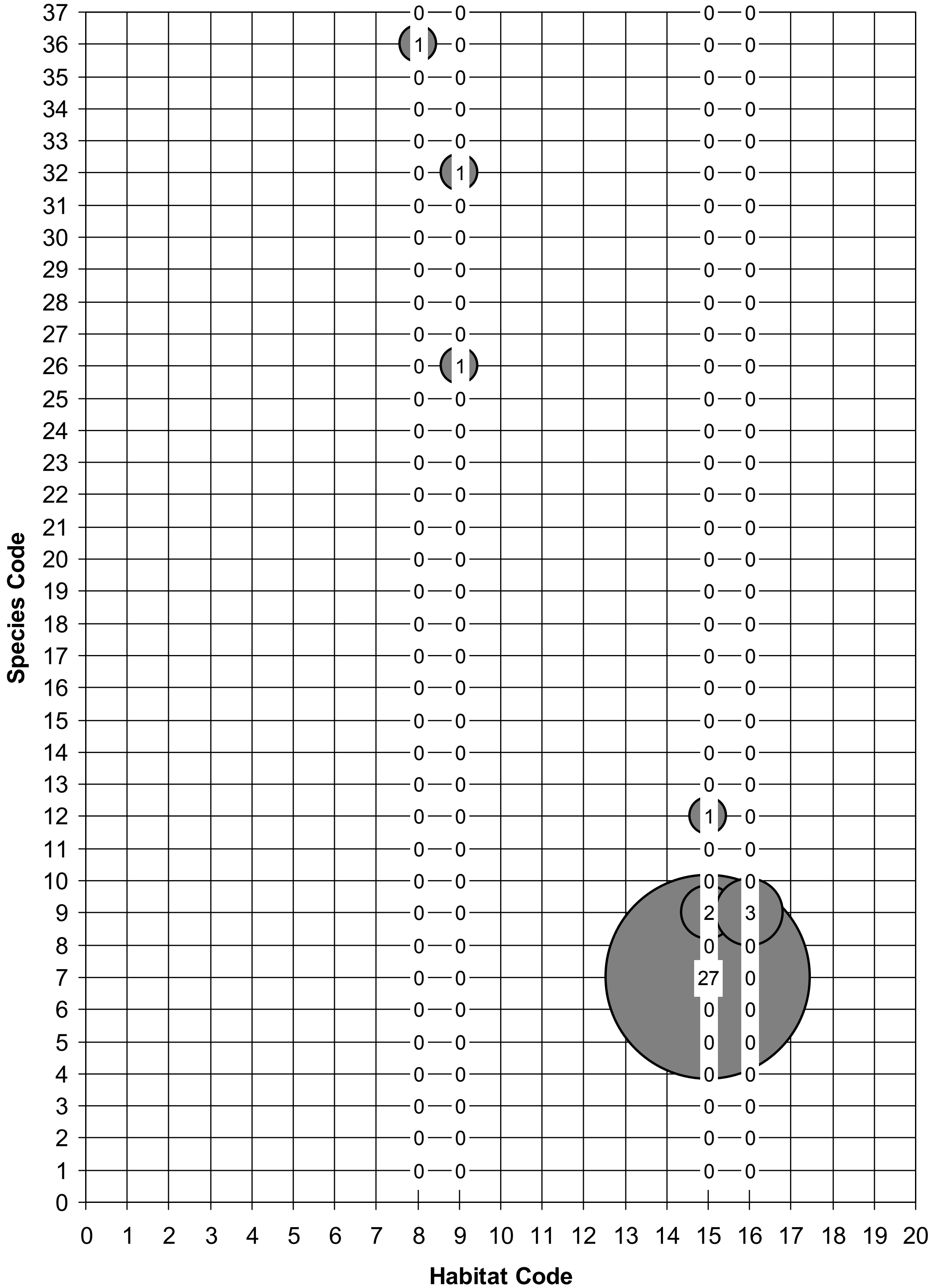


Figure 118. Total number of fishes collected from site 6 in the Sulphur River on 14 January 1999 during the winter-middle flow range (340-33 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

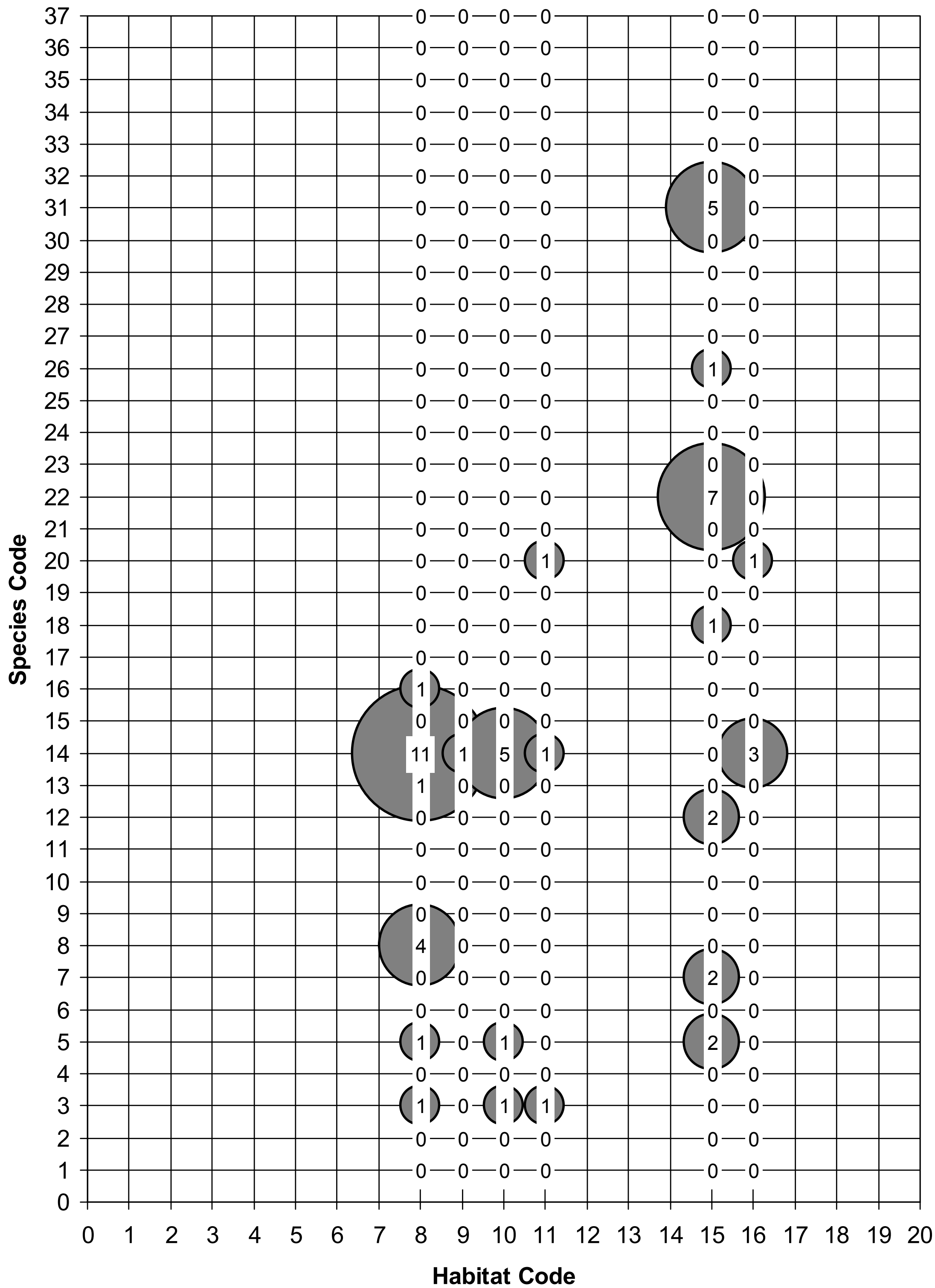


Figure 119. Total number of fishes collected from site 7 in the North Sulphur River on 19 June 1999 during the summer-high flow range (13-2.6 cfs). Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. Species and habitat codes are in Table 11.

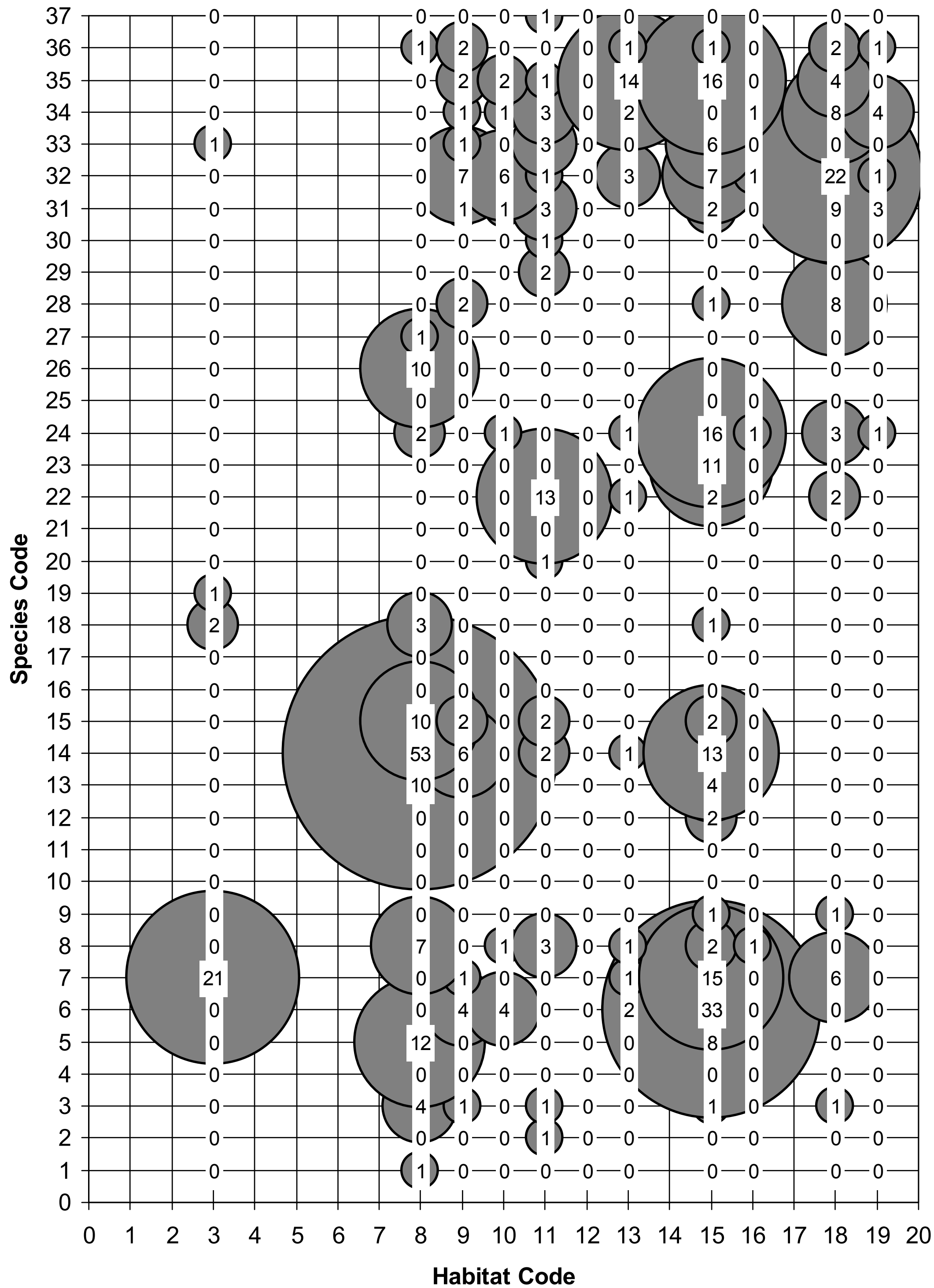


Figure 120. Total number of fishes collected in the proposed George Parkhouse I Reservoir study sites during the summer seasonal flow periods. Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. No number at an intersection indicates the habitat was absent. Species and habitat codes are in Table 11.

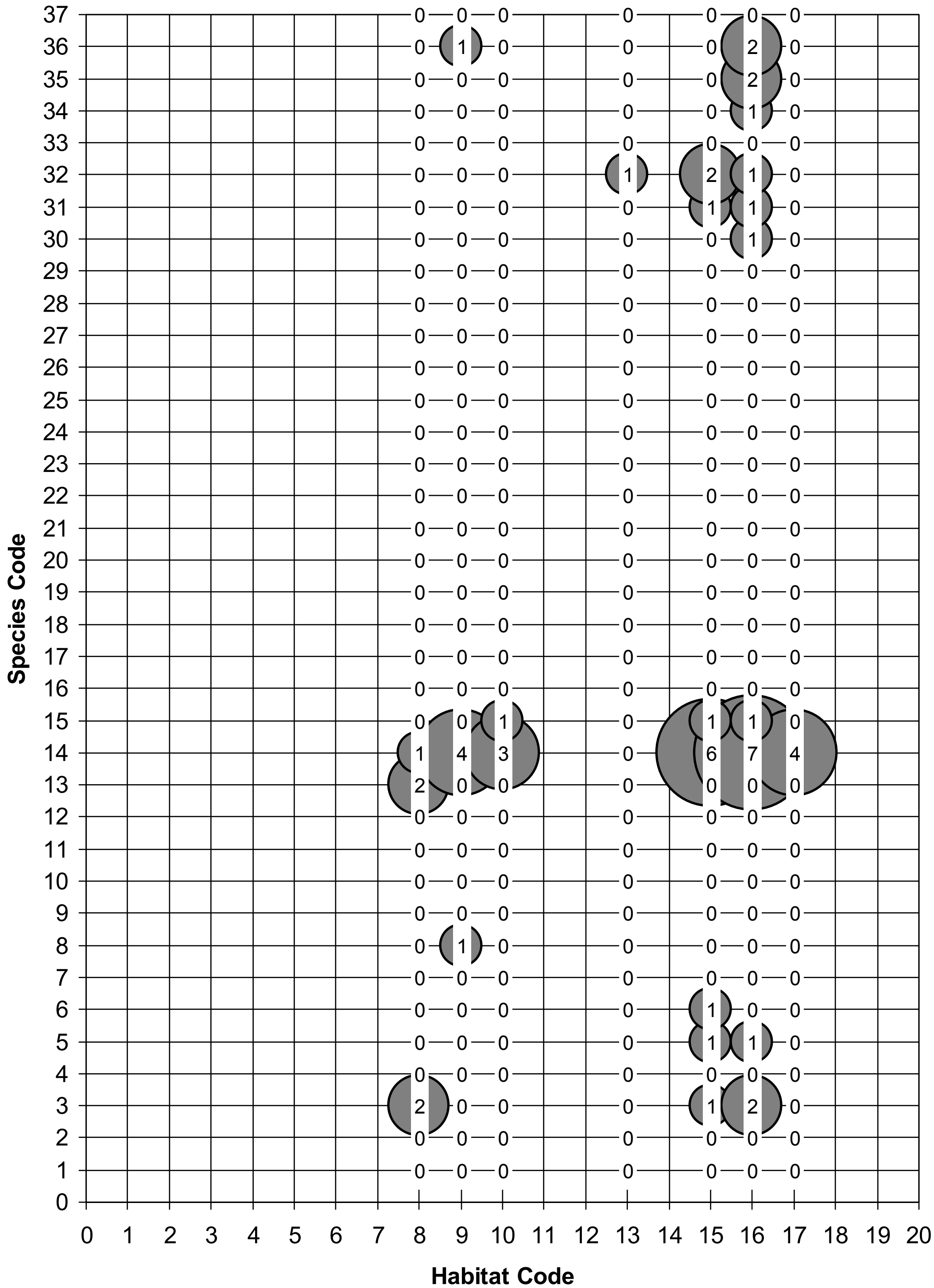


Figure 121. Total number of fishes collected in the proposed George Parkhouse I Reservoir study sites during the winter seasonal flow periods. Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. No number at an intersection indicates the habitat was absent. Species and habitat codes are in Table 11.

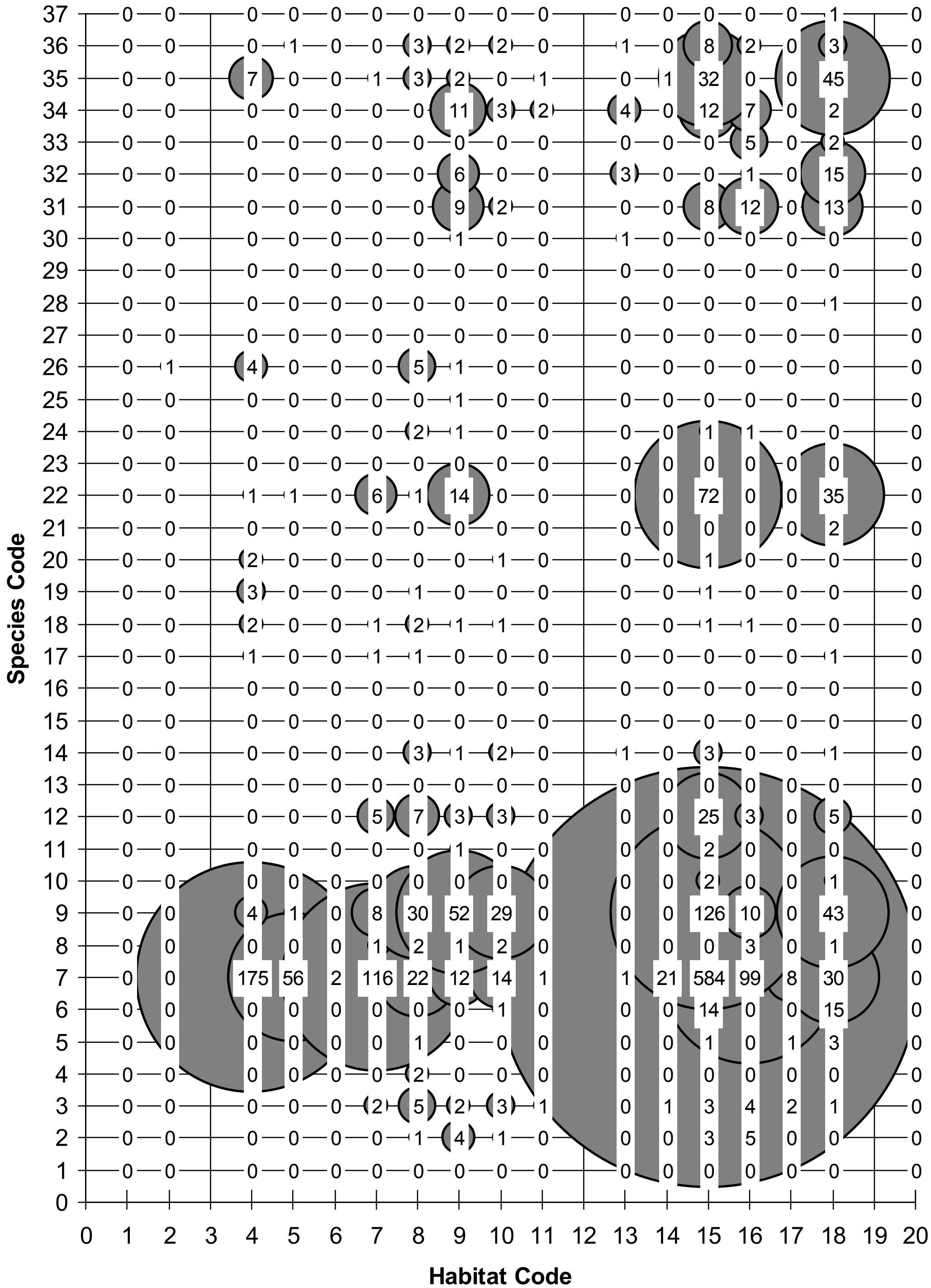


Figure 122. Total number of fishes collected in the proposed George Parkhouse I Reservoir study sites during the winter and summer seasonal flow periods. Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. No number at an intersection indicates the habitat was absent. Species and habitat codes are in Table 11.

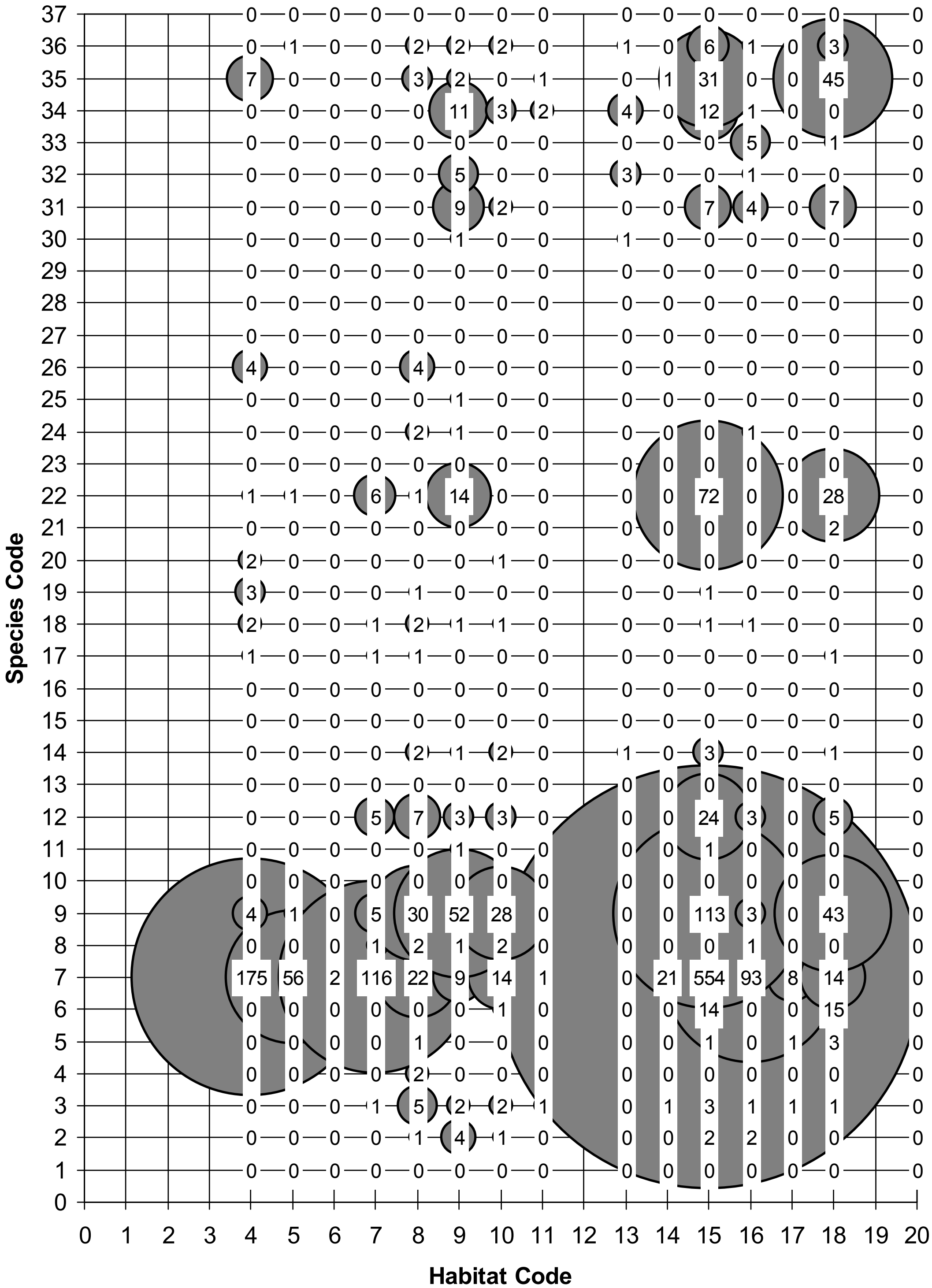


Figure 123. Total number of fishes collected in the proposed Marvin Nichols I Reservoir study sites during the summer seasonal flow periods. Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. No number at an intersection indicates the habitat was absent. Species and habitat codes are in Table 11.

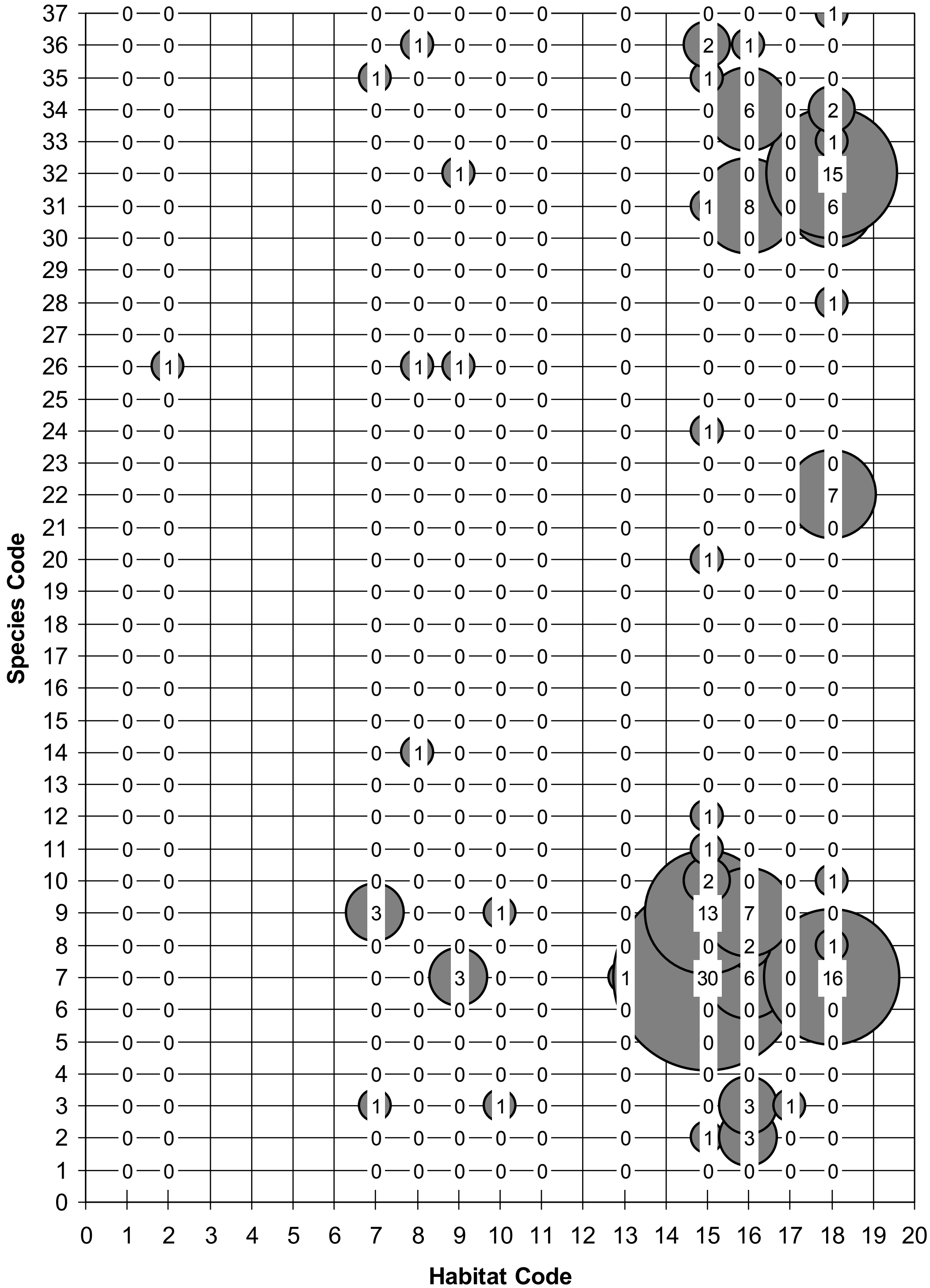


Figure 124. Total number of fishes collected in the proposed Marvin Nichols I Reservoir study sites during the winter seasonal flow periods. Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. No number at an intersection indicates the habitat was absent. Species and habitat codes are in Table 11.

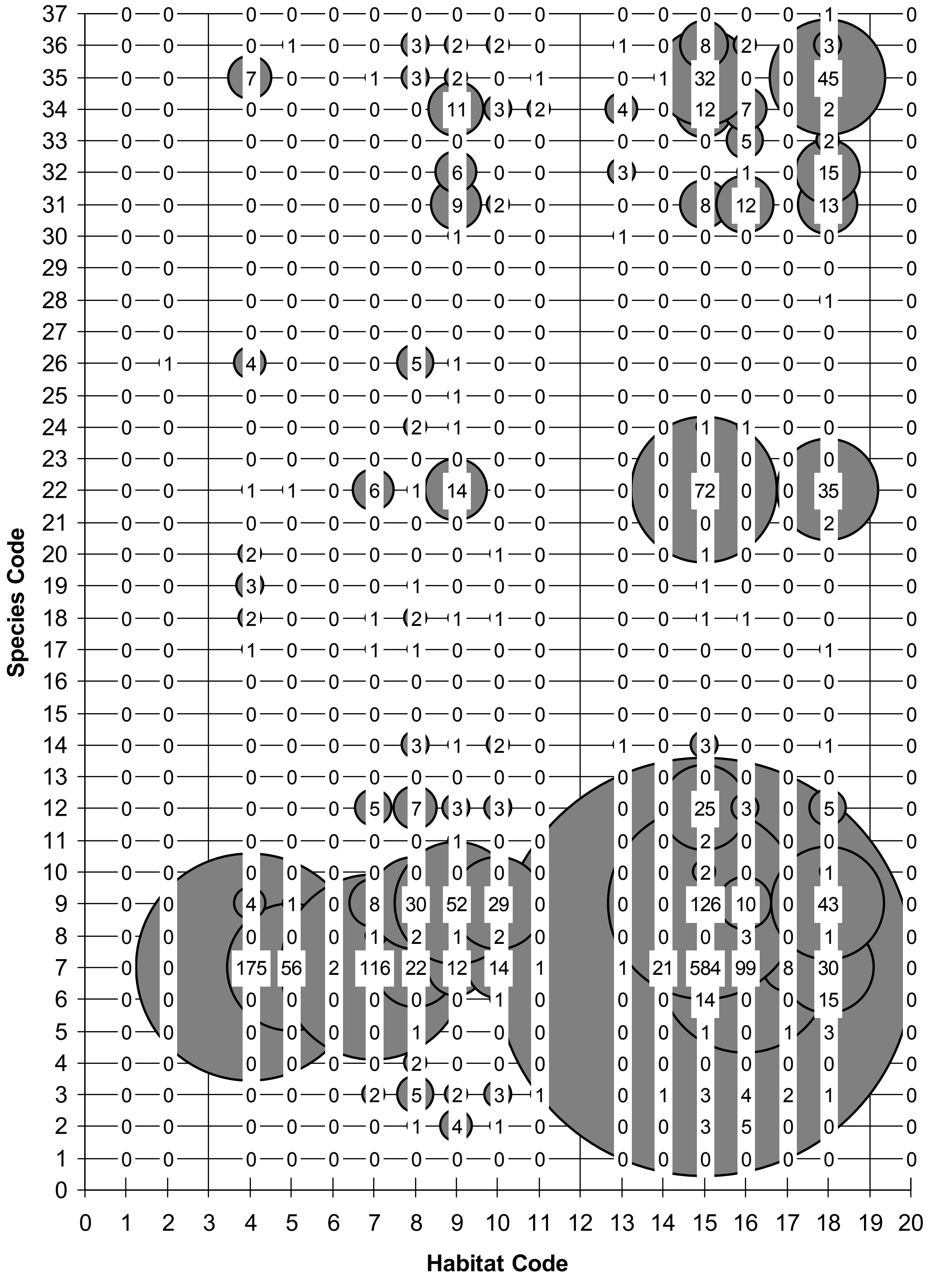


Figure 125. Total number of fishes collected in the proposed Marvin Nichols I Reservoir study sites during the summer and winter seasonal flow periods. Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. No number at an intersection indicates the habitat was absent. Species and habitat codes are in Table 11.

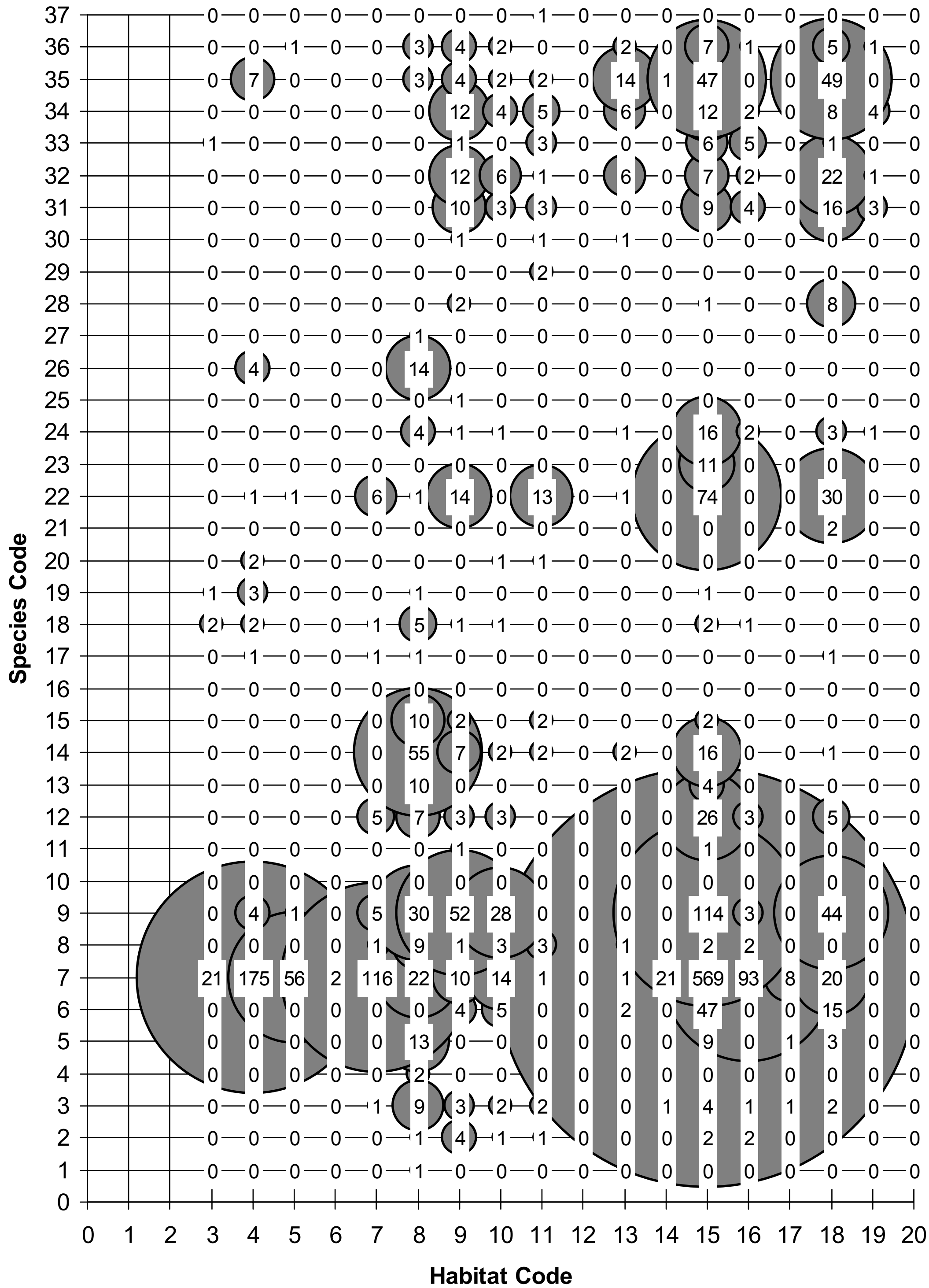


Figure 126. Total number of fishes collected in the proposed George Parkhouse I and Marvin Nichols I reservoir study sites during the summer seasonal flow periods. Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. No number at an intersection indicates the habitat was absent. Species and habitat codes are in Table 11.

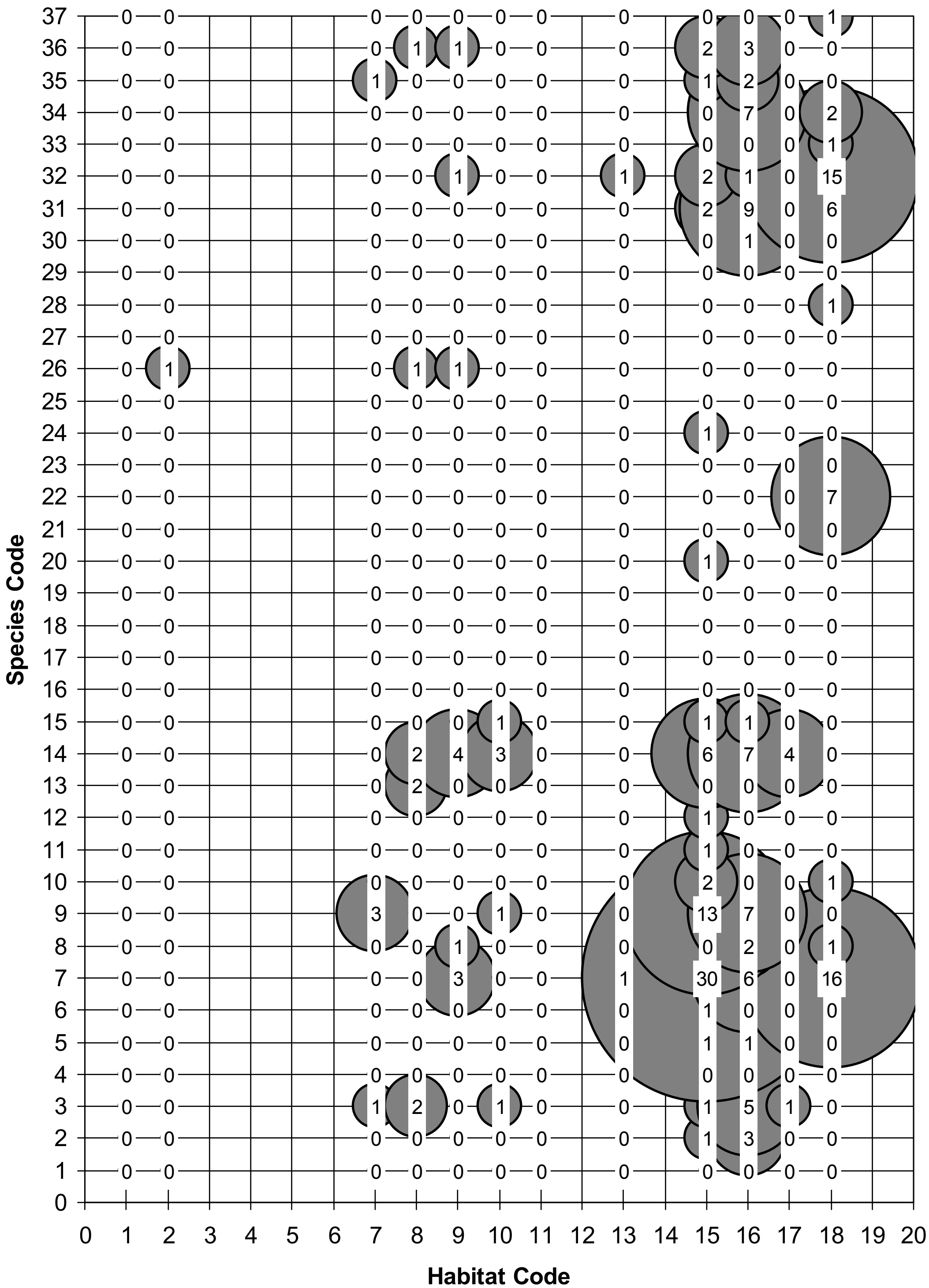


Figure 127. Total number of fishes collected in the proposed George Parkhouse I and Marvin Nichols I reservoir study sites during the winter seasonal flow periods. Number of fish is indicated at the intersections of species and habitat codes and also by relative size of bubbles centered at the intersections. Zeros indicate the species was not collected from the habitat. No number at an intersection indicates the habitat was absent. Species and habitat codes are in Table 11.

Table 12. Modified IBI metrics and sum ranks for the Sulphur River.

| | | Ranks | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Site | | | | | | |
| Category | Metric | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Species richness and composition | No. fish species | 3 | 4 | 6 | 5 | 7 | 2 | 1 |
| | No. darter species | 5.5 | 2 | 2 | 5.5 | 5.5 | 5.5 | 2 |
| | No. sunfish species | 4.5 | 4.5 | 7 | 2.5 | 6 | 2.5 | 1 |
| | No. sucker species | 5.5 | 5.5 | 5.5 | 2 | 2 | 2 | 5.5 |
| | No. intolerant species | 3.5 | 3.5 | 7 | 3.5 | 3.5 | 3.5 | 3.5 |
| | % tolerant species | 4 | 7 | 5 | 2 | 1 | 3 | 6 |
| | % mosquitofish | 5.5 | 7 | 4 | 3 | 2 | 5.5 | 1 |
| Trophic composition | % omnivores | 5.5 | 1 | 7 | 4 | 5.5 | 2 | 3 |
| | % invertivores | 4 | 2 | 7 | 3 | 6 | 1 | 5 |
| | % piscivores | 7 | 4 | 6 | 2 | 3 | 1 | 5 |
| | Sum | 48 | 40.5 | 56.5 | 32.5 | 41.5 | 28 | 33 |
| | % of possible score | 69 | 58 | 81 | 46 | 59 | 40 | 47 |

Table 13. Indicator values for fish based on relative abundance and frequency of occurrence in Sulphur River habitat groups. *P* is the proportion of Monte Carlo randomized trials (1000) with indicator values equal to or exceeding the observed indicator value. Bold numbers indicate the value that is highest for each species.

| | | Habitat groups[a] | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| Species | *P* | Run, Pool, Pool-bank snag, Pool-channel snag, Pool-debris dam, Pool-tree | Pool-rootwad, Backwater, Backwater-bank snag | Riffle-snag complex, Riffle-debris dam, Riffle-edge | Pool-snag complex, Pool-vegetation |
| Bluegill | 0.002 | 0 | 2 | 1 | **95** |
| Freshwater drum | 0.003 | 0 | 1 | 1 | **96** |
| White crappie | 0.004 | 1 | 1 | 0 | **95** |
| Longear sunfish | 0.005 | 0 | 1 | 4 | **95** |
| Longnose gar | 0.015 | 0 | **71** | 20 | 3 |
| Red shiner | 0.018 | **72** | 14 | 1 | 9 |
| Orangespotted sunfish | 0.187 | 0 | 1 | 2 | **63** |
| Mosquitofish | 0.246 | 4 | 1 | 1 | **60** |
| Threadfin shad | 0.275 | 0 | 17 | 0 | **40** |
| Common carp | 0.302 | 0 | 8 | 11 | **52** |
| Smallmouth buffalo | 0.491 | 0 | **38** | 6 | 27 |
| Bullhead minnow | 0.655 | 0 | **28** | 3 | 18 |
| Gizzard shad | 0.723 | 0 | 11 | 0 | **27** |
| Mississippi silvery minnow | 0.889 | 2 | 7 | 0 | **29** |

[a]An additional group containing only riffle-channel snag habitat was formed during the cluster analysis. This group was not included because the habitat occurred only once during sampling and the only species collected was red shiner.

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# APPENDIX

## Fish Collections and Habitat Measurements

The additional data collected during January 2000 are given for abundance of fishes in each habitat type that was present at each site (Table A1). Extensive measurements of depth and velocity in run and riffle habitats for use in models to be developed for these sites by the Texas Water Development Board are also reported (Table A2).

Table A1. Number of fish collected by habitat type at sites 2-6 during ancillary sampling, 23-24 January 2000 for species and habitat types that were present at the site.

**Site 2**

| | Habitat type | | | |
|---|---|---|---|---|
| Species | Pool | Pool-bank snag | Pool-channel snag | Pool-edge |
| Common carp | 0 | 1 | 0 | 1 |
| Smallmouth buffalo | 2 | 0 | 1 | 0 |

Table A1. Continued.

**Site 3**

| Species | Habitat type | | | |
|---|---|---|---|---|
| | Pool | Pool-bank snag | Pool-snag complex | Pool-edge |
| Longnose gar | 1 | 0 | 1 | 0 |
| Common carp | 0 | 0 | 1 | 1 |
| River carpsucker | 1 | 0 | 0 | 0 |
| Smallmouth buffalo | 5 | 0 | 0 | 1 |
| Bigmouth buffalo | 2 | 0 | 0 | 1 |
| Blue catfish | 0 | 0 | 0 | 1 |
| Largemouth bass | 0 | 0 | 1 | 2 |
| Green sunfish | 0 | 0 | 1 | 0 |
| Orangespotted sunfish | 0 | 1 | 0 | 1 |
| Black crappie | 1 | 0 | 0 | 0 |

Table A1. Continued.

**Site 4**

| Species | Habitat type: Riffle-snag complex | Run | Pool-bank snag | Pool-channel snag | Pool-edge | Backwater-bank snag |
|---|---|---|---|---|---|---|
| Gizzard shad | 0 | 0 | 0 | 1 | 0 | 0 |
| Red shiner | 40 | 249 | 4 | 2 | 0 | 0 |
| Mississippi silvery minnow | 3 | 8 | 44 | 16 | 3 | 0 |
| Emerald Shiner | 0 | 3 | 1 | 0 | 0 | 0 |
| Bullhead minnow | 8 | 34 | 3 | 2 | 0 | 0 |
| Channel catfish | 0 | 3 | 1 | 2 | 1 | 0 |
| Freckled madtom | 1 | 0 | 0 | 0 | 0 | 0 |
| White bass | 0 | 0 | 1 | 2 | 1 | 1 |
| Spotted bass (*Micropterus punctulatus*) | 0 | 0 | 0 | 1 | 0 | 0 |
| Orangespotted sunfish | 0 | 0 | 1 | 1 | 0 | 0 |
| Bluegill | 0 | 0 | 0 | 0 | 0 | 1 |
| Longear sunfish | 0 | 4 | 0 | 5 | 0 | 1 |
| Slough darter (*Etheostoma gracile*) | 1 | 2 | 0 | 0 | 0 | 0 |

Table A1. Continued.

**Site 5**

| Species | Habitat type | | | | |
|---|---|---|---|---|---|
| | Pool | Pool-bank snag | Pool-channel snag | Pool-undercut bank | Pool-edge |
| Gizzard shad | 2 | 0 | 1 | 0 | 1 |
| Common carp | 0 | 0 | 0 | 0 | 1 |
| Mississippi silvery minnow | 0 | 0 | 0 | 0 | 6 |
| Emerald shiner | 0 | 0 | 0 | 0 | 1 |
| Smallmouth buffalo | 0 | 0 | 0 | 1 | 0 |
| Mosquitofish | 0 | 0 | 0 | 0 | 1 |
| Freshwater drum | 0 | 0 | 0 | 0 | 2 |
| White bass | 14 | 0 | 0 | 0 | 1 |
| Longear sunfish | 0 | 2 | 2 | 0 | 1 |

Table A1.  Continued.

**Site 6**

| Species | Habitat type<br>Riffle-channel snag | Pool-bank snag | Pool-channel snag | Pool-edge | Backwater |
|---|---|---|---|---|---|
| Red shiner | 230 | 0 | 4 | 0 | 4 |
| Mississippi silvery minnow | 9 | 3 | 20 | 12 | 1 |
| Emerald shiner | 4 | 0 | 2 | 0 | 0 |
| Bullhead minnow | 71 | 0 | 2 | 0 | 0 |
| Channel catfish | 1 | 0 | 0 | 0 | 0 |
| Longear sunfish | 2 | 0 | 0 | 0 | 0 |
| Black crappie | 0 | 0 | 1 | 0 | 0 |
| Logperch (*Percina caprodes*) | 1 | 0 | 0 | 0 | 0 |
| Slough darter | 12 | 0 | 0 | 0 | 0 |

Table A2. Ancillary depths and velocities were measured to provide replication within a habitat type on 23-24 January 2000. Discharge during this period was 4.4 cfs. Pool mesohabitats had velocities of zero and were not selected for sampling. Measurements were taken at several horizontal and vertical positions within the habitat type.

**Site 4**

| Habitat type | Depth (m) | Velocity (m/s) |
|---|---|---|
| Riffle-snag complex | 0.45 | 0.56 |
| | 0.43 | 0.48 |
| | 0.46 | 0.05 |
| | 0.51 | 0.43 |
| | 0.16 | 0.14 |
| | 0.36 | 0.08 |
| | 0.31 | 0.34 |
| | 0.20 | 0.10 |
| | 0.48 | 0.38 |
| | 0.39 | 0.12 |
| | 0.24 | 0.11 |
| Run | 0.36 | 0.26 |
| | 0.60 | 0.13 |
| | 0.32 | 0.03 |
| | 0.53 | 0.32 |
| | 0.65 | 0.13 |
| | 0.30 | 0.04 |
| | 0.46 | 0.25 |
| | 0.60 | 0.31 |
| | 0.41 | 0.03 |

Table A2.  Continued.

**Site 6**

| Habitat type | Depth (m) | Velocity(m/s) |
|---|---|---|
| Riffle-channel snag | 0.45 | 0.56 |
| | 0.43 | 0.48 |
| | 0.46 | 0.05 |
| | 0.51 | 0.43 |
| | 0.16 | 0.14 |
| | 0.36 | 0.08 |
| | 0.31 | 0.34 |
| | 0.20 | 0.10 |
| | 0.48 | 0.38 |
| | 0.39 | 0.12 |
| | 0.24 | 0.11 |

## Index of Biological Integrity

Results for IBI metrics that included data for additional collections are given in Table A3. As before, the range of possible total value for IBI metrics was the sum of the ranks (10-70). Site 3 again had the highest sum of ranks (52.2) and therefore highest percentage (75%) of the maximum score. Site 7 had the lowest sum of ranks (32) and therefore the lowest percentage of the maximum (46%). Intermediate IBI values among sites 2, 4, and 6 were very similar to each other (35.5, 36.5, and 37 respectively), as were those of sites 1 and 5 (44.5 and 42 respectively, Table A3).

The mean of scores for the upstream sites 1, 2, and 3 (within the channelized area to be influenced by George Parkhouse I) was 63.3% (59.0% if site 7 was included in that average). The mean of scores for the downstream sites 4, 5, and 6 (to be influenced by Marvin Nichols I) was 55.0%. As for the initial data, IBI values for the two site groups did not differ (ANOVA, $F = 2.46$, $P = 0.18$). To determine if IBI values changed when the ancillary data was added, IBI values for initial data (Table 12) and combined data (initial plus ancillary) were considered as separate dependent variables measured on the same sites, and therefore analyzed using a one-way Multivariate Analysis of Variance (MANOVA). The difference between site groups for mean IBI values was smaller for combined data than for initial data, and at a higher level of significance ($F = 5.56$, $P = 0.08$). Although IBI values for both initial and combined datasets were similar, larger F-values and smaller P-values for ANOVAs in the combined dataset indicated that differences between site groups were closer to being statistically significant, but smaller than that estimated by the initial dataset.

## Indicator species

The additional collections allowed the use of more species and data for rarer habitat types (e.g., riffle-channel snag and riffle-bank snag). As for the analysis of initial data, habitat groups could be characterized by a basic separation into mesohabitat groups based on stream hydraulics. Two groups primarily included riffles and runs, and two included primarily pools and backwaters (Table A4). Significant indicator species for the riffle-channel snag, riffle-snag complex and run group (group 1) were slough darter, bullhead minnow, channel catfish and freckled madtom. Slough darter, and freckled madtom were almost exclusively found in these habitats, which were most abundant at downstream sites 4 and 6. Red shiner was moderately significant as an indicator of this habitat group, but was more associated with habitat group 2, which included not only edge, bank, and debris dams in riffles, but also undercut banks, debris dams, and trees in pools. Three other species (smallmouth buffalo, longnose gar, and white bass) were more strongly associated with habitat group 2 than other groups, but were not significant indicators.

Bigmouth buffalo and spotted gar were significant indicators for habitat group 3, most likely because they were almost exclusively found in those kinds of pool habitat types. Six species were indicators of habitat group 4, including freshwater drum, longear sunfish, bluegill, white crappie, orangespotted sunfish, and mosquitofish. These species are associated with lentic conditions and somewhat shallower habitats than are indicator species in habitat group 3. In addition, all individuals, including those of larger-bodied species (freshwater drum, white crappie) collected in group 4 habitats were young-of-the-year or juveniles. This likely indicates the importance of these habitats as “nurseries” or “predator-free” habitats for smaller fishes.

Table A3. Modified IBI metrics and sum ranks for the Sulphur River including ancillary data from 23-24 January 2000.

| | | Ranks | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Site | | | | | | |
| Category | Metric | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Species richness and composition | No. fish species | 2 | 3 | 6 | 5 | 7 | 4 | 1 |
| | No. darter species | 4.5 | 2 | 2 | 6 | 4.5 | 7 | 2 |
| | No. sunfish species | 3.5 | 3.5 | 7 | 3.5 | 6 | 3.5 | 1 |
| | No. sucker species | 5.5 | 5.5 | 5.5 | 2 | 2 | 2 | 5.5 |
| | No. intolerant species | 4 | 1.5 | 4 | 6 | 4 | 7 | 1.5 |
| | % tolerant species | 4 | 7 | 5 | 2 | 1 | 3 | 6 |
| | % mosquitofish | 5 | 6.5 | 3 | 4 | 2 | 6.5 | 1 |
| Trophic composition | % omnivores | 5 | 1 | 7 | 3 | 6 | 2 | 4 |
| | % invertivores | 4 | 2 | 7 | 3 | 6 | 1 | 5 |
| | % piscivores | 7 | 3.5 | 6 | 2 | 3.5 | 1 | 5 |
| | Sum | 44.5 | 35.5 | 52.5 | 36.5 | 42 | 37 | 32 |
| | % of possible score | 64 | 51 | 75 | 52 | 60 | 53 | 46 |

Table A4. Indicator values for fish based on relative abundance and frequency of occurrence in Sulphur River habitat groups including ancillary data from 23-24 January 2000. *P* is the proportion of Monte Carlo randomized trials (1000) with indicator values equal to or exceeding the observed indicator value. Bold numbers indicate the value that is highest for each species.

| | | Habitat groups | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| Species | *P* | Riffle-channel snag, Riffle-snag complex, Run | Riffle-bank snag, Riffle-edge, Riffle-debris dam, Pool-undercut bank, Pool-debris dam, Pool-tree | Pool, Pool-bank snag, Pool-channel snag, Pool-snag complex, Pool-edge, Pool-vegetation | Pool-rootwad, Backwater, Backwater-bank snag |
| Slough darter | 0.001 | **100** | 0 | 0 | 0 |
| Bigmouth buffalo | 0.001 | 0 | 0 | **99** | 0 |
| Spotted gar | 0.001 | 1 | 1 | **98** | 1 |
| Freshwater drum | 0.002 | 0 | 0 | 4 | **96** |
| Longear sunfish | 0.004 | 2 | 0 | 5 | **93** |
| Bullhead minnow | 0.004 | **94** | 0 | 3 | 3 |
| Channel catfish | 0.005 | **98** | 0 | 2 | 0 |
| Bluegill | 0.005 | 0 | 0 | 6 | **94** |
| White crappie | 0.005 | 0 | 4 | 4 | **92** |
| Orangespotted sunfish | 0.023 | 0 | 0 | 5 | **95** |
| Freckled madtom | 0.035 | **99** | 0 | 0 | 0 |
| Mosquitofish | 0.046 | 3 | 2 | 3 | **93** |
| Red shiner | 0.057 | **66** | 22 | 2 | 10 |
| Emerald shiner | 0.096 | **86** | 0 | 13 | 0 |
| Common carp | 0.119 | 18 | 0 | 21 | **62** |
| River carpsucker | 0.226 | 1 | 1 | **98** | 1 |
| Threadfin shad | 0.236 | 0 | 0 | 40 | **60** |
| Warmouth | 0.269 | 0 | 0 | 12 | **87** |
| Gizzard shad | 0.321 | 0 | 15 | 9 | **76** |
| Blue catfish | 0.325 | **83** | 0 | 3 | 14 |
| Black crappie | 0.328 | 0 | 0 | 10 | **90** |
| Logperch | 0.329 | **98** | 1 | 1 | 1 |
| Largemouth bass | 0.371 | 0 | 0 | 2 | **97** |
| Flathead catfish | 0.374 | **93** | 0 | 7 | 0 |
| Blackstripe topminnow | 0.376 | 1 | 1 | 1 | **97** |
| Mississippi silvery minnow | 0.383 | 7 | 1 | 16 | **76** |

Table A4. Continued.

| | | Habitat groups | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| Species | *P* | Riffle-channel snag, Riffle-snag complex, Run | Riffle-bank snag, Riffle-edge, Riffle-debris dam, Pool-undercut bank, Pool-debris dam, Pool-tree | Pool, Pool-bank snag, Pool-channel snag, Pool-snag complex, Pool-edge, Pool-vegetation | Pool-rootwad, Backwater, Backwater-bank snag |
| Smallmouth buffalo | 0.442 | 0 | **64** | 15 | 21 |
| Golden shiner | 0.460 | 0 | 0 | 2 | **98** |
| Longnose gar | 0.535 | 15 | **49** | 28 | 8 |
| Dollar sunfish | 0.541 | **73** | 0 | 2 | 25 |
| White bass | 0.970 | 13 | **48** | 7 | 32 |
| Pirate perch | 0.999 | 9 | 9 | **72** | 9 |
| Alligator gar | 0.999 | 7 | 7 | **79** | 7 |
| Black buffalo | 0.999 | 7 | 7 | **79** | 7 |
| Green sunfish | 0.999 | 2 | 2 | **93** | 2 |
| Shortnose gar | 0.999 | 4 | 4 | **88** | 4 |
| Brook silverside | 0.999 | 4 | 4 | **88** | 4 |
| Spotted bass | 0.999 | 9 | 9 | **74** | 9 |
| Striped bass | 0.999 | 7 | 7 | **79** | 7 |