A Survey of Freshwater Mussel Aggregations on the Lower Chippewa River, Wisconsin.

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CONVERSION FACTORS

Multiply	By	To obtain
Foot (ft)	3.048×10^{-1}	meter
Mile (mi)	1.609×10^{0}	kilometer
Square mile (mi^2)	2.590×10^{0}	square kilometer
Cubic foot (ft^3)	2.832×10^{-2}	cubic meter
Cubic foot per second (cfs)	2.832×10^{-2}	cubic meter per second
Ton (short)	9.072×10^{-1}	megagram or metric ton

INTRODUCTION

This report summarizes 2001 and 2002 results of a survey of freshwater mussel habitat and aggregations on the lower Chippewa River in western Wisconsin. The purpose of this survey was to inventory and describe potential locations for introduction of the federally endangered Higgins' eye freshwater mussel (*Lampsilis higginsii*). This effort was part of mussel propagation efforts related to the continued operation and maintenance of the Mississippi River System Navigation project by the U. S. Army Corps of Engineers in cooperation with the associated, multi-agency Mussel Coordination Team.

The lower Chippewa River was chosen, along with other upper Midwestern rivers, for potential *L. higginsii* introduction due to its geographic location, size, mussel community composition and its relatively low risk level for zebra mussel (*Dreissena polymorpha*) colonization.

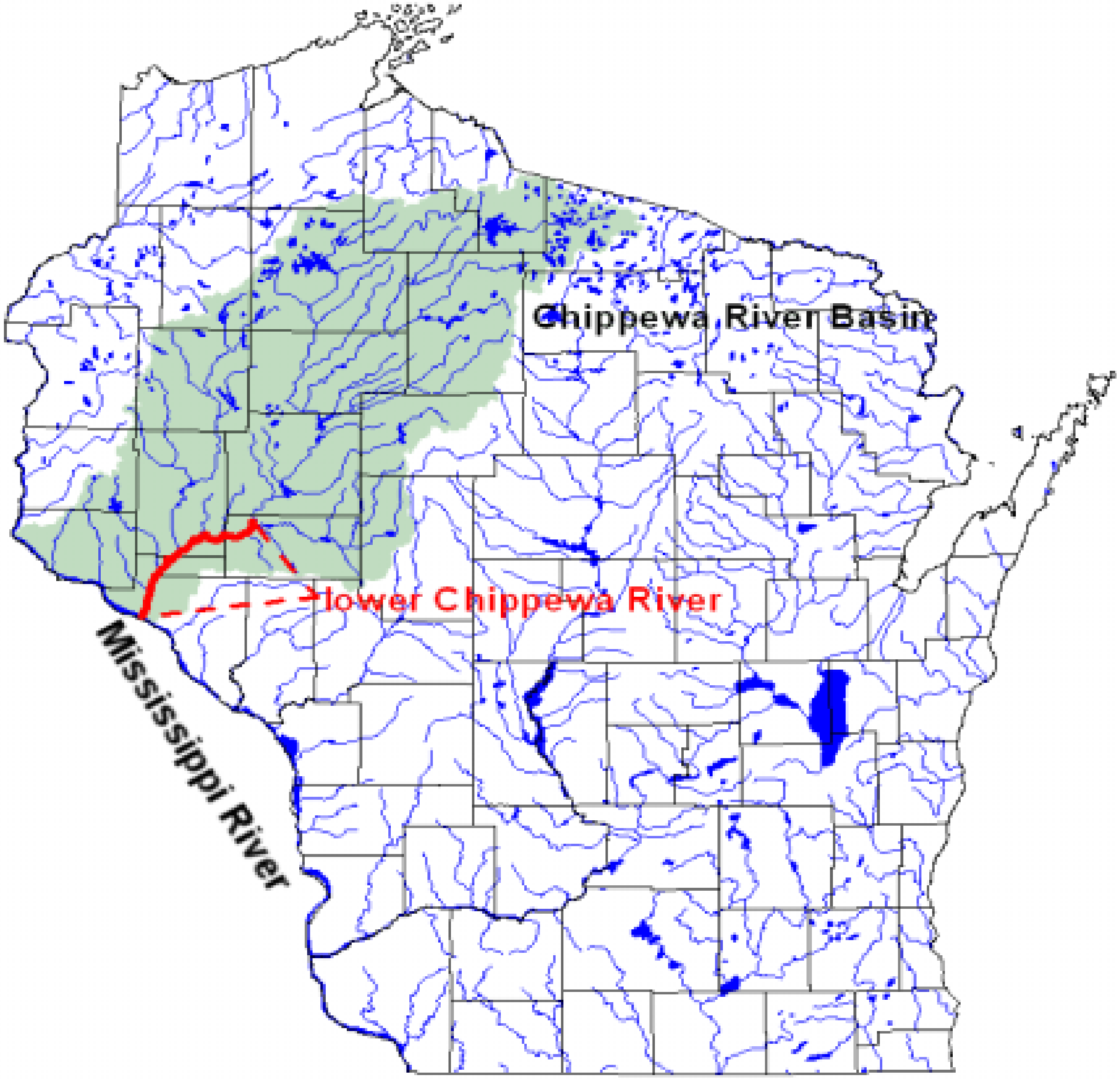
Recent mussel communities in the lower Chippewa River are well known. Survey work done during 1986-1996 (Balding, 1992; Balding Pers. Com.) recorded 25 species represented by living individuals and an additional species by a dead individual. Locations of mussel aggregations were not reported nor were locations that may be suitable for mussel introductions.

The questions we wanted answered were 1) Where are the potential mussel aggregations located? 2) Where are known mussel aggregations located? 3) What is the quality and community composition within the known mussel aggregations? 4) Which of the known mussel aggregations is of the highest quality and which ones could potentially support the introduction of *L. higginsii*?

STUDY AREA

The Chippewa River is a 176 mile-long stream located in west central Wisconsin (Figure 1). It has a drainage basin of 9410 mi² (Henrich and Daniel, 1983) and empties directly into the Mississippi River 3.4 miles upstream of the City of Wabasha, Minnesota. It descends from its headwaters to the dam at the City of Eau Claire (river mile 59.2) an

Figure 1. Chippewa River Basin in Wisconsin.



average of 6.4 ft/mi (Smith, 1980). Downstream of this dam, it descends towards the Mississippi River an average of approximately 1.8 ft/mi.

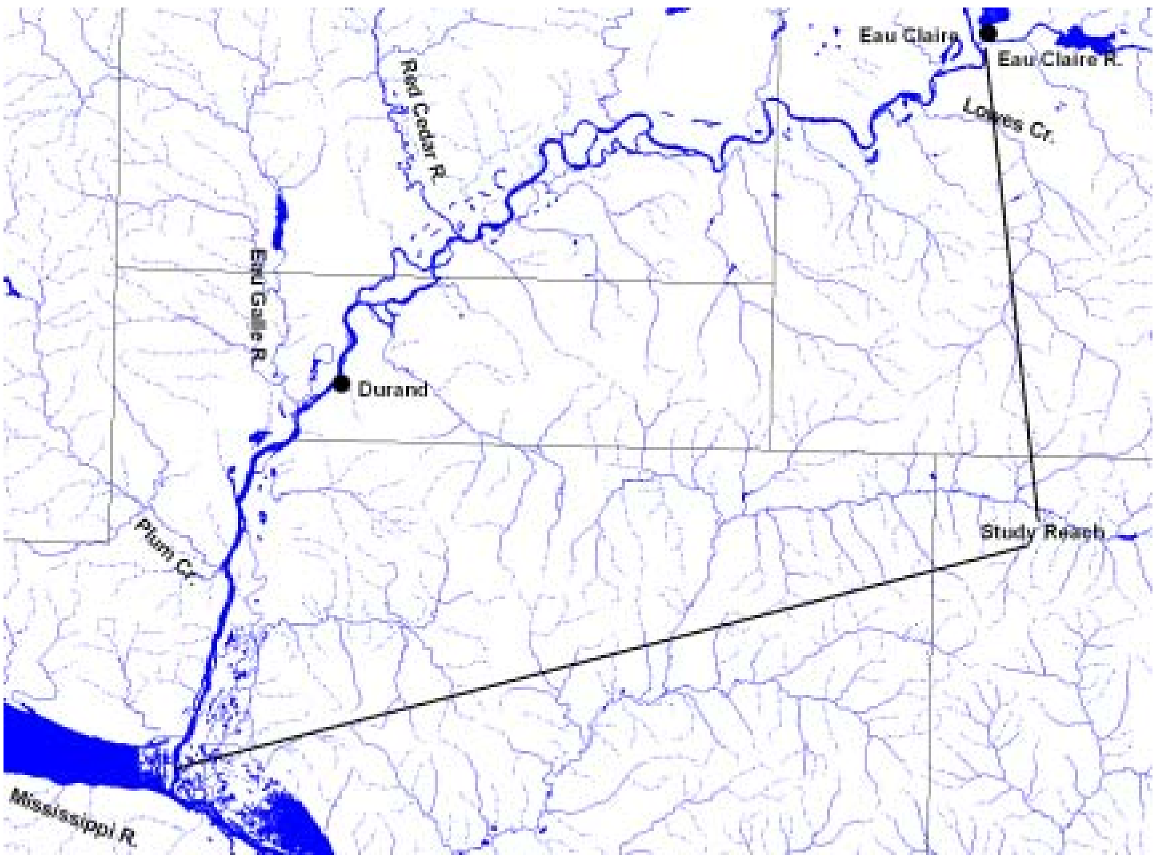
Rock substrates, derived from Precambrian crystalline bedrock, are present from Chippewa Falls (river mile 73.3) upstream. Sandy substrates, derived from Cambrian sandstones, and gravel outwash, dominate the streambed from Chippewa Falls downstream to the confluence with the Mississippi River. These sandstones and eroded sands contribute to a large bedload in the stream. The total annual sediment load estimated from measurements taken near the mouth averaged 940,000 tons during the water years 1976-1983 (Rose, 1992).

At the Durand gaging station, located at river mile 17.5, the mean daily flow was 7738 cubic feet per second (cfs) for the 1928-2002 period of record. The maximum and minimum flows recorded were 117,000 and 1100 cfs, respectively (United States Geological Survey data).

METHODS AND MATERIALS

We conducted this investigation on most of the lower 59.2 miles of the Chippewa River from the City of Eau Claire downstream to its confluence with the Mississippi River (Figure 2). We surveyed gravel and rock bars from the mouth of the Eau Claire River (river mile 58.0) downstream to 2.1 river miles upstream from the confluence with the Mississippi River.

Figure 2. Reach of Chippewa River Studied in 2002.



Mussel aggregations were surveyed from river miles 57.3 to 23.7. Effort for mussel aggregation surveys were concentrated in the upper half of the lower Chippewa River because Balding (1992) found more mussels and species here compared to the lower half.

We began by first reviewing all mussel information previously collected from this reach. Based on previous mussel-related work on the lower Chippewa River and other similar rivers in the upper Midwest, we assumed that most mussel aggregations were associated with gravel or rock bars and that very few mussels occur in shifting sand, which is the dominant substrate type in this study reach.

Then, we reconnoitered the river using an outboard engine powered boat and airboat to locate and map gravel and rock bars as well as visible mussel aggregations. We also surveyed for shoreline midden piles. We located and mapped these either visually or using a 10 ft-long pole that was probed into the substrate. Bars and aggregations were recorded using a Lowrance Globalnav ® 212 Geographic Positioning System receiver as well as United States Geological Survey 7.5 Minute Series Topographic maps and aerial photographs from various sources. Approximate widths, lengths and general substrate characteristics were taken at each bar and mussel aggregation.

Bars and preliminarily identified mussel aggregations found during the reconnaissance survey were prioritized for future detailed examination based on the potential for a mussel aggregation. The potential existence of a mussel aggregation was based on the size of the bar, its' substrate characteristics and presence or absence of mussels or mussel shells.

Detailed examinations were done by sampling mussels using SCUBA divers. Two divers both visually and tactilely characterized substrates in a portion of, or throughout the entire previously identified bar or aggregation. All locations examined were sampled for at least 5 minutes during which we collected all living and dead mussels encountered. We defined a mussel aggregation as a location where we found at least one living mussel in one hour of collecting. All mussels encountered both living and dead, were brought to the surface, identified and counted. We did not measure mussel population density, but at some locations examined, we visually estimated this density.

RESULTS AND DISCUSSION

Previous Mussel Work

A number of surveys limited in scope and extent have been done on the lower Chippewa River. During 1974 and 1976, Mathiak (1979) examined 4 locations and found about 19 individuals representing 9 species (Table 1). From 1986-1996, Balding (1992, Pers. Com.) found a total of 2211 living and 4831 dead representing 26 species. Various collectors, including Heath (Unpub), Wisconsin Department of Natural Resources (Unpub.) and Baker (1928) recorded a total of 20 living individuals representing 15 species. No living or dead *L. higginsii* were recorded from any of these investigations.

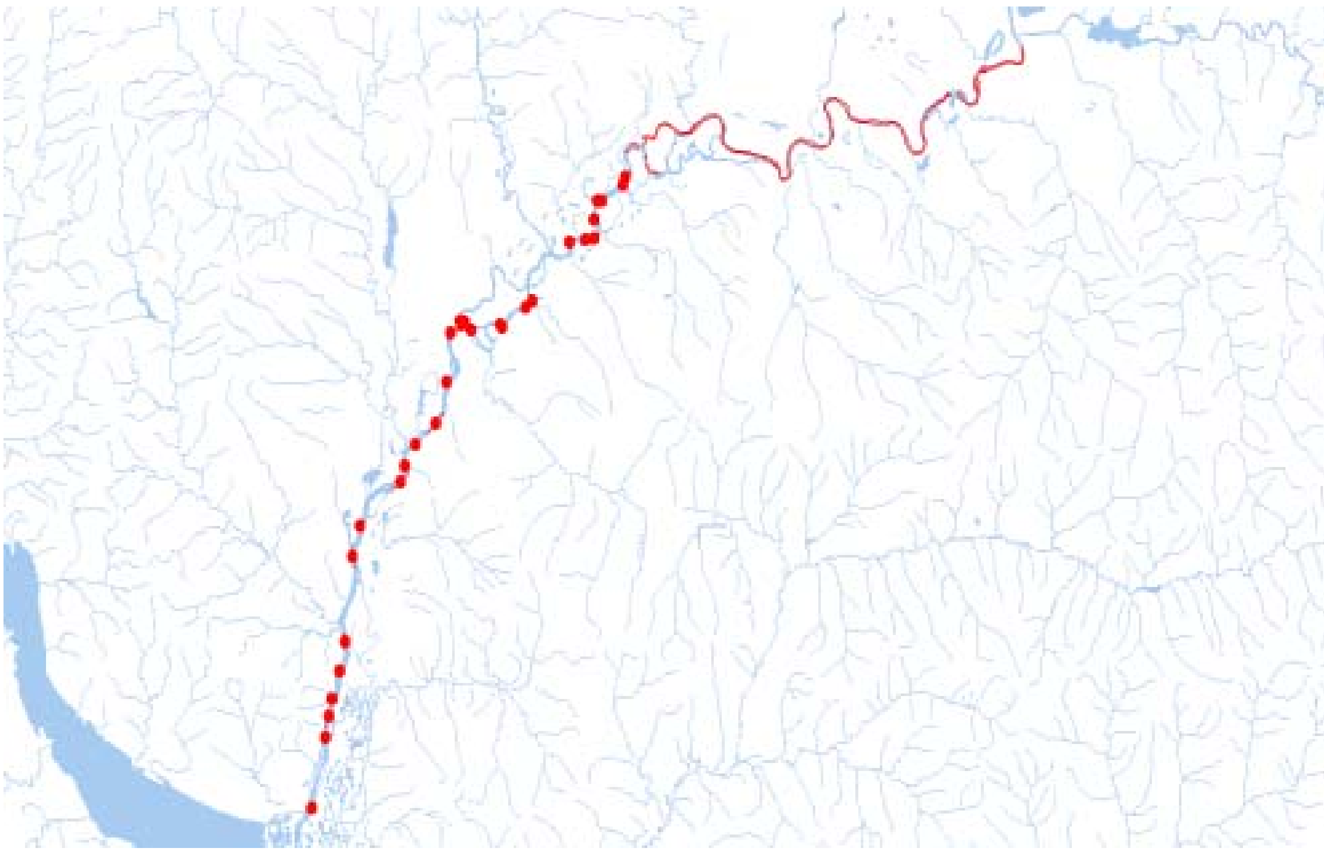
Table 1. List of Freshwater Mussel Species Found in the Lower Chippewa River, Wisconsin. (SC=Special Concern, THR=Threatened, END=Endangered).

TAXON	Various 1928-1988	Mathiak 1976	Balding 1986-1996	This Study 2001-2002	WI Listing Status
Actinonaias ligamentina carinata			L	L	
Alasmidonta marginata	L		L	L	SC
Amblema plicata plicata		L	L	L	
Anodonta grandis form corpulenta	L		L	L	
Elliptio dilatata			D	L	
Fusconaia flava	L	L	L	L	
Lampsilis siliquoidea	L		L	L	
Lampsilis cardium	L	L	L	L	
Lasmigona complanata complanata	L	L	L	L	
Lasmigona costata			L	L	
Leptodea fragilis	L	L	L	L	
Ligumia recta	L		L	L	
Obliquaria reflexa			L	L	
Obovaria olivaria	L	L	L	L	
Plethobasus cyphyus			L	L	END
Pleurobema sintoxia			L	L	SC
Potamilus alatus	L		L	L	
Potamilus ohiensis		L	L	L	
Quadrula metanevra	L		L		THR
Quadrula pustulosa pustulosa			L	L	
Simpsonaias ambigua	L		L	L	THR
Strophitus undulatus undulatus	L		L	L	
Toxolasma parvus		L	L	L	
Tritogonia verrucosa	L		L	L	THR
Truncilla donaciformis	L		L	L	SC
Truncilla truncata			L	L	
Utterbackia imbecillis		L			
TOTAL INDIVIDUALS	20	19	2211	757	
TOTAL SPECIES REPRSENTED LIVING	15	9	25	25	
ADDITIONAL SPECIES REPRESENTED DEAD	0	0	1	0	
GRAND TOTAL SPECIES			27		

Reconnaissance Survey of Gravel and Rock Bars

A total of 38 gravel bars, rock bars or mussel aggregations were found during the reconnaissance survey. These gravel bars had a surface area of 496 ha, or about 21% of the 2319 ha watered surface area of the lower Chippewa River. These locations are shown in Figure 3. No shoreline midden piles were found. We believe none were present due to the erosive nature of the river channel and floodplain.

Figure 3. Location of 38 Gravel Bars and Rock Bars Found During the 2001-2002 Lower Chippewa River Reconnaissance Survey.

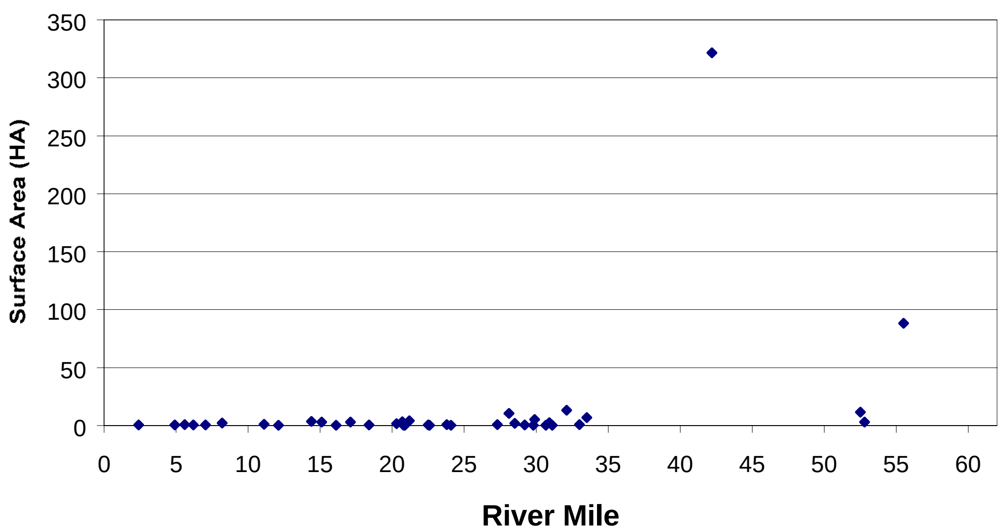


Total surface area of bars was distributed differently from downstream to upstream. Surface area was much greater in upstream locations compared to downstream ones. The upstream 17 river miles of the study reach (28.7% of lower river) accounted for 86% of the total bar surface area. This is consistent with the geology of the lower

Chippewa River. There are decreasing remnants of the crystalline bedrock and increasing volumes of unconsolidated sand the farther one is downstream from Eau Claire. Nearly the entire 26.5 upstream river miles, exclusive of the side channels, was one large gravel and rock bar interrupted only for a 1.4 mile long sandy area, which happened to be adjacent to an active gravel and sand mining operation.

The average size of bars increased from downstream to upstream. Near the mouth, the average bar size was close to 1.3 ha, at river mile 25.5 the average size was about 2.4 ha while near Eau Claire at mile 51, the mean size was about 106.1 ha (Figure 4). Nearly this entire size differential was due to two very large upstream gravel bars.

Figure 4. Size of Rock and Gravel Bars Found During the 2001-2002 Lower Chippewa River Survey.



A total of 8 of the 38 bars were examined in detail for mussels. Of the priority one locations, 1 of the 2 was examined in detail. A total of 7 of the 23 priority two and none of the 13 priority three locations were examined (Table 2). In addition to the 8 bars examined in detail, 4 locations outside of identified gravel bars were examined for mussels.

Mussel Aggregations

Of the 8 bars that were examined in detail, 6 (75%) had at least one mussel found per hour and were consequently considered mussel aggregations (Table 2). Two additional aggregations were found in sampling outside of mapped gravel bars. Also,

Table 2. List of Gravel and Rock Bars, Rivermile, Survey Priority, Detailed Examination Status, Bed Status, Catch Per Hour and Total Surface Area. Lower Chippewa River, 2001-2002.

GRAVEL BAR	RIVER MI	PRIORITY	EXAMINED	BED	CPHLIVE	AREA (HA)
AH	2.39	3	n	n*	0.63	0.50
AG	4.90	3	n	y*	2.84	0.44
AF	5.60	2	n		0.00	0.77
AE	6.20	3	n		0.00	0.59
AD	7.05	2	n		0.00	0.55
AC	8.20	2	n		0.00	2.09
AB	11.10	2	n		0.00	1.14
AA	12.10	2	n		0.00	0.31
Z	14.40	2	n	n*	0.11	3.64
Y	15.10	3	n		0.00	3.00
X	16.10	3	n		0.00	0.37
W	17.10	2	n		0.00	3.15
V	18.40	2	n		0.00	0.48
U	20.30	2	n		0.00	1.77
T	20.70	3	n		0.00	3.29
S	20.80	3	n		0.00	0.26
R	20.90	2	n		0.00	0.38
Q	21.20	2	n		0.00	4.19
O	22.50	2	n		0.00	0.47
P	22.60	3	n		0.00	0.14
N	23.80	2	y	n	0.92	0.96
M	24.08	2	y	y	31.03	0.14
none	24.1		y	n	0	
L	27.30	2	n		0.00	0.72
K	28.10	3	n		0.00	10.37
J	28.50	2	y	y	1.36	2.04
I	29.20	2	n		0.00	0.48
none	29.66		y	y	7.2	
H	29.79	3	n		0.00	0.41
G	29.88	3	n		0.00	5.28
F	30.67	3	n	n	0.00	0.27
E	30.90	2	y	n	0.00	2.47
D	31.10	2	n		0.00	0.29
C	32.10	2	y	y	14.50	13.33
B	33.00	3	n		0.00	0.77
A	33.50	2	y	y	20.54	6.76
AL	42.20	2	y	y	25.53	321.69
AK	52.50	1	n		0.00	11.58
none	52.62		y	n	0	
none	52.72		y	y	13.333	
AJ	52.80	2	n		0.00	2.96
AI	55.50	1	y	y	23.71	88.23

* = identified as bed by Balding (Pers. Com.)

Figure 5. Location of Mussel Aggregations Found During the 2001-2002 Lower Chippewa River. ●= Known Mussel Aggregation Locations. O = Examined & Not an Aggregation.

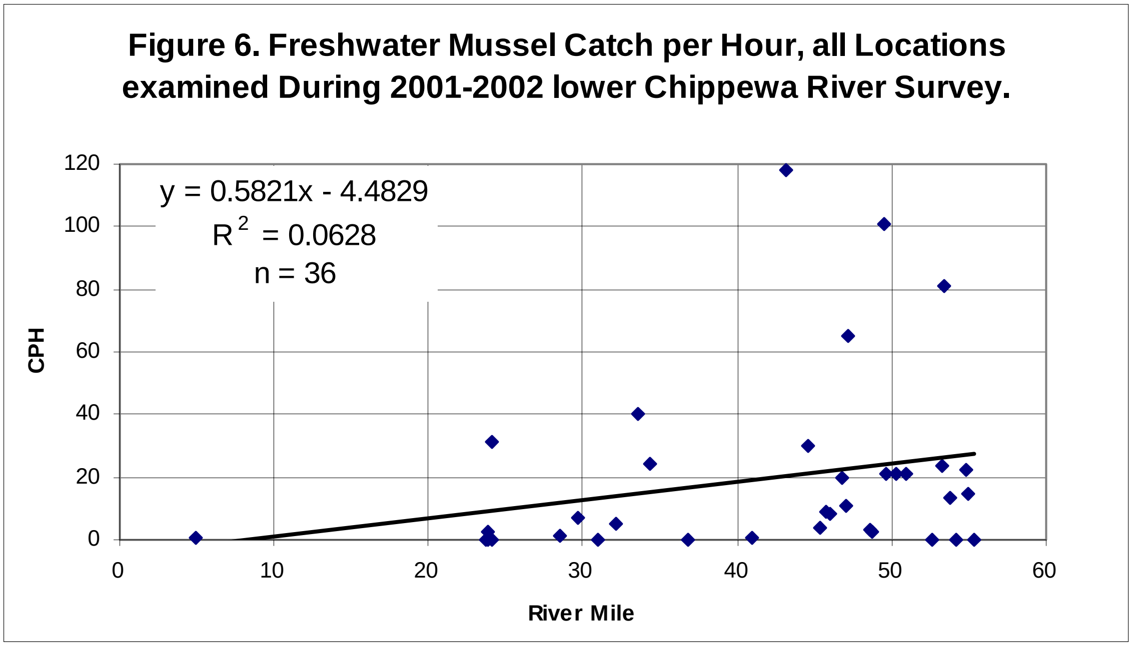
Balding (Pers. Com.) found an additional bed in a gravel bar. In all, there was a total of 9 aggregations identified. Locations of mussel aggregations are given in Figure 5.

Mussels sampled within locations determined to be aggregations had a mean catch per hour (CPH) of 23.4 (maximum = 118.2, minimum = 0. This was lower than other local large rivers. For example, the lower Black River, Wisconsin had a mean catch of 34.8 (Heath et al., 2004).

The CPH for all locations sampled for mussels (including those in mussel aggregations and non-aggregations) showed a positive correlation with river mile, although this correlation was not statistically significant ($n = 36$, $r^2 = 0.063$, $p = 0.1404$). CPH decreased from upstream to downstream (Figure 6) and was about 8.9 at river mile 23 and 28.1 at river mile 56. The mean CPH for all locations sampled for mussels was 19.6.

A similar, but not significant positive trend between river mile and CPH was seen for mussel sampling locations that were identified within aggregations ($n = 30$, $r^2 =$

0.025, p = 0.41). An inverse trend was seen between river mile and CPH for locations not within mussel aggregations, but this relationship was not significant and the sample size was very small (n = 6, $r^2 = 0.066$, p = 0.62). This suggests that there may be a



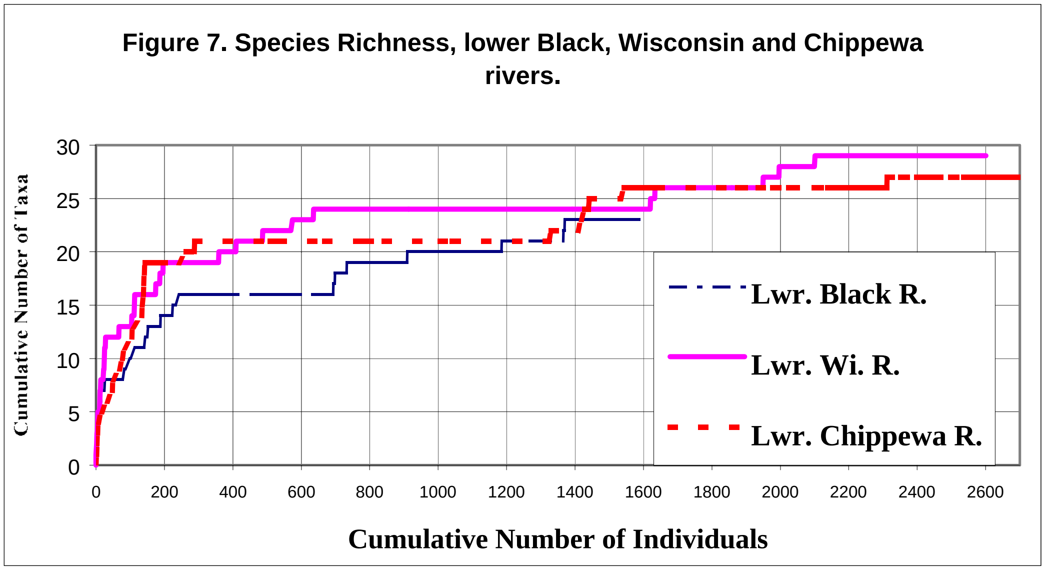
longitudinal pattern of mussel density throughout the study reach within bars and aggregations with higher densities in upstream locations. Similar findings were noted by Balding (1992) but his results were significantly different for numbers of individuals and species.

Species Richness

During this survey, a total of 25 species were represented among 757 living individuals (Table 1). Dead individuals represented no additional species. We found every species that has been recorded from the river prior to 2001 except for two: *Utterbackia imbecillis* and *Quadrula metanevra*. No specimens of *L. higginsii* were found in this or any other Chippewa River survey.

Species richness for the lower Chippewa River was average compared to other large Mississippi River tributaries in Wisconsin. The lower Wisconsin River, which contains *L. higginsii*, has about 29 species while the lower Chippewa River has 27

(Figure 7). For similar sample sizes (about 1600 individuals), species richness was slightly greater in the lower Chippewa River compared to the other two. The lower Black



River contained 23 species, while the lower Chippewa had 26 and the lower Wisconsin River 24.

We analyzed species associates of *L. higginsii* over a broad geographic scale in the upper Midwest. Several mussels were associated with this species in particular river reaches and some were weakly associated or mutually exclusive. Results of this analysis are given in Table 3.

Table 3. Species Associates of Lampsilis higginsii.

Strongly Associated	Moderately Associated	Weakly or Never Associated
Arcidens confragosus	*Tritogonia verrusoca*	*Alasmidonta viridis*
Ellipsaria lineolata.	*Obovaria olivaria*	*Anodonta cataracta*
Elliptio crassidens crassiden	*Truncilla truncata*	*Anodontoides ferusscianus*
Fusconaia ebena		*Lasmigona compressa (occasionally found with L.h.)*
Lampsilis teres form anodontoides		*Lasmigona costata (occasionally found with L.h.)*
Lampsilis teres form teres		*Venustaconcha e. ellipsiformis (rarely found with L.h.)*
Megalonaias nervosa		*Villosa i. iris*
Potamilus ohiensis		
Quadrula metanevra		
Quadrula nodulata		
Truncilla donaciformis		

A total of 11 taxa are strongly associated with *L. higginsii*. Of these, only three taxa (*Q. metanevra*, *Potamilus ohiensis* and *T. donaciformis*) were present on the lower Chippewa River. All three of these were uncommon or rare. On the lower Wisconsin River and the Mississippi River, where *L. higginsii* is present, 9 of these 11 and all 11 associates are present, respectively. All three moderate associates are present in the lower Chippewa River. These three are also present in the lower Wisconsin River and Mississippi River while only two are present on the lower Black River. Of the weakly associated or mutually exclusive taxa, one of the seven was present on the lower Chippewa River, two of the seven are present in the lower Black River while three are present in the lower Wisconsin River and none in the Mississippi River. A summary of these counts is given in Table 4. A relative ranking of these counts implies that the Mississippi River ranks first, followed by the lower Wisconsin and lower Chippewa rivers, and finally the lower Black River. The Mississippi and Wisconsin rivers were most similar distantly followed by the Chippewa and Black rivers.

Table 4. Numbers of Species Associates of Lampsilis higginsii for large Wisconsin Rivers.

	Number of Strong Associates	Number of Moderate Associates	Number of Weak Associates
lower Chippewa River	*3*	*3*	*1*
lower Black River	*2*	*2*	*2*
lower Wisconsin River	*9*	*3*	*3*
Mississippi River	*11*	*3*	*0*

Relative Abundance and Species Distribution Patterns

In this survey, the fauna was dominated by *Potamilus alatus* which accounted for 16.6% of the sample (Table 5). *Fusconaia flava* (13.9%) and *Lampsilis cardium* (13.1%) were the next most abundant species. Only single specimens each were found of *Toxolasma parvus*, *Truncilla donaciformis* and *P. ohiensis.* Using data from this and previous studies, all but seven of the twenty-four most common species were found throughout the lower river.

Three of these seven were seen predominately in the upstream half of the lower river and were very rare or absent from the downstream half. These were *Actinonaias ligamentina carinata*, *Pleurobema sintoxia* and *Quadrula p. pustulosa.*

Table 5. Number of Living and Dead Mussels Found, Relative Abundance, lower Chippewa River, 2001-2002.

OBS	TAXON	LIVE	DEAD	RANK	% REL. ABUNDANCE
1	*Actinonaias ligamentina carinata*	4	0	19	0.5
2	*Alasmidonta marginata*	43	8	6	5.7
3	*Amblema plicata plicata*	7	2	16	0.9
4	*Anodonta grandis form corpulenta*	14	2	12	1.8
5	*Elliptio dilatata*	2	1	20	0.3
6	*Fusconaia flava*	105	1	2	13.9
7	*Lampsilis cardium*	99	32	3	13.1
8	*Lasmigona complanata complanata*	24	4	10	3.2
9	*Lampsilis siliquoidea*	25	19	9	3.3
10	*Lasmigona costata*	10	1	15	1.3
11	*Leptodea fragilis*	27	19	7	3.6
12	*Ligumia recta*	73	24	5	9.6
13	*Obliquaria reflexa*	11	1	14	1.5
14	*Obovaria olivaria*	86	16	4	11.4
15	*Plethobasus cyphyus*	5	0	18	0.7
16	*Pleurobema sintoxia*	6	0	17	0.8
17	*Potamilus alatus*	126	11	1	16.6
18	*Potamilus ohiensis*	1	0	21	0.1
19	*Quadrula pustulosa pustulosa*	27	1	7	3.6
20	*Simpsonaias ambigua*	13	0	13	1.7
21	*Strophitus undulatus undulatus*	16	8	11	2.1
22	*Toxolasma parvus*	1	0	21	0.1
23	*Tritogonia verrucosa*	4	1	19	0.5
24	*Truncilla donaciformis*	1	0	21	0.1
25	*Truncilla truncata*	26	7	8	3.4
26	unidentified	1	1	21	0.1
	Total	**757**	**159**		**100.0**

Three species were found only in the middle reach of the lower river. These were *Plethobasus cyphyus*, *Quadrula metanevra* and *Simpsonaias ambigua.* One species, *Potamilus ohiensis*, was found only in the downstream half.

Suggested Locations for Introduction of *L. higginsii*

We did a rank analysis of locations that *L. higginsii* could be introduced. Mussel aggregations were ranked based on a measure of relative population density, using CPH, and the absolute length of the gravel and rock bar downstream of the mussel sampling location. This ranking was dependent upon the following assumptions.

We assumed that *L. higginsii* would do best in locations with relatively high population densities. Also, locations with relatively high population densities would have a greater chance for a successful introduction and habitation and provide for instream mussel reproduction. Past work on various rivers has suggested that sometimes *L. higginsii* is associated with relatively high total mussel population densities. (Baker, et al. 1994; Miller, and Payne. 1997).

A second assumption was that introductions at locations where the size of the aggregation or gravel bar was relatively large would be more successful than locations that were smaller. Larger aggregations may have more long term stability, a factor that is probably very important in a stream like the Chippewa River which is dominated by shifting, sandy substrates and large fluctuations in water elevations and discharge. Also, due to the broadcast nature of some introduction methods, for example the release of free-ranging fish infested with glochidia or the use of inoculated host fish confined in open-bottomed cages placed in substantial current, the chances of newly dropped juvenile mussels settling on suitable substrate would be greater in a bar that extends downstream of the introduction location.

The rank analysis is given in Table 6. We did not include species richness in the ranking because of highly variable and often small sample sizes which can influence richness values. The mussel aggregations with the highest ranking of CPH and had at least 0.2 miles of gravel bar downstream were locations "15-2", "11-4", "12-2", "21-3" and "14-3". All five of these aggregations ranked in the top seven of CPH. A total of eight of the top-ranked ten locations were in gravel bar "AL", located between river mile 32.7 and 52.2, which is the longest and largest gravel bar we located (Figure 8).

Location "15-2" is a 350 m-long aggregation located on the right descending bank at river mile 43.1 (Figure 9). It has a surface area of 13630 m² and a maximum width of 45m. The substrate here was primarily rubble and gravel, followed in composition by coarse sand. The current during normal low discharges was relatively slow and the maximum depth was 1.5m. We found a total of 20 mussel species here among a total of 253 individuals collected. We found no locations that could be protective of caged fish inoculated with mussel glochidia during high discharges, although in general, this area is somewhat protected from the highest current velocities. This suggests that there is some

Table 6. Ranking of lower Chippewa River Sampling Locations for Introduction of Lampsilis higginsii.

Gravel Bar	RIVER MI	CPH LIVE	CPH RANK	MILES OF DOWNSTREAM BARS	OVERALL RANK	SITE	STATION
AL	43.1	118.2	1	10.4	1	15	2
AL	49.48	100.9	2	17.1	2	11	4
AL	47.23	64.9	4	14.5	3	12	2
A	33.5	40.2	5	0.23	4	21	3
AL	44.53	30.0	7	11.8	5	14	3
AI	54.79	22.5	10	1.6	6	7	14
AL	50.89	21.4	11	18.2	7	10	2
AL	50.26	21.3	12	17.6	8	10	3
AL	49.61	21.1	13	16.9	9	11	3
AL	46.82	20.0	14	14.1	10	13	4
AI	54.91	15.0	15	1.6	11	7	13
AL	46.98	11.1	17	14.3	12	13	3
AL	45.7	9.0	18	13	13	13	6
AL	45.99	8.0	19	13.3	14	13	5
C	32.2	5.0	21	0.2	15	22	2
AL	45.31	3.8	22	12.6	16	13	7
AL	48.56	3.4	23	15.9	17	11	5
AL	48.75	2.4	25	16.1	18	11	2
J	28.47	1.4	26	0.31	19	25	3
AL	41	0.9	27	8.3	20	16	1
AI	55.32	0.0	29	2.1	21	7	12
AI	54.11	0.0	29	0.9	22	8	2
AL	36.86	0.0	29	4.2	23	20	2
AI	53.36	81.0	3	0		8	4
M	24.08	31.0	6	0.02		27	3
C	34.3	24.0	8	0		21	2
AI	53.24	23.8	9	0		8	3
none	53.72	13.3	16	0		9	3
none	29.66	7.2	20	0		24	2
N	23.8	2.8	24	0		28	4
none	52.62	0.0	29	0		9	2
E	30.92	0.0	29	0		23	2
none	24.1	0.0	29	0		27	2
N	23.72	0.0	29	0		28	3
N	23.8	0.0	29	0		28	4

risk of cage disturbance and dislodgment here if mussel introductions or reintroduction were attempted here. This area was previously identified by Balding (Pers. Com.) as an aggregation.

Figure 8. Location of 10 Highest Ranked Mussel Sampling Locations for Higgins' eye Introductions.

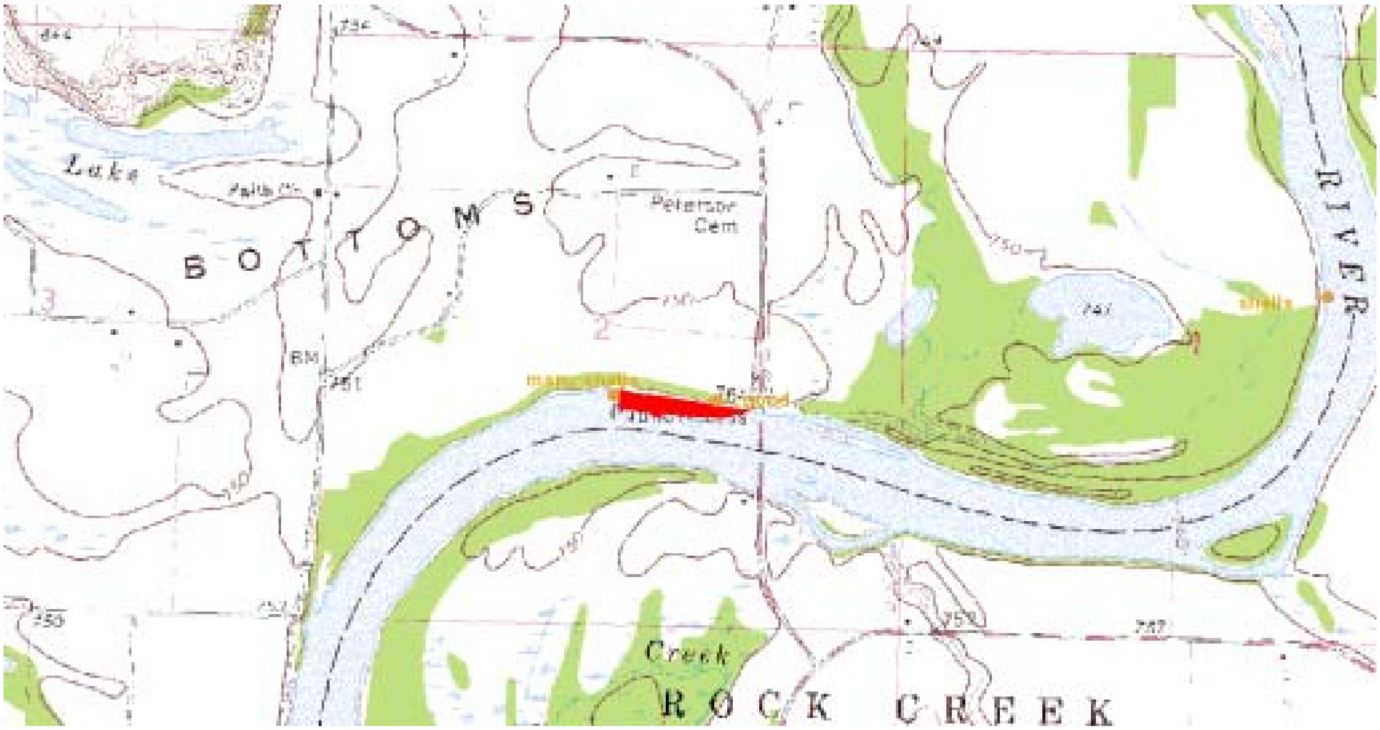
Location "11-4" is a 472 m-long aggregation located in the center of the channel at river mile 49.3 (Figure 10). It has a surface area of 41924 m² and a width of 90m. The substrate here was primarily gravel and sand followed by rubble. We found a total of 18 mussel species here among a total of 176 individuals collected. A large number of very young mussels were found in the upstream portion. We found no locations that could be protective of caged fish inoculated with mussel glochidia during high discharges. There was no structure present and no drop-offs. The bottom was quite level and flat and the current was fairly swift. This area was previously identified by Balding (Pers. Com.) as an aggregation

Location "12-2" is a 245 m-long aggregation located on the right descending bank at river mile 47.2 (Figure 11). It has a surface area of 15647 m² and a width of 40 to 60 m. The substrate here was primarily rubble followed by sand and gravel. We found a total of 16 mussel species here among a total of 66 individuals collected. We found no locations that could be protective of caged fish inoculated with mussel glochidia during high discharges.

Location "21-3" is a 980 m-long aggregation located primarily on the left descending bank at river mile 33.5 (Figure 12). It has a surface area of 66560 m² and a width of 18 to 118 m. The substrate here was primarily rubble and gravel followed by coarse sand. We found a total of 14 mussel species here among a total of 89 individuals collected. We found no locations that could be protective of caged fish inoculated with mussel glochidia during high discharges. If cages are placed here, they should be placed on the upstream end since this gravel bar is not very long.

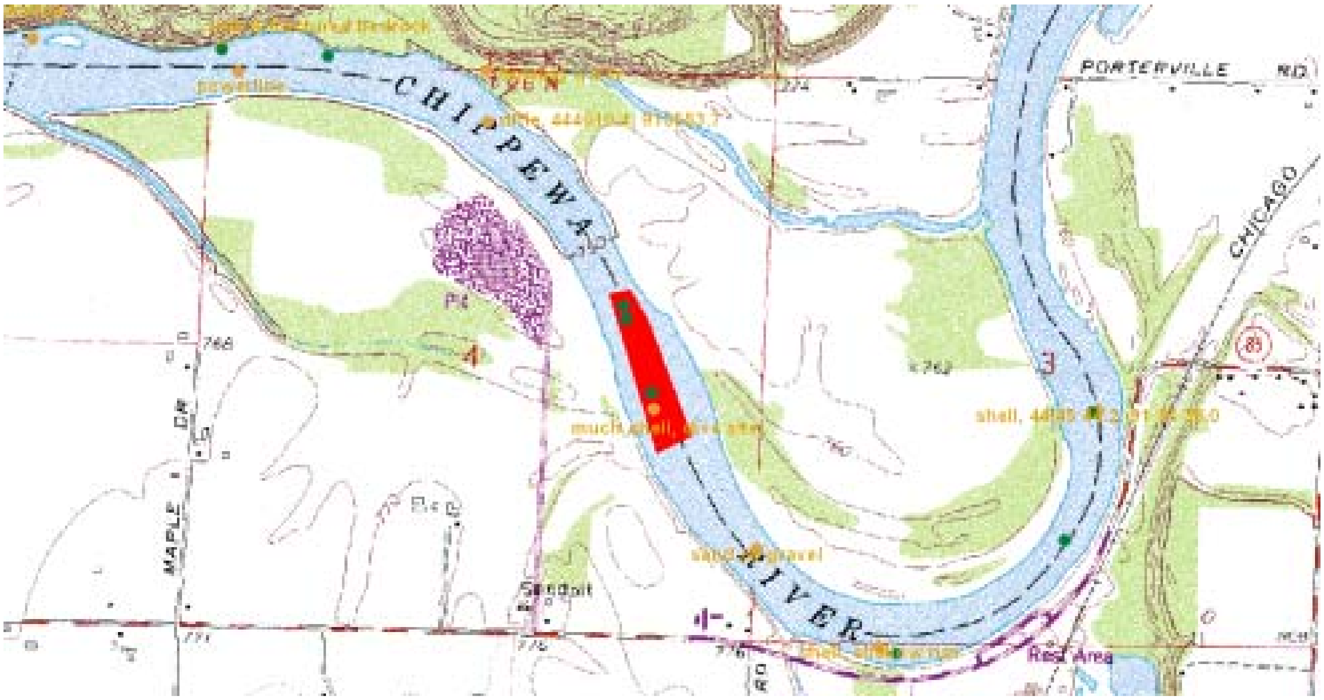
Location "14-3" is a 194 m-long aggregation located on the right descending bank at river mile 44.5 (Figure 13). It has a surface area of 7246 m^2 and a width of 40 m. The substrate here was primarily gravel followed by sand and lesser amounts of rubble. We found a total of 13 mussel species here among a total of 23 individuals collected. Balding (Pers. Com.) found 20 mussel species here among 148 individuals for a total of 21 species among 171 individuals. Although while collecting we did not feel that this was a very dense bed based on a visually estimated population density of $<1/m^2$, we did find about 20 mussels per hour which ranked it in the top seven. We found no locations that could be protective of caged fish inoculated with mussel glochidia during high discharges.

Figure 9. Map of Mussel Aggregation "15-2".



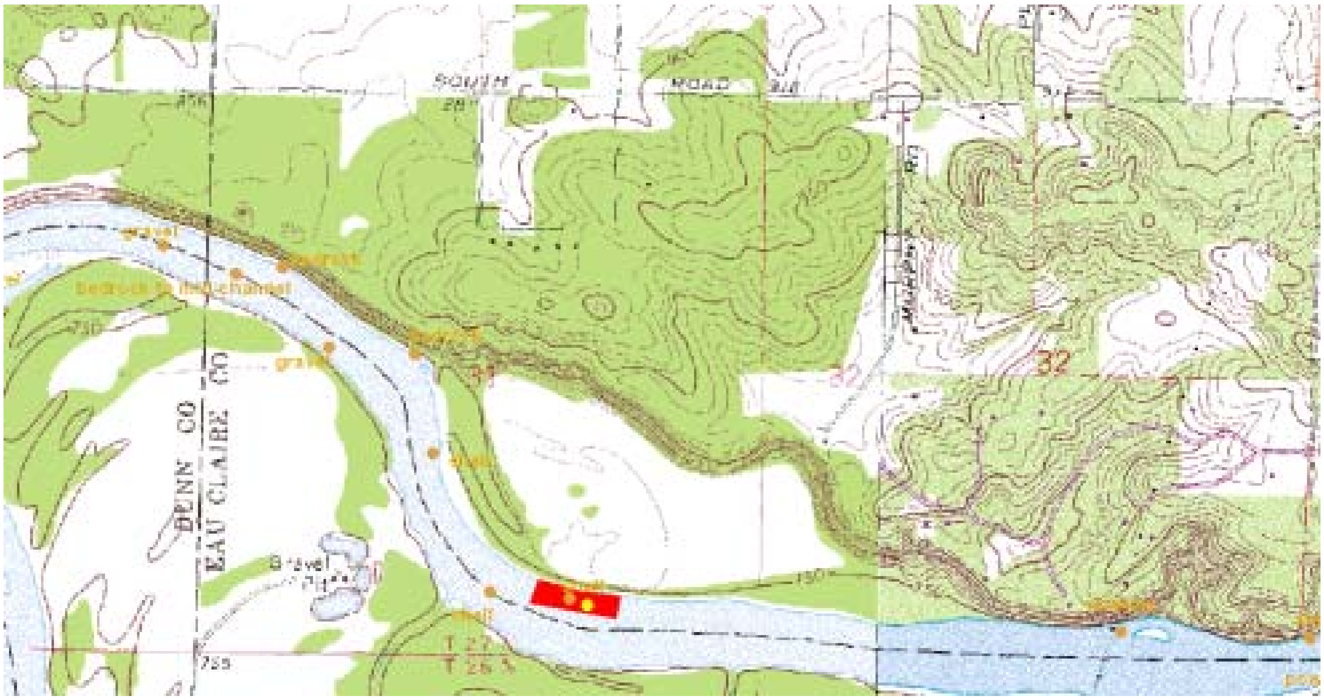
MUSSEL AGGREGATION "15-2"	
Latitude/Longitude	44° 45' 40.9"N, 91° 40' 41.2"W
Public Land Survey	Twp. 26N, Rng. 11W, Sec. 2 SE ¼, Dunn County, Wisconsin.
River Mile	43.1
Visually Est. Density	2.5/m²
Rank	1

Figure 10. Map of Mussel Aggregation "11-4".



MUSSEL AGGREGATION "11-4	
Latitude/Longitude	44° 45' 47.2"N, 91° 35' 37.0"W
Public Land Survey	Twp. 26N, Rng. 10W, Sec. 4, Eau Claire County, Wisconsin.
River Mile	49.3
Visually Est. Density	3.5/m²
Rank	2

Figure 11. Map of Mussel Aggregation "12-2”.

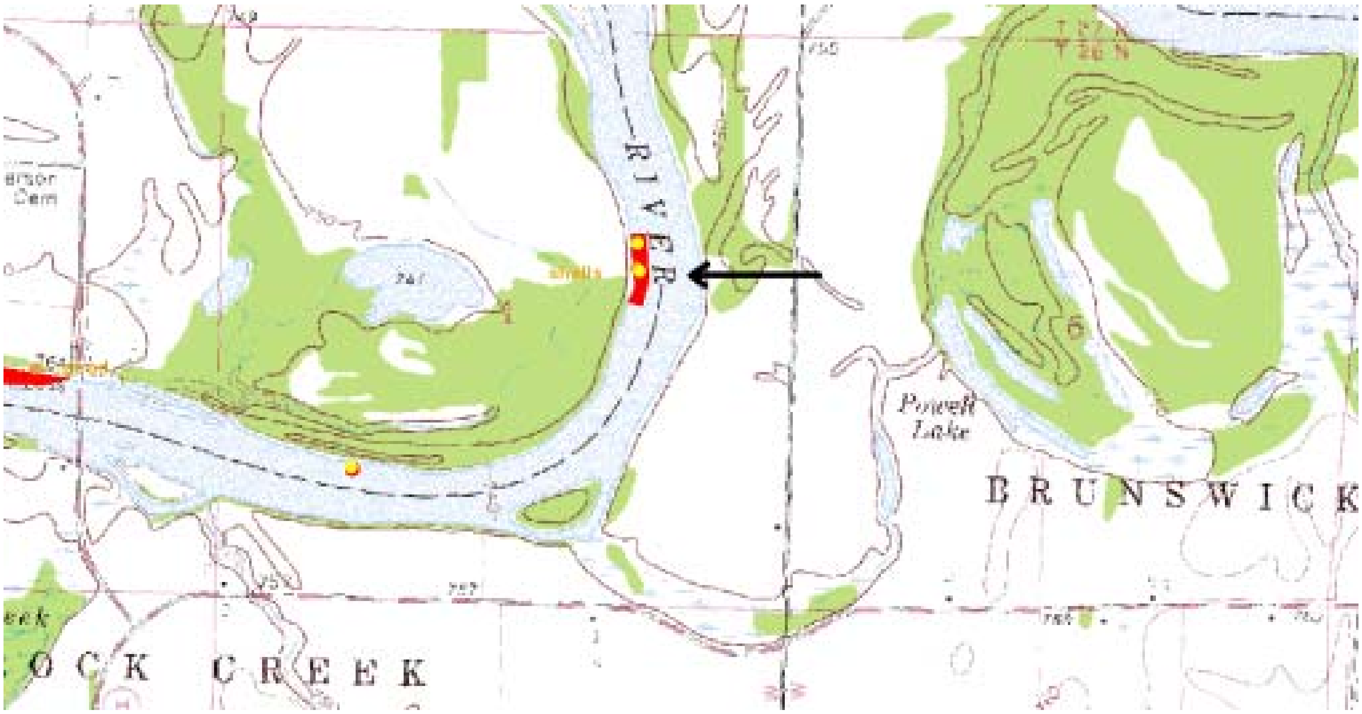


MUSSEL AGGREGATION “12-2”	
Latitude/Longitude	44° 46’ 18.9”N, 91° 38’ 9.6”W
Public Land Survey	Twp. 27N, Rng. 10W, Sec. 31 SE ¼ Eau Claire County, Wisconsin.
River Mile	47.2
Visually Est. Density	
Rank	3

Figure 12. Map of Mussel Aggregation "21-3".

MUSSEL AGGREGATION "21-3"	
Latitude/Longitude	44° 44' 43.5"N, 91° 48' 16.1"W
Public Land Survey	Twp. 26N, Rng. 12W, Sec. 11 SW ¼, Dunn County, Wisconsin.
River Mile	33.5
Visually Est. Density	1/m² (Max. 4/m²)
Rank	4

Figure 13. Map of Mussel Aggregation "14-3".



MUSSEL AGGREGATION "14-3"	
Latitude/Longitude	44° 45' 51.9"N, 91° 39' 18.8"W
Public Land Survey	Twp. 26N, Rng. 11W, Sec. 1 NE ¼, Dunn County, Wisconsin.
River Mile	44.5
Visually Est. Density	$<0.1/m^2$
Rank	5

CONCLUSIONS AND RECOMMENDATIONS

1) A total of 38 gravel and rock bars were identified during a census of the lower 59.2 miles of the Chippewa River, Wisconsin. The total surface area of bars (496 ha) covered 21% of the total instream surface area of 2319 ha. The greatest proportion of bar surface area was located in the upstream one-quarter of the study reach.

2) Of the eight bars that were examined in detail, six (75%) were mussel aggregations as defined here (>1 mussel/hour).

3) During 2001-2002, we found a total of 25 species were represented among 757 living individuals. Dead individuals represented no additional species. Two additional species were found in historic surveys: *U. imbecillis* and *Q. metanevra*. Lower Chippewa River species richness was comparable to other large tributary stream to the Mississippi River in Wisconsin. The lower Wisconsin River contains has about 29 while the lower Black River contains 23.

4) The lower Chippewa River contains a mussel community that is moderately associated with the presence of *L. higginsii*. A total of three of the taxa strongly associated with *L. higginsii* were found compared to all 11 in the Mississippi River and nine in the lower Wisconsin River. All three moderate associates were found. A relative ranking of major Wisconsin streams for *L. higginsii* associates placed the Mississippi River highest followed by the lower Wisconsin River, lower Chippewa River and the lower Black River.

5) Although *L. higginsii* has never been recorded from the lower Chippewa River, we cannot dismiss the possibility it occurred there or that an introduced population would survive there. Although there are no historic records, it remains somewhat speculative as to whether the species can be ruled out as having a historic presence. The hydrology and erosive nature (shifting sand, tanic acid) of the Chippewa River on shells could have destroyed any evidence of *L. higginsii*. Given its size, mussel fauna present, proximity to historic *L. higginsii* populations, lack of zebra mussels and presence of mussel aggregations, the lower Chippewa River may serve as an adequate relocation site. It's uncertain if populations would persist over very long periods (>50 years), but may be present long enough to serve as a temporary refugia until, and if, Mississippi River conditions are more conducive to habitation.

6) Of the 35 mussel aggregations, we recommended 5 based on CPH, total surface area, and proximity to known gravel bars, as locations where *L. higginsii* introductions may be most successful.

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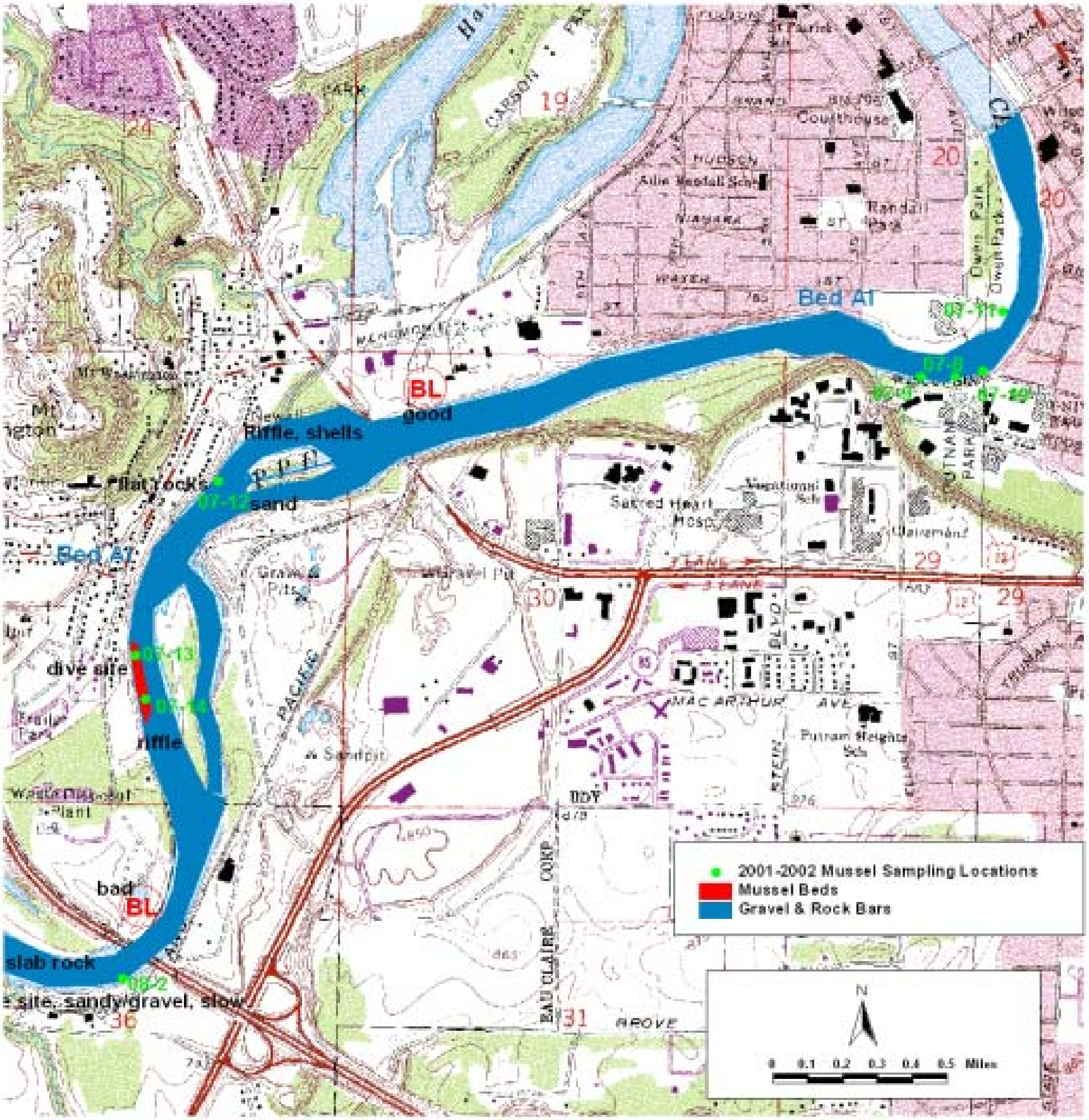
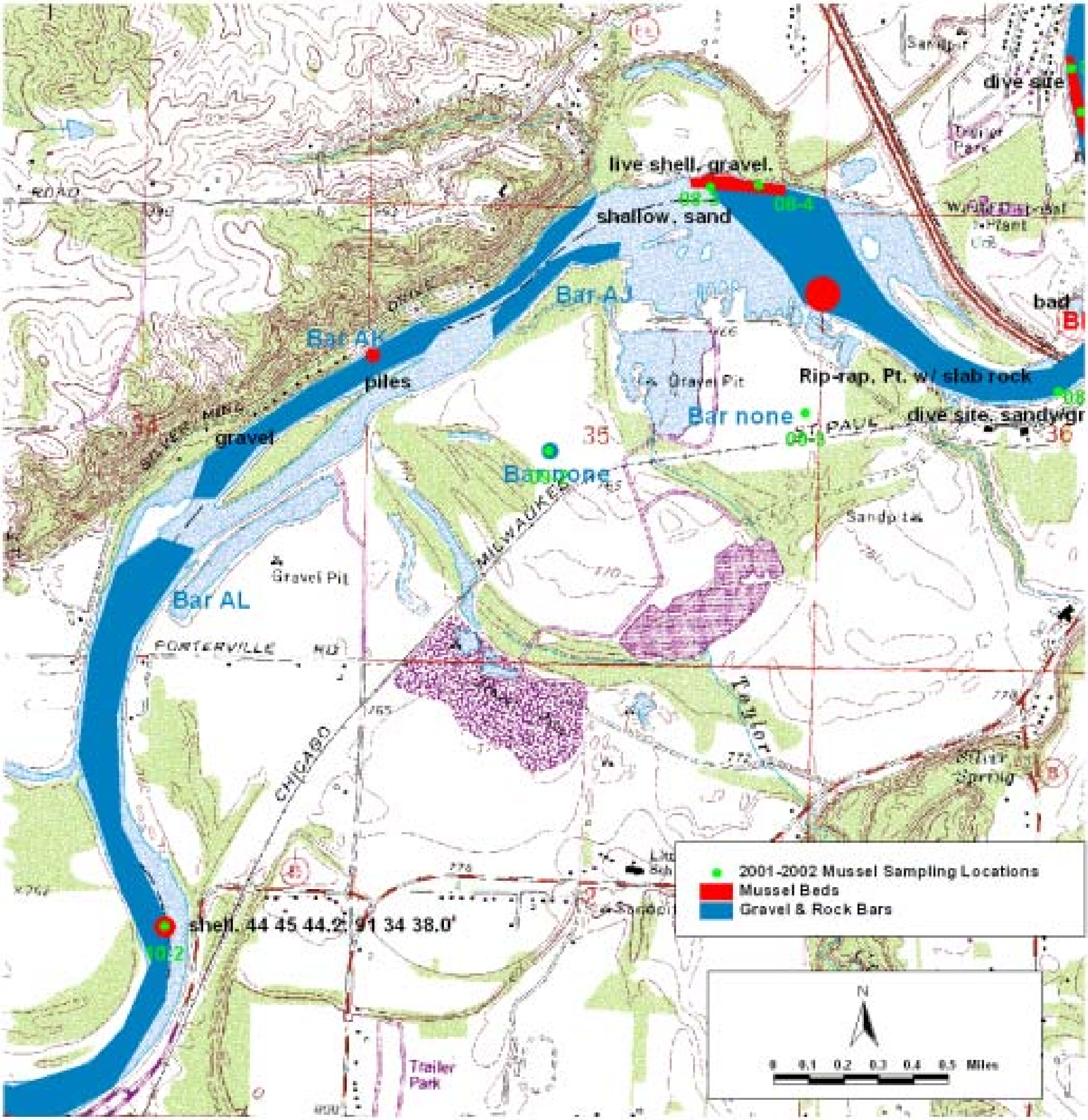
APPENDIX A

LOCATIONS OF GRAVEL BARS AND MUSSEL AGGREGATIONS IN THE LOWER CHIPPEWA RIVER, WISCONSIN, 2001-2002.

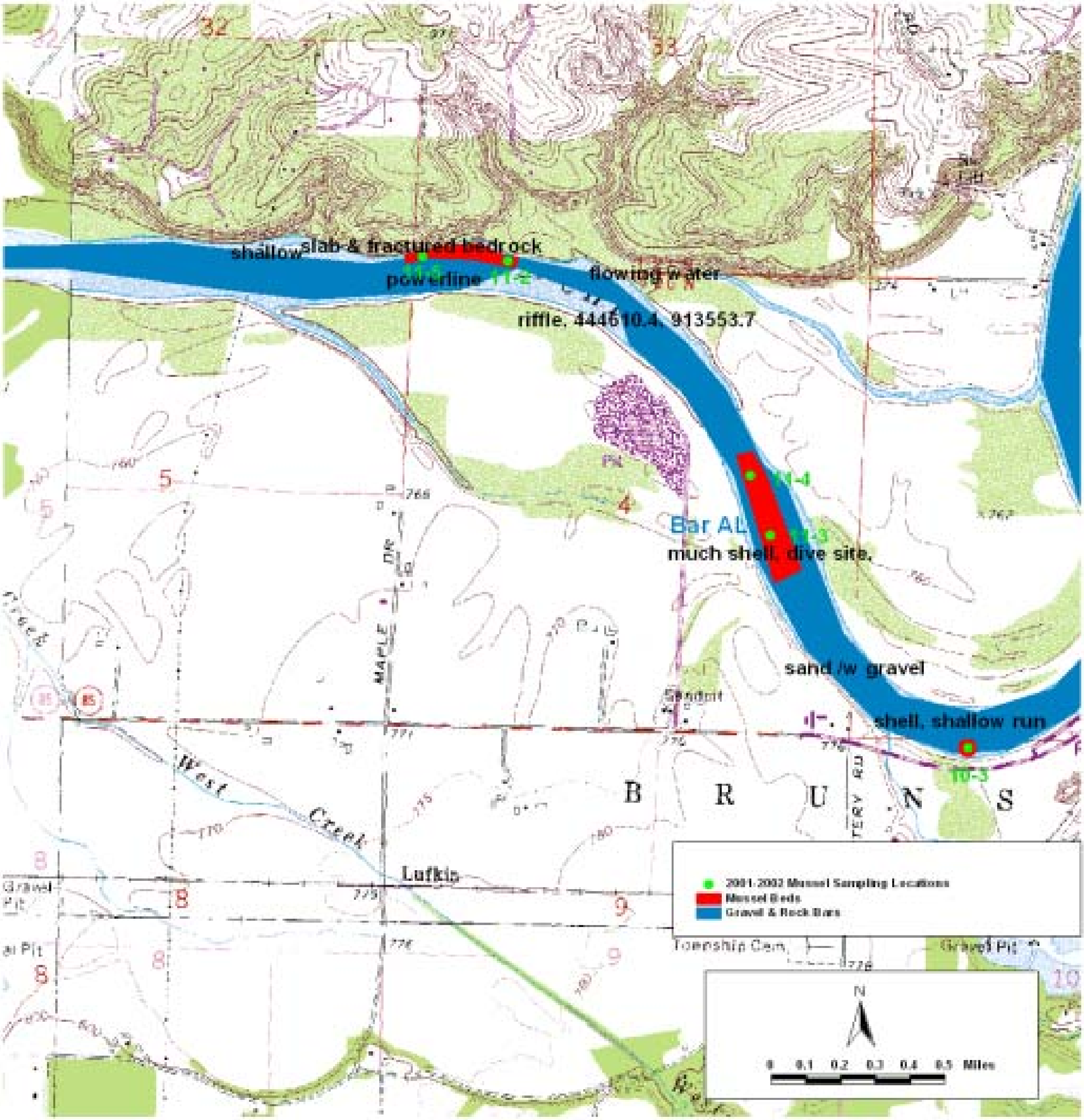
Lower Chippewa River, Mussel Aggregations, Gravel and Rock Bars, River Miles 58.0-54.0.



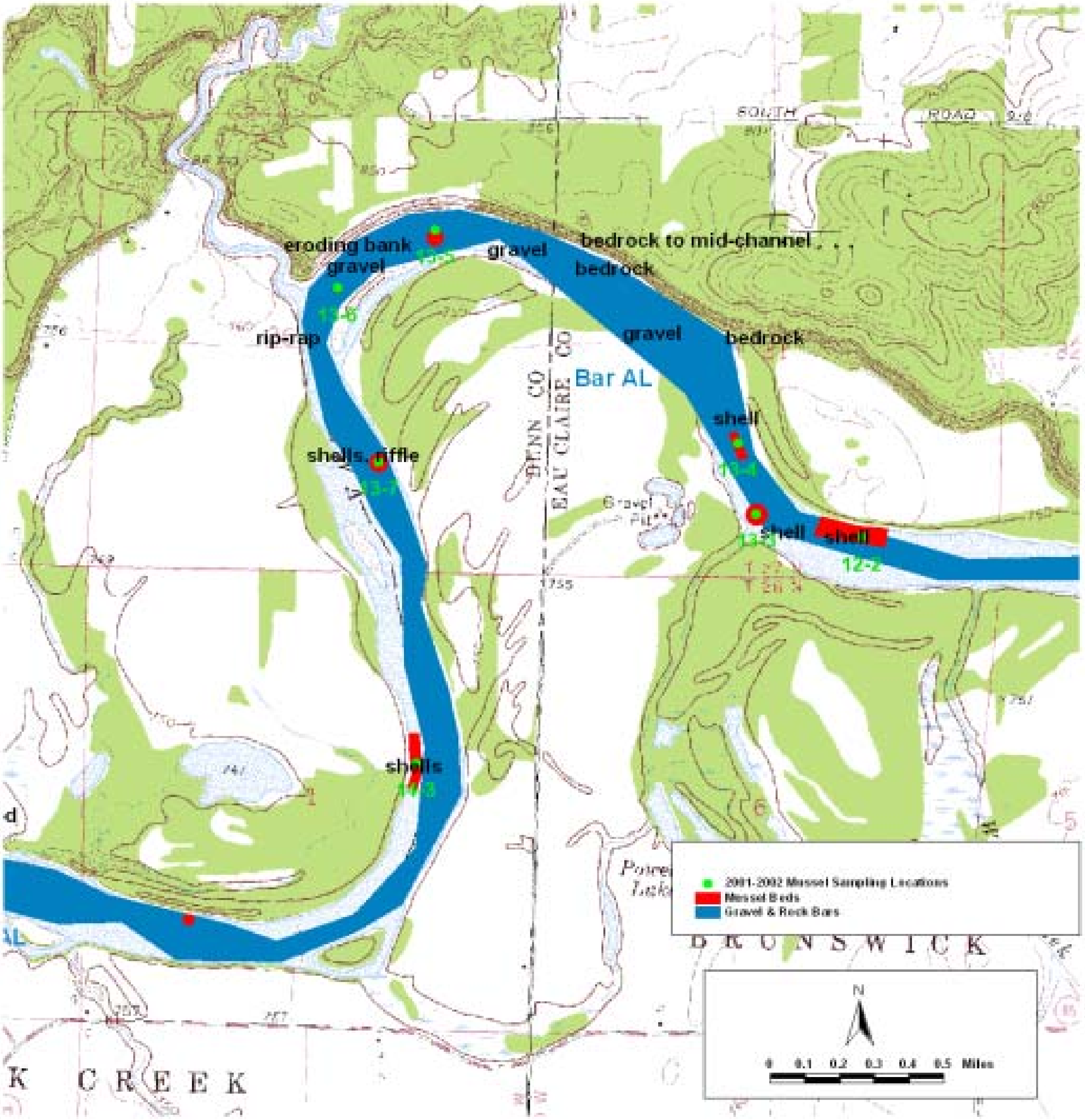
Lower Chippewa River, Mussel Aggregations, Gravel and Rock Bars, River Miles 54.0-50.5.



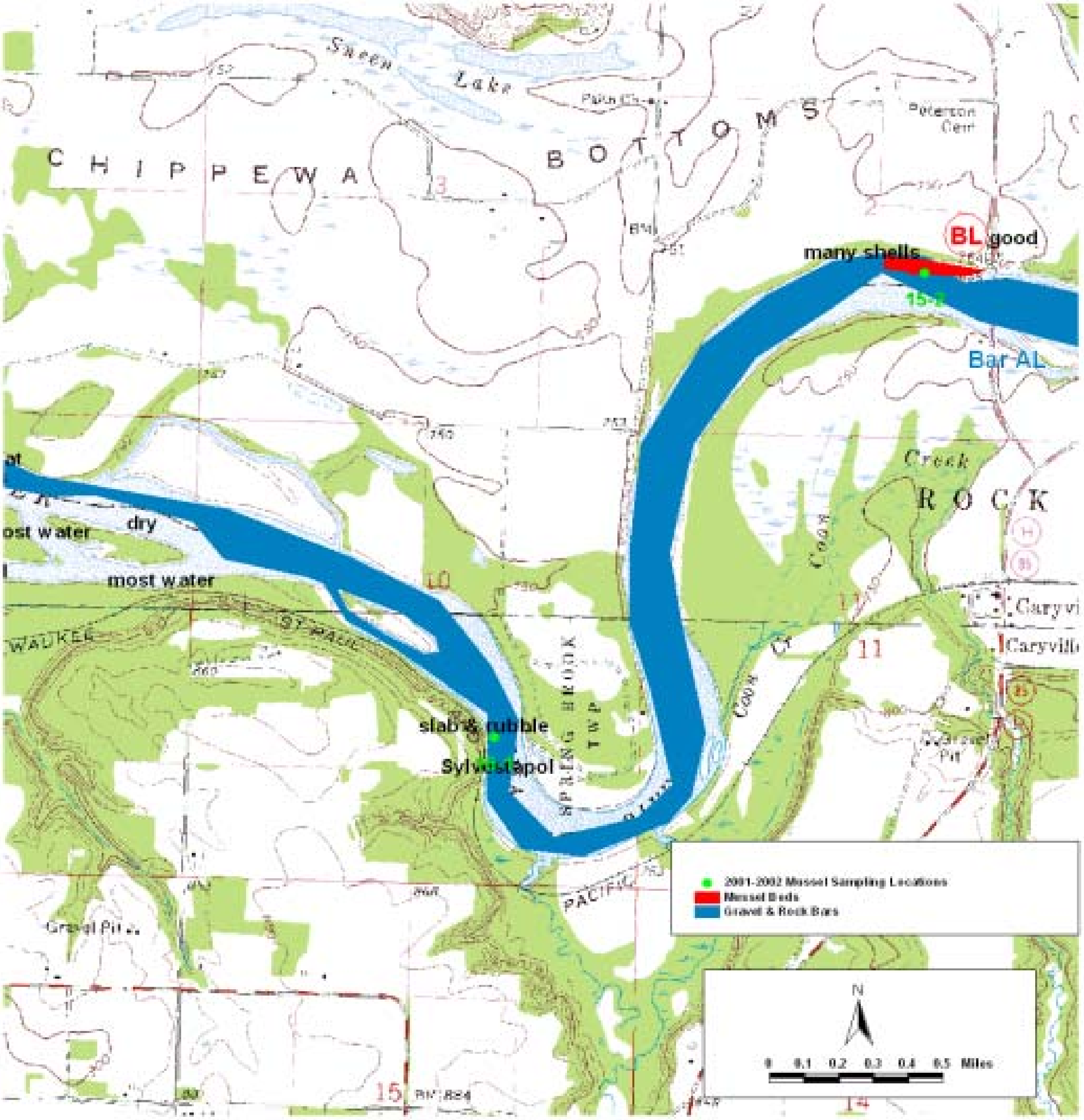
Lower Chippewa River, Mussel Aggregations, Gravel and Rock Bars, River Miles 50.5-47.8.



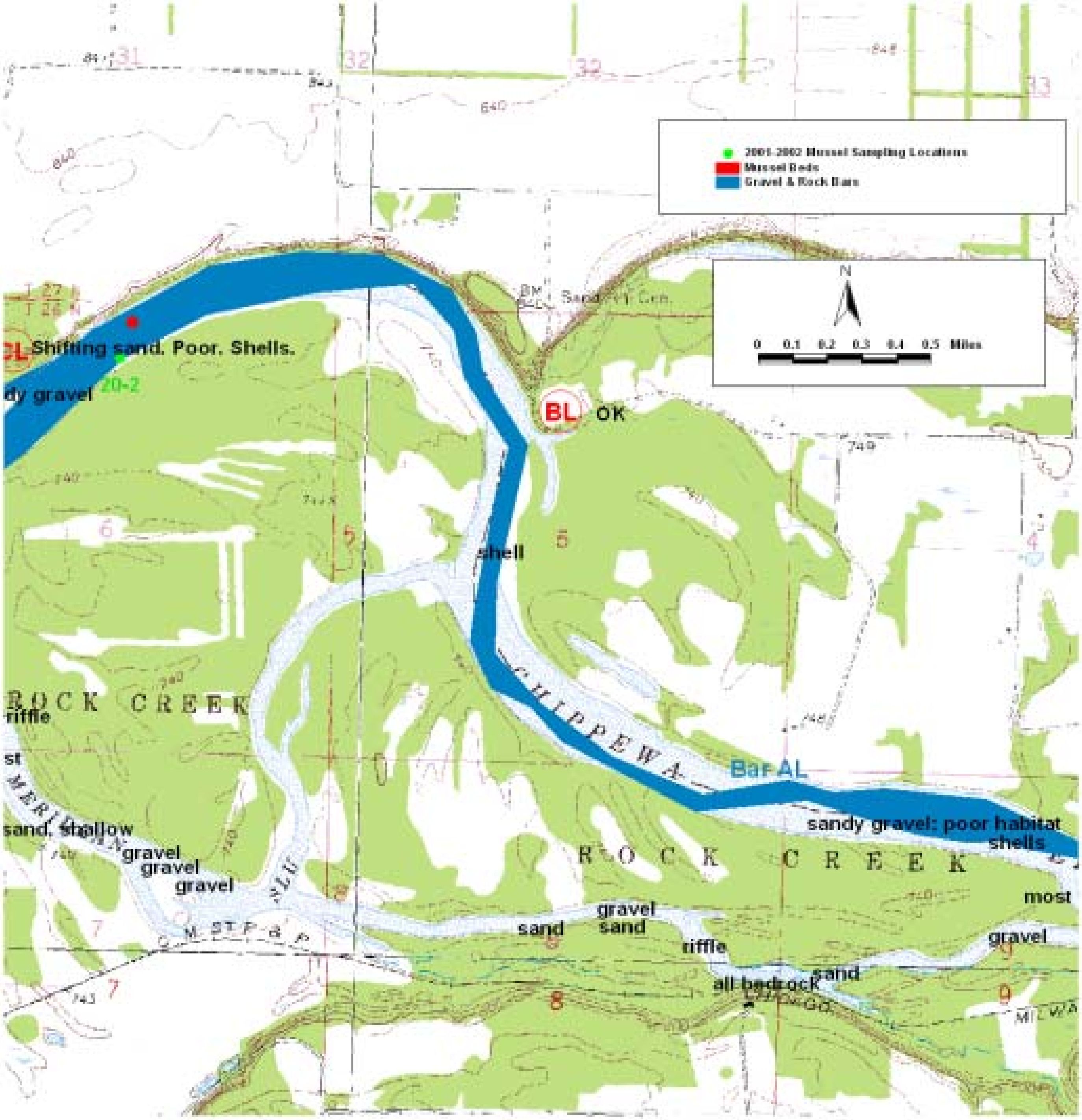
Lower Chippewa River, Mussel Aggregations, Gravel and Rock Bars, River Miles 47.8 - 43.9.



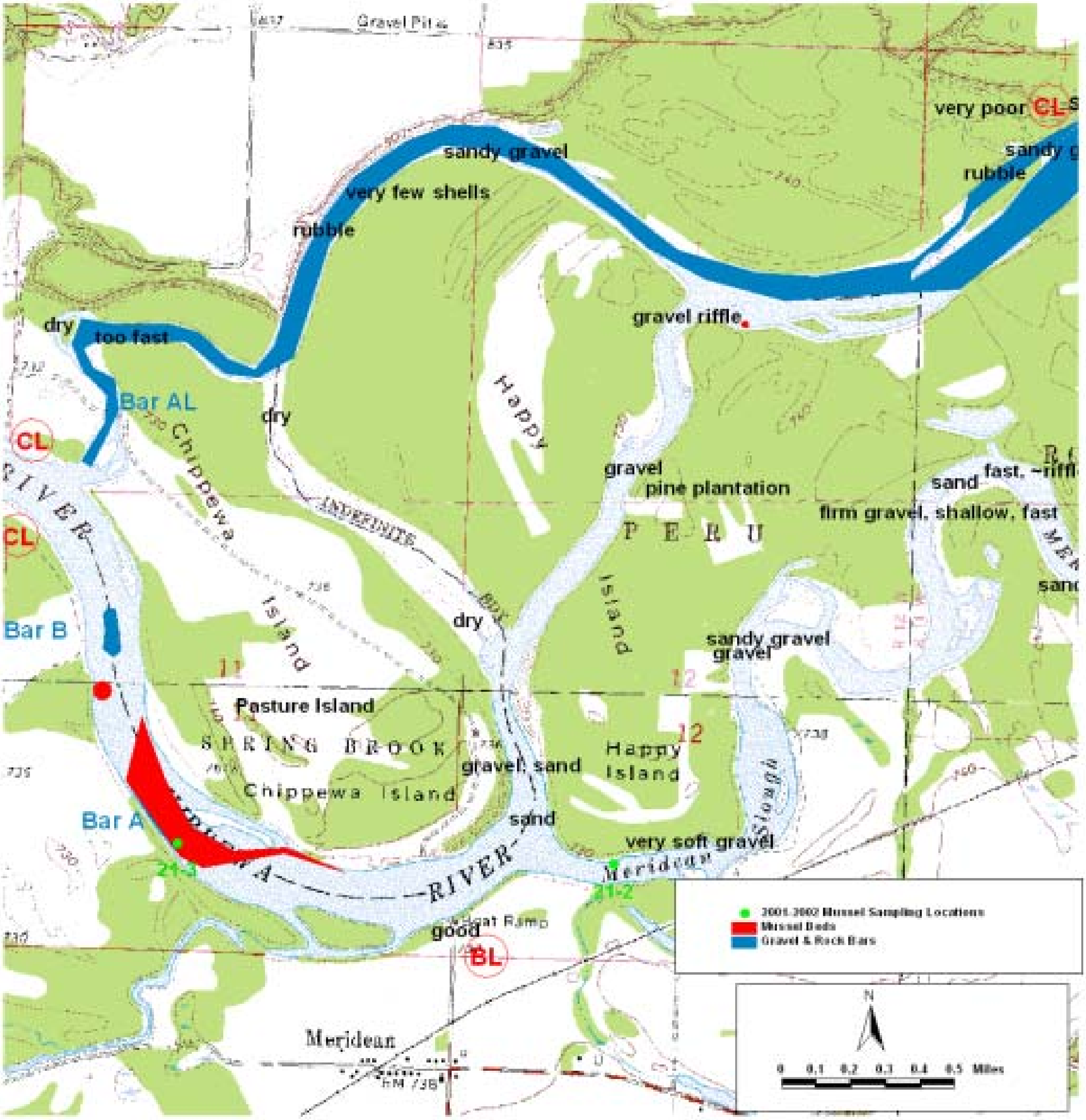
Lower Chippewa River, Mussel Aggregations, Gravel and Rock Bars, River Miles 43.9 - 39.7.



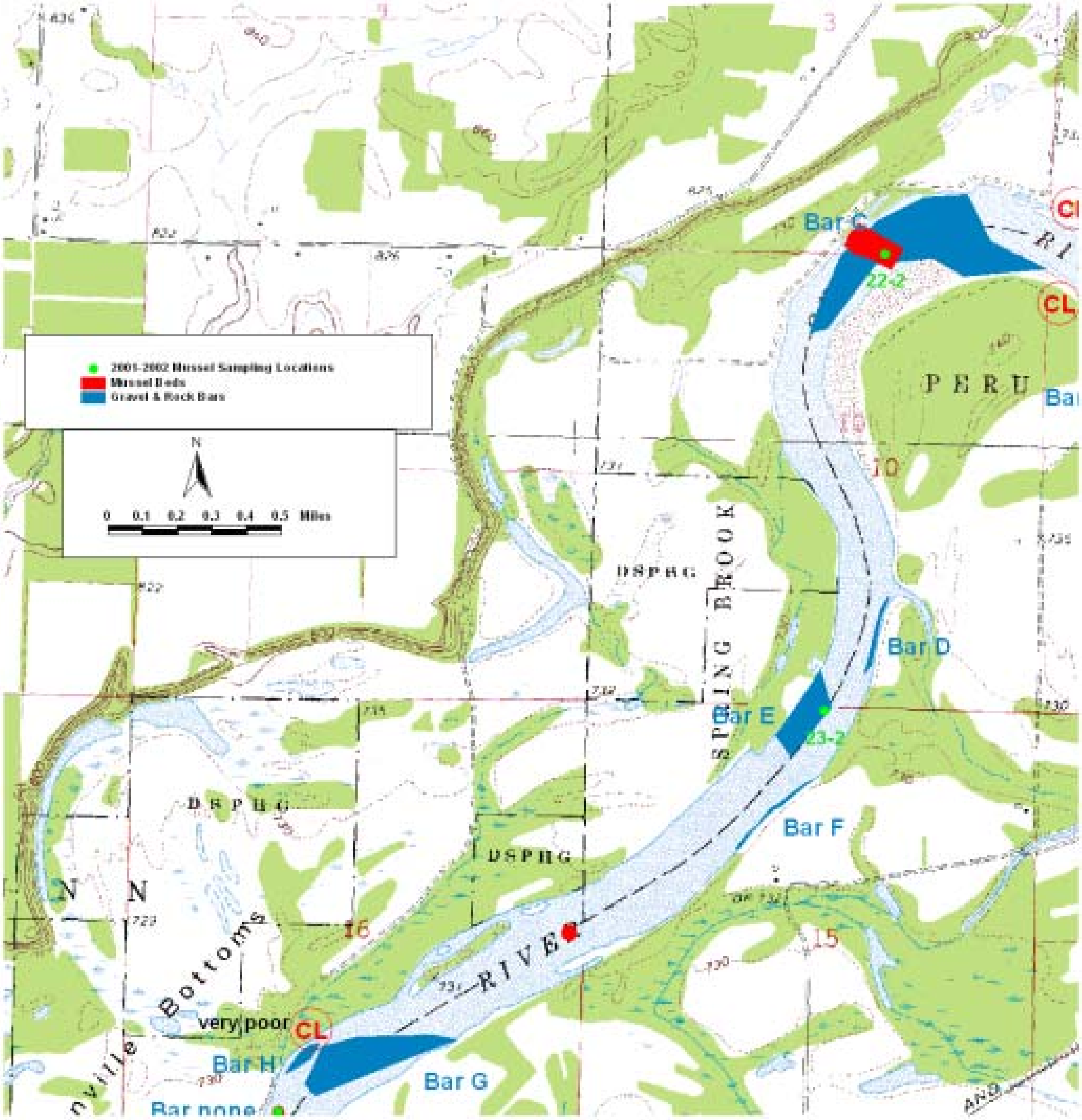
Lower Chippewa River, Mussel Aggregations, Gravel and Rock Bars, River Miles 39.7 - 36.7.



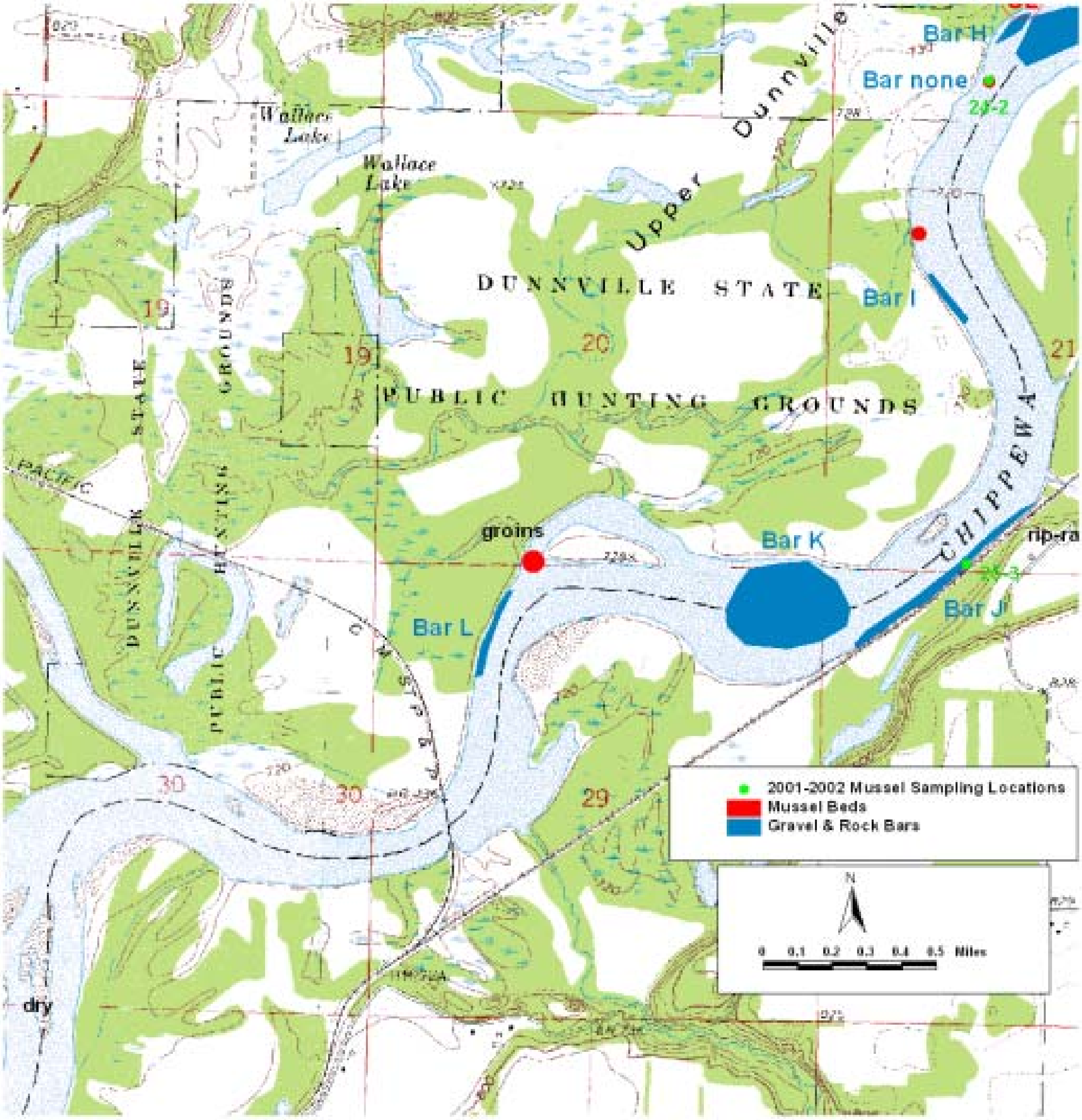
Lower Chippewa River, Mussel Aggregations, Gravel and Rock Bars, River Miles 36.7 - 32.5.



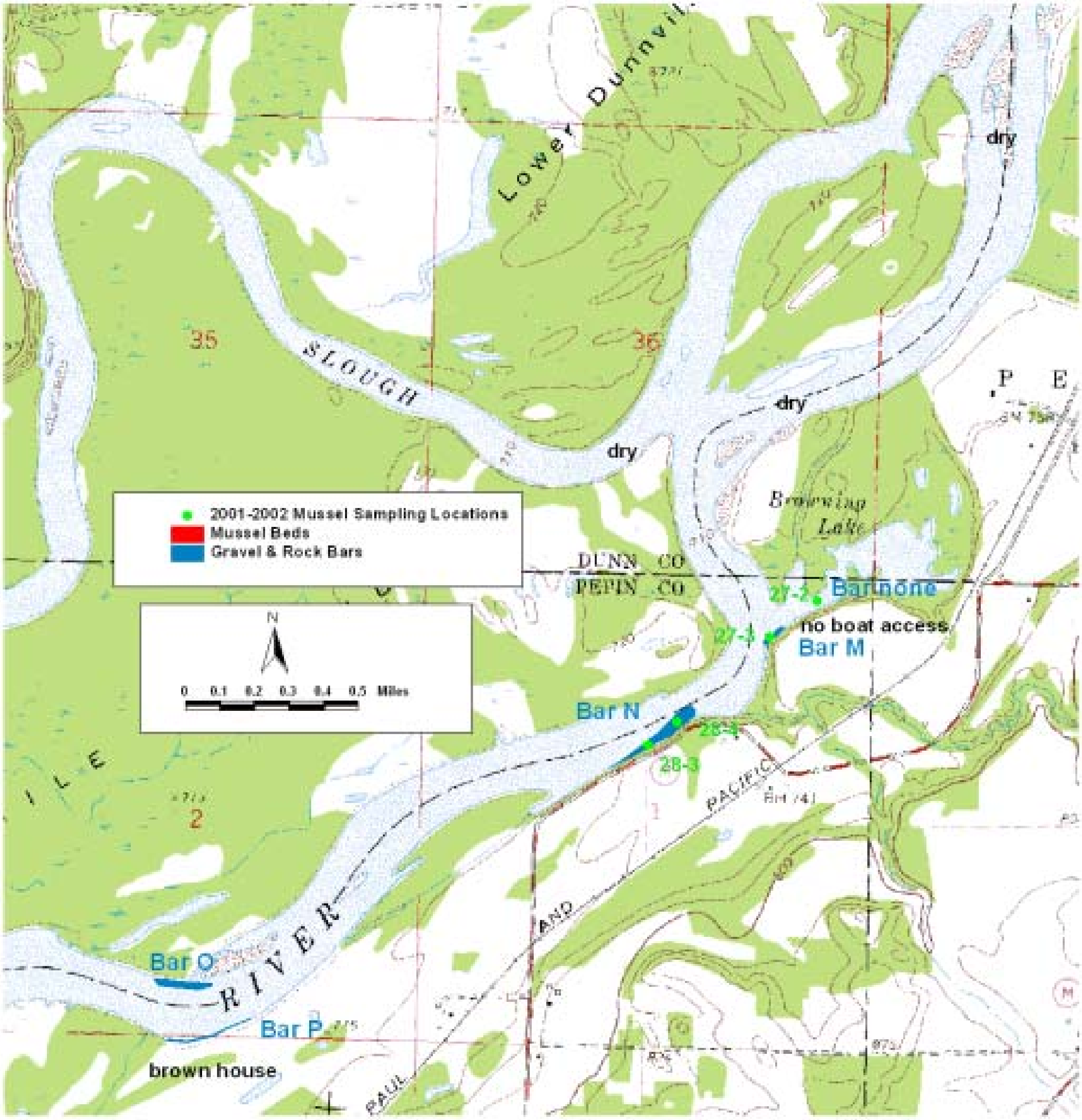
Lower Chippewa River, Mussel Aggregations, Gravel and Rock Bars, River Miles 32.5 - 30.0.



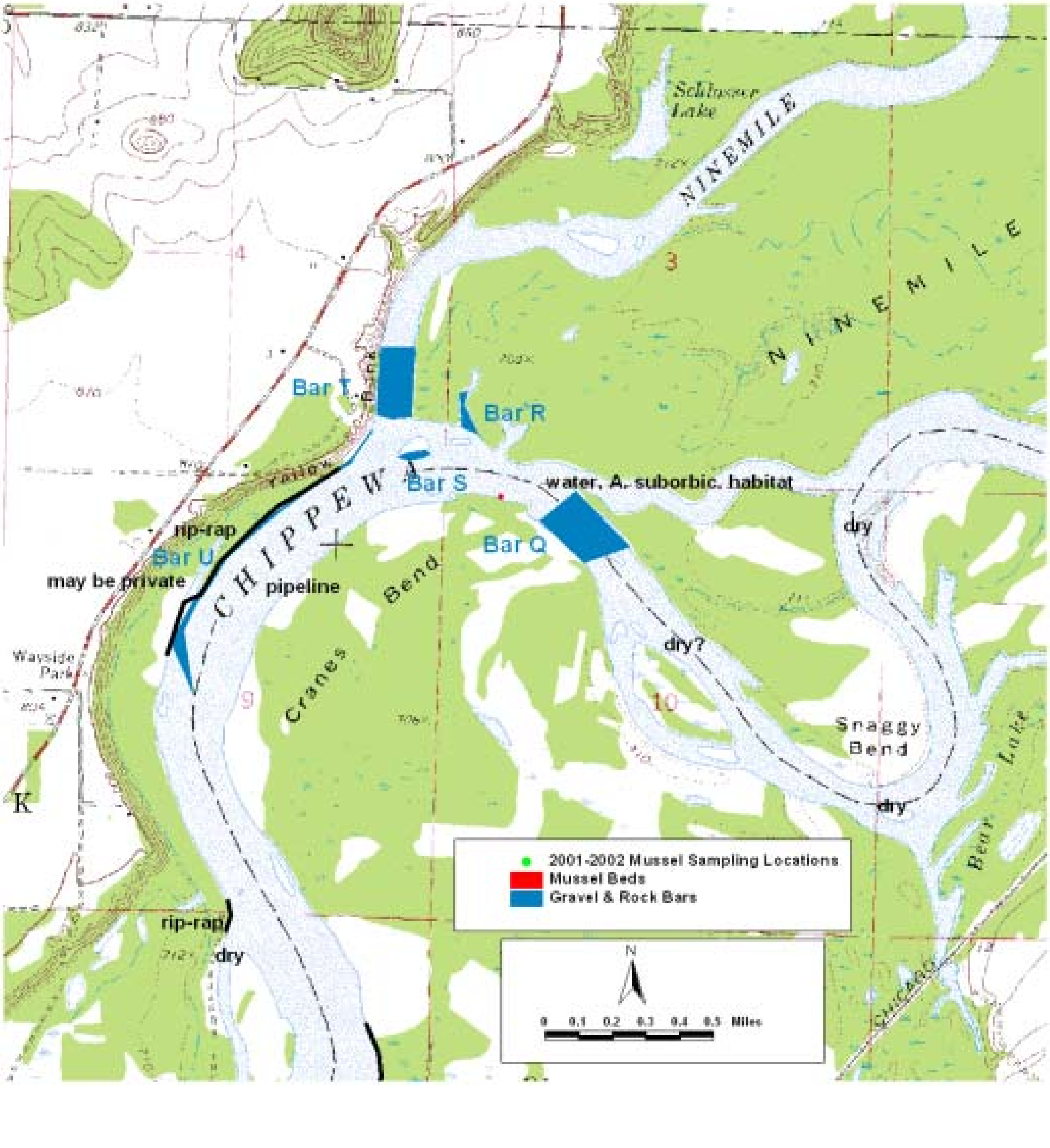
Lower Chippewa River, Mussel Aggregations, Gravel and Rock Bars, River Miles 30.0. - 26.0



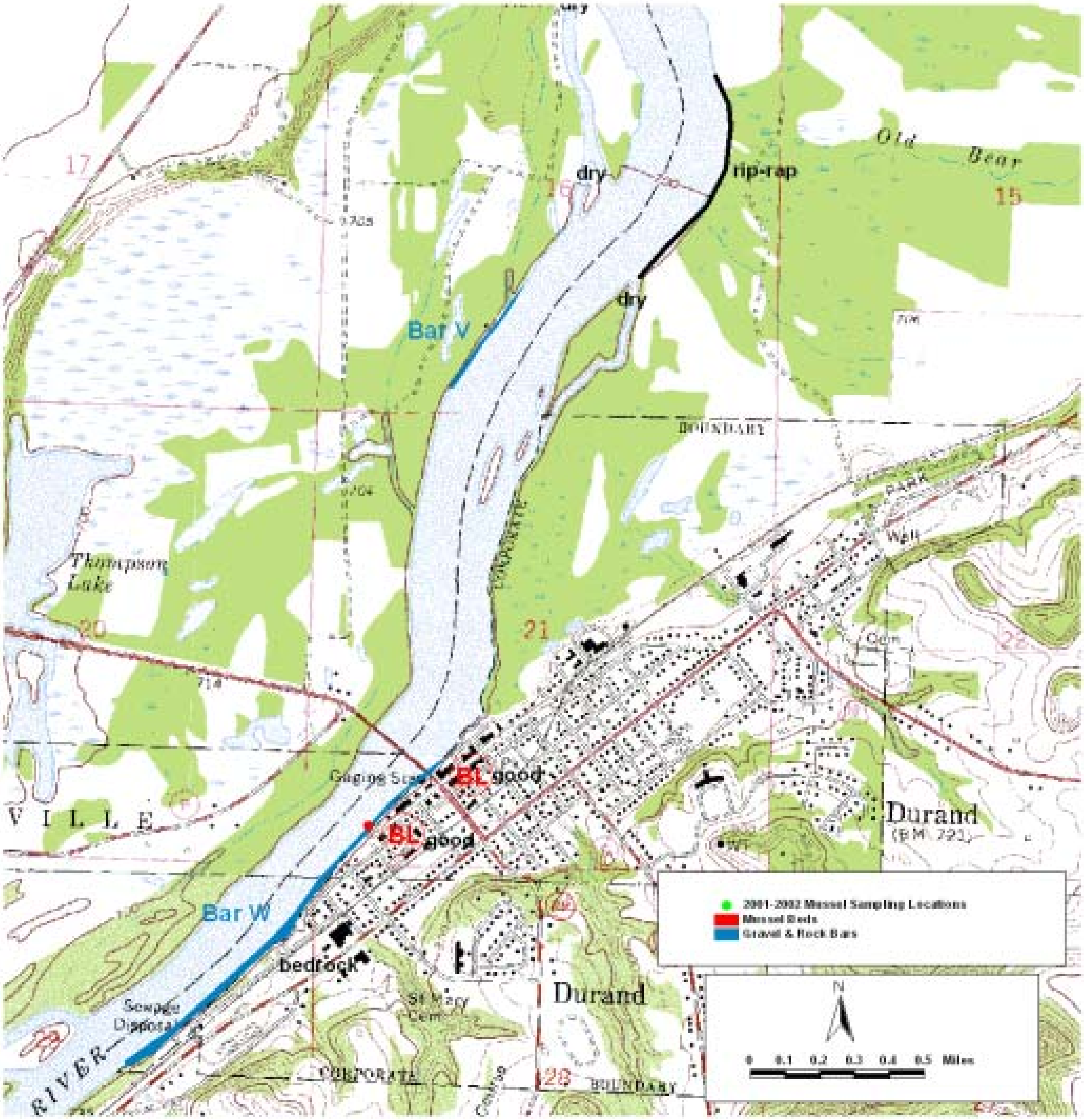
Lower Chippewa River, Mussel Aggregations, Gravel and Rock Bars, River Miles 26.0 - 22.2



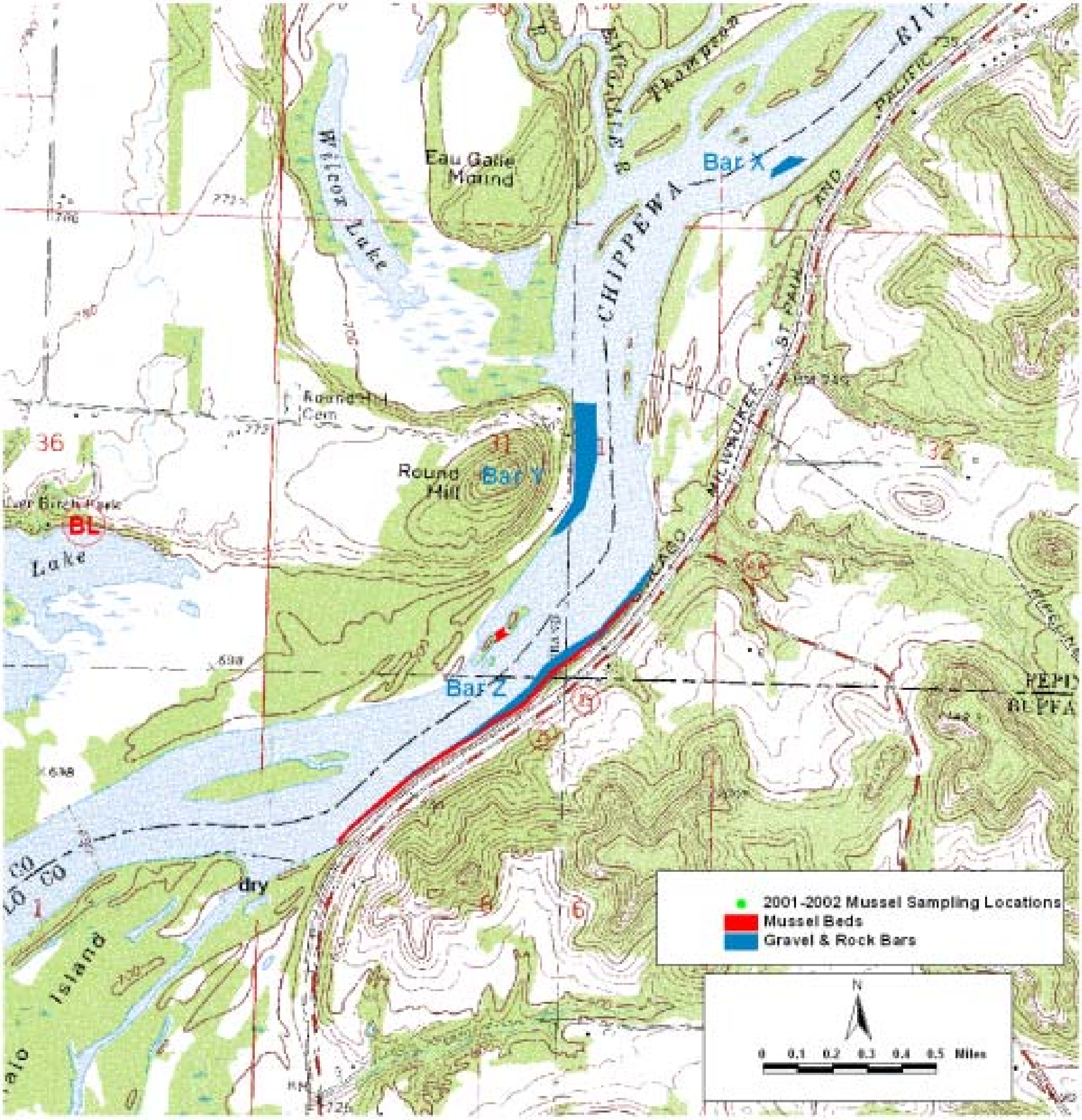
Lower Chippewa River, Mussel Aggregations, Gravel and Rock Bars, River Miles 22.2 - 19.0



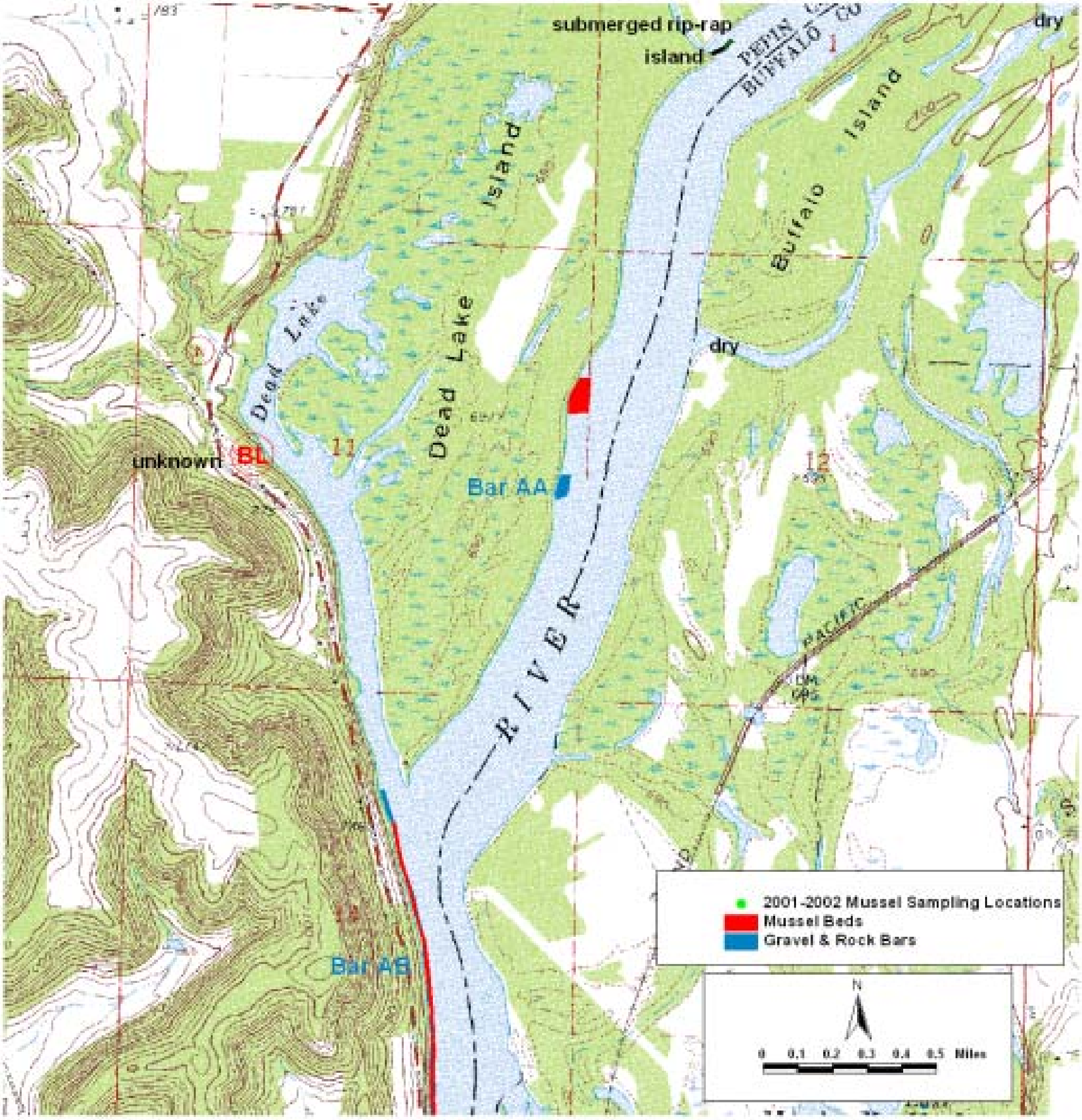
Lower Chippewa River, Mussel Aggregations, Gravel and Rock Bars, River Miles 19. 0 - 16.4.



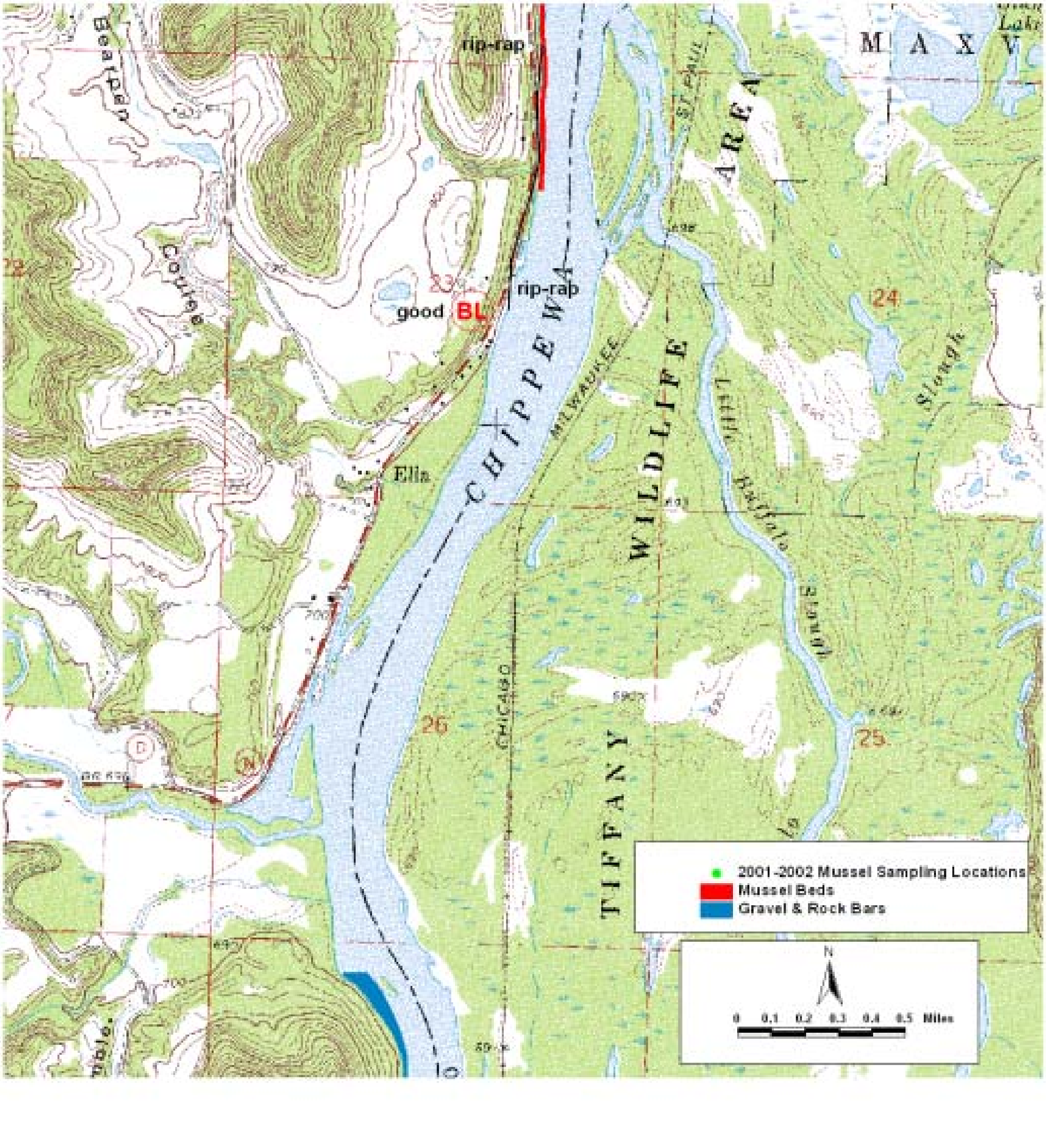
Lower Chippewa River, Mussel Aggregations, Gravel and Rock Bars, River Miles 16.4 - 13.3



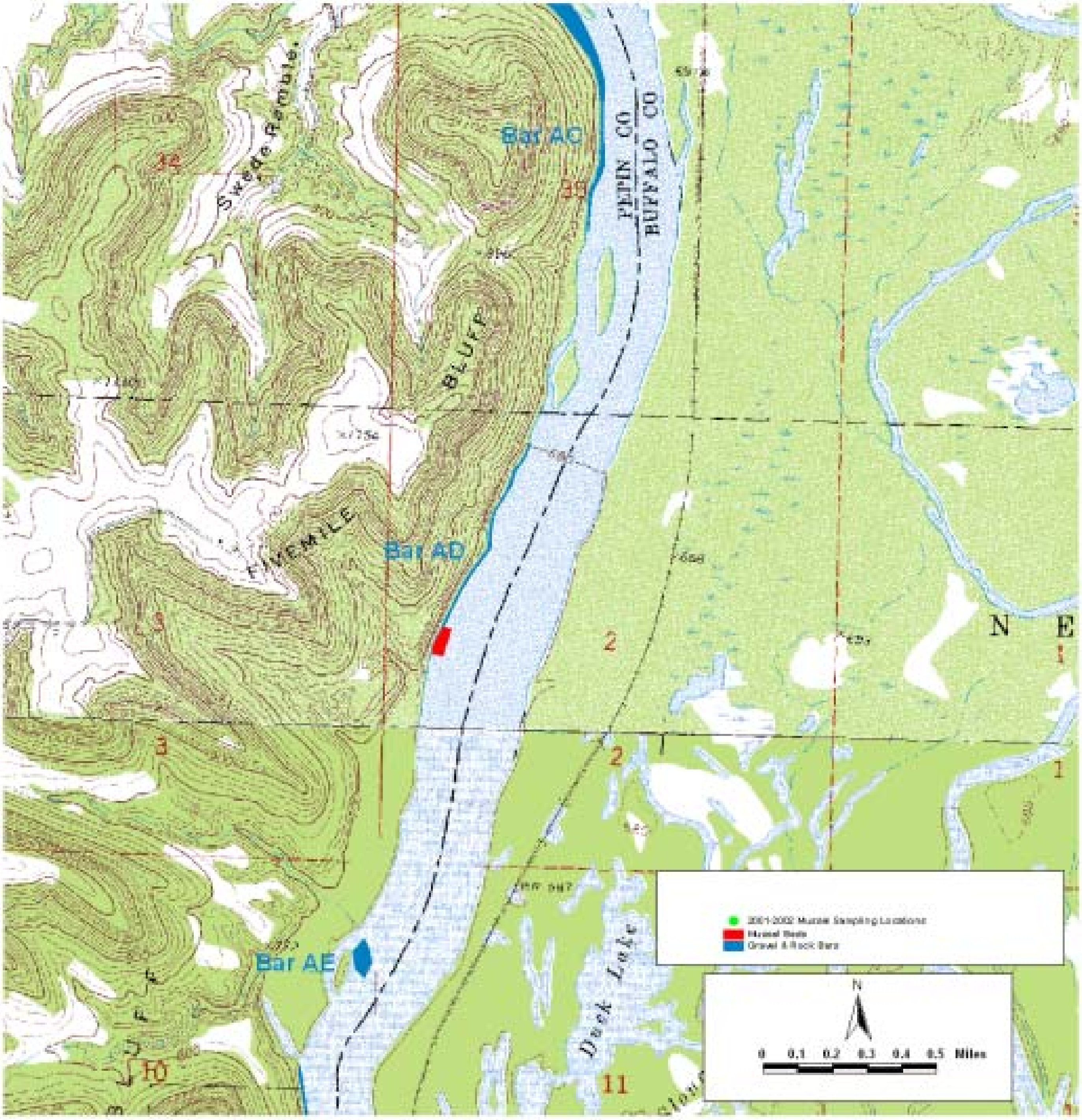
Lower Chippewa River, Mussel Aggregations, Gravel and Rock Bars, River Miles 13.3 - 10.7.



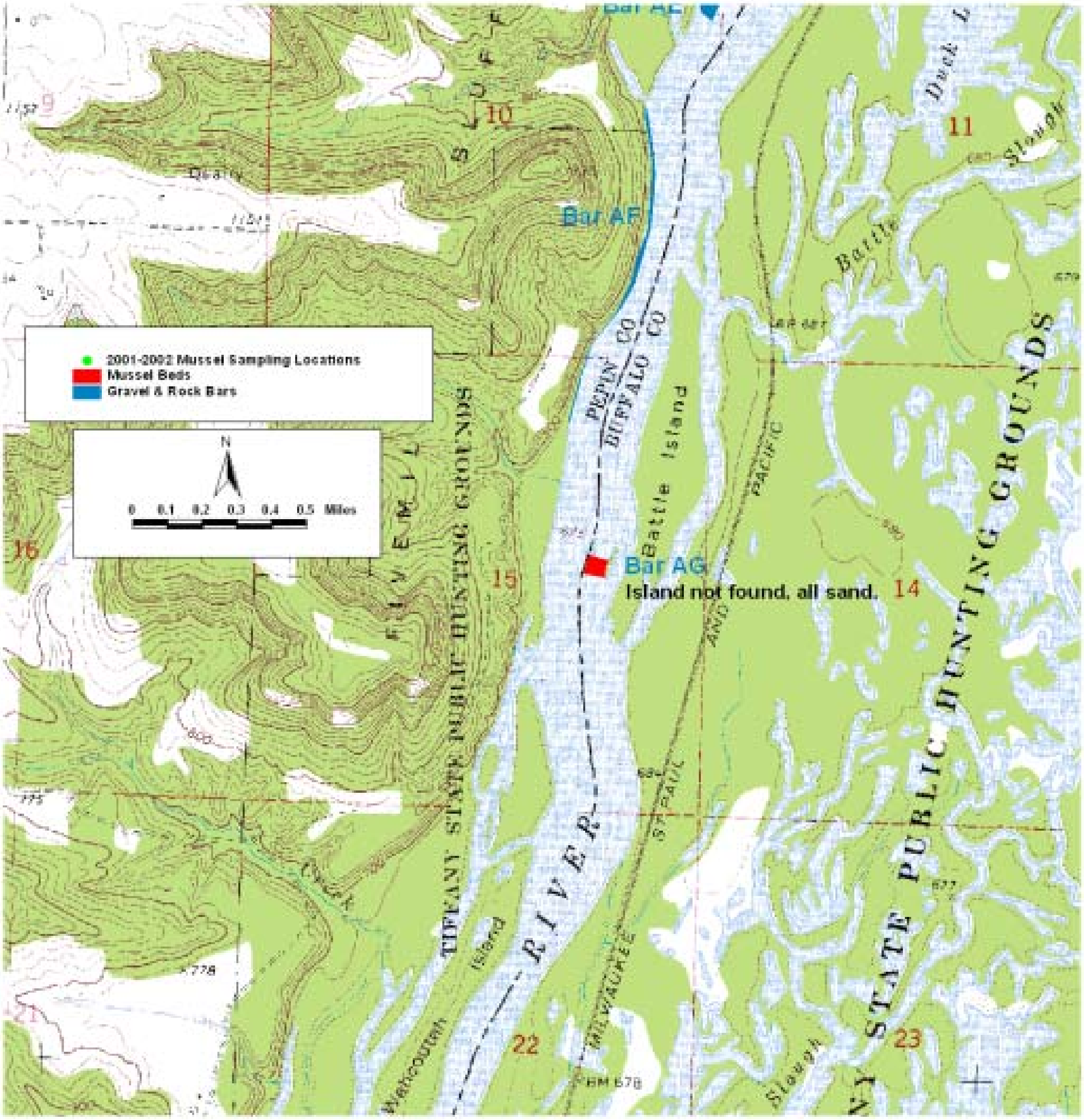
Lower Chippewa River, Mussel Aggregations, Gravel and Rock Bars, River Miles 10.7 - 8.3.



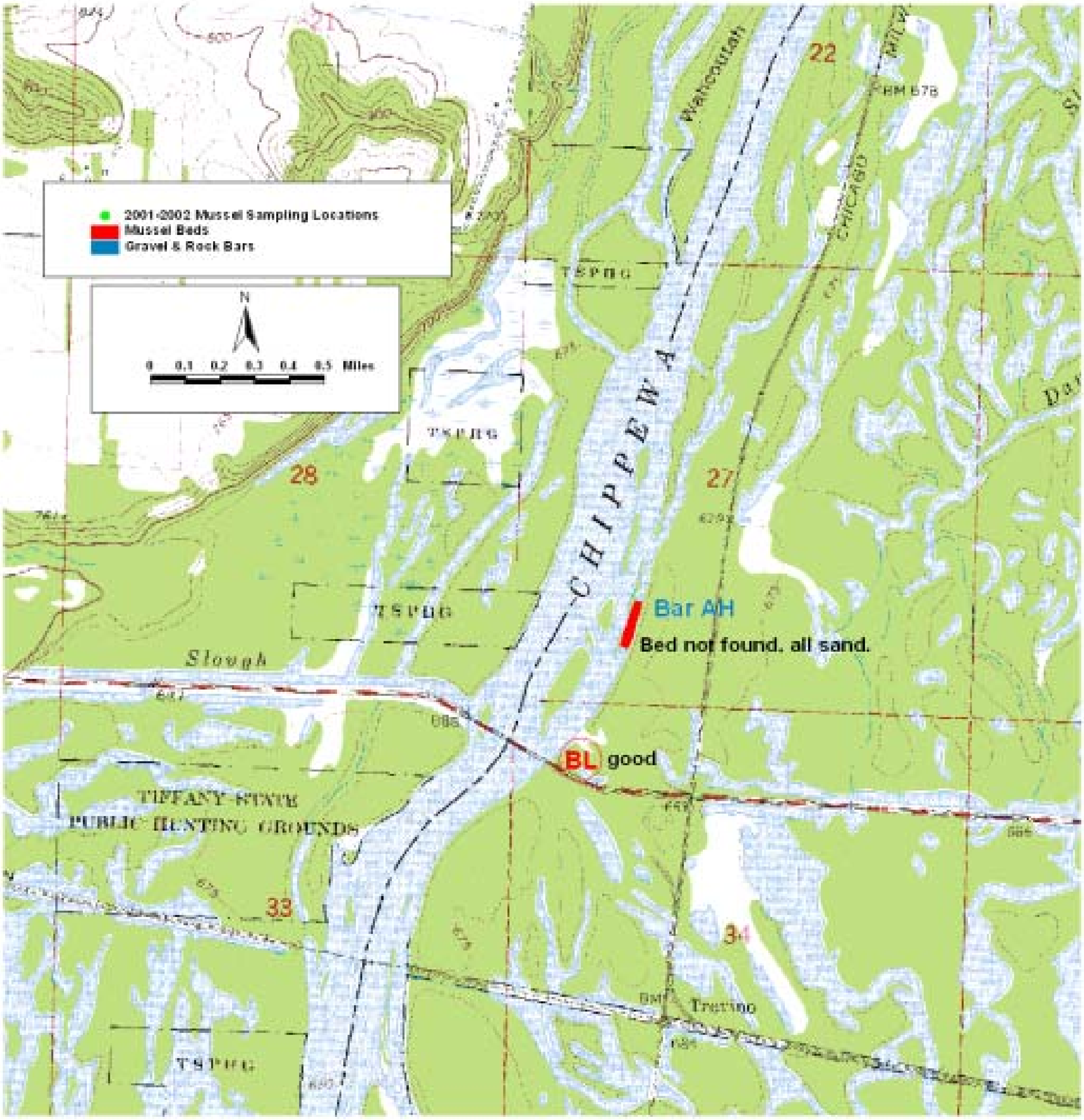
Lower Chippewa River, Mussel Aggregations, Gravel and Rock Bars, River Miles 8.3 - 5.8.



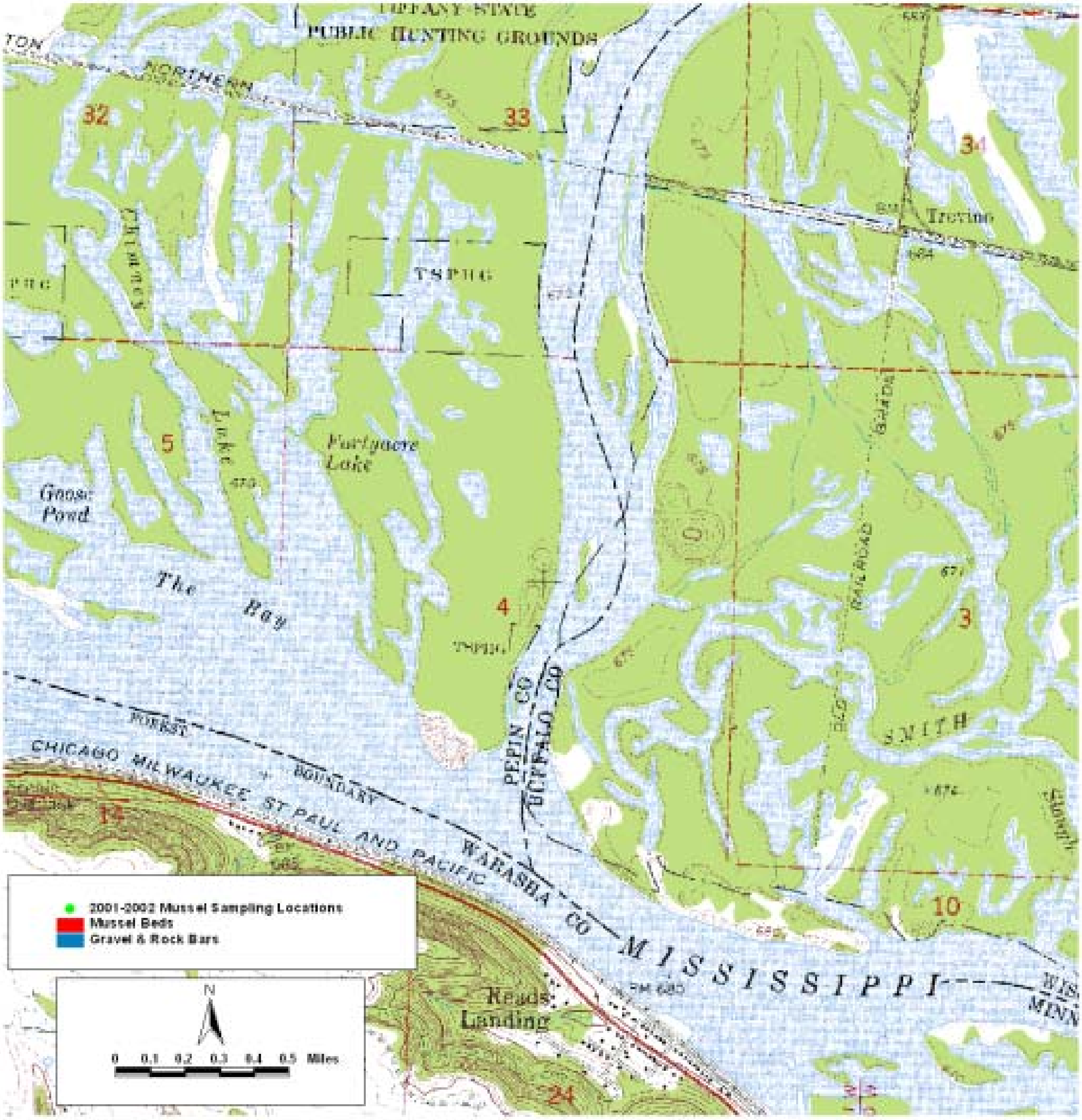
Lower Chippewa River, Mussel Aggregations, Gravel and Rock Bars, River Miles 5.8 - 3.6.



Lower Chippewa River, Mussel Aggregations, Gravel and Rock Bars, River Miles 3.6 - 1.3.



Lower Chippewa River, Mussel Aggregations, Gravel and Rock Bars, River Miles 1.3 - 0.00.



APPENDIX B

MUSSEL DATA FROM THE LOWER

CHIPPEWA RIVER, WISCONSIN, 2001-2002.

TAXON	AGGREGATION	RIVER MILE	SUMLIVE	SUMDEAD
A. g. form corpulenta	07-11	57.25	0	1
A. marginata	07-11	57.25	0	2
E. dilatata	07-11	57.25	1	1
L. c. complanata	07-11	57.25	0	2
L. cardium	07-11	57.25	0	29
L. fragilis	07-11	57.25	0	12
L. recta	07-11	57.25	0	21
L. siliquoidea	07-11	57.25	0	17
O. olivaria	07-11	57.25	1	12
O. reflexa	07-11	57.25	0	1
P. alatus	07-11	57.25	0	4
Q. pustulosa pustulosa	07-11	57.25	0	1
S. u. undulatus	07-11	57.25	0	5
T. truncata	07-11	57.25	0	5
A. marginata	07-10	57.12	1	0
L. fragilis	07-10	57.12	1	0
L. recta	07-10	57.12	1	0
L. siliquoidea	07-10	57.12	6	1
O. olivaria	07-10	57.12	1	0
P. alatus	07-10	57.12	2	0
T. truncata	07-10	57.12	1	0
A. g. form corpulenta	07-8	57.06	1	0
L. cardium	07-8	57.06	3	0
L. recta	07-8	57.06	4	0
L. siliquoidea	07-8	57.06	6	0
P. alatus	07-8	57.06	1	0
A. g. form corpulenta	07-9	56.99	2	0
A. marginata	07-9	56.99	2	0
L. cardium	07-9	56.99	1	1
L. fragilis	07-9	56.99	1	0
L. siliquoidea	07-9	56.99	4	0
P. alatus	07-9	56.99	1	0
unidentified	07-9	56.99	0	1
A. marginata	07-13	54.91	1	0
L. cardium	07-13	54.91	2	0
L. fragilis	07-13	54.91	0	1
L. recta	07-13	54.91	3	0
O. olivaria	07-13	54.91	1	0
P. alatus	07-13	54.91	2	0
Q. pustulosa pustulosa	07-13	54.91	1	0
A. marginata	07-14	54.79	1	0
L. c. complanata	07-14	54.79	1	0
L. cardium	07-14	54.79	1	0
L. costata	07-14	54.79	1	0

L. fragilis	07-14	54.79	1	1
L. recta	07-14	54.79	1	0
L. siliquoidea	07-14	54.79	2	0
O. olivaria	07-14	54.79	1	0
O. reflexa	07-14	54.79	2	0
P. alatus	07-14	54.79	2	0
T. verrucosa	07-14	54.79	2	0
A. g. form corpulenta	09-3	53.72	4	1
L. c. complanata	09-3	53.72	0	1
A. g. form corpulenta	08-4	53.36	6	0
F. flava	08-4	53.36	25	0
L. c. complanata	08-4	53.36	8	0
L. cardium	08-4	53.36	1	0
L. fragilis	08-4	53.36	2	0
O. olivaria	08-4	53.36	7	0
O. reflexa	08-4	53.36	2	0
P. alatus	08-4	53.36	13	0
Q. pustulosa pustulosa	08-4	53.36	16	0
T. verrucosa	08-4	53.36	1	0
A. l. carinata	08-3	53.24	3	0
F. flava	08-3	53.24	7	0
L. c. complanata	08-3	53.24	1	0
L. cardium	08-3	53.24	3	0
L. fragilis	08-3	53.24	1	0
L. recta	08-3	53.24	1	2
O. olivaria	08-3	53.24	1	0
P. alatus	08-3	53.24	1	0
P. sintoxia	08-3	53.24	1	0
Q. pustulosa pustulosa	08-3	53.24	2	0
A. marginata	10-2	50.89	2	0
F. flava	10-2	50.89	2	0
L. cardium	10-2	50.89	10	0
L. fragilis	10-2	50.89	1	0
L. recta	10-2	50.89	3	0
O. olivaria	10-2	50.89	7	0
O. reflexa	10-2	50.89	1	0
P. alatus	10-2	50.89	3	0
Q. pustulosa pustulosa	10-2	50.89	2	0
S. u. undulatus	10-2	50.89	1	0
A. marginata	10-3	50.26	1	0
F. flava	10-3	50.26	1	0
L. c. complanata	10-3	50.26	2	0
L. fragilis	10-3	50.26	1	0
L. recta	10-3	50.26	1	0
O. olivaria	10-3	50.26	1	0

P. alatus	10-3	50.26	3	0
S. u. undulatus	10-3	50.26	1	0
A. marginata	11-3	49.61	2	0
F. flava	11-3	49.61	5	0
L. cardium	11-3	49.61	10	0
L. fragilis	11-3	49.61	1	0
L. recta	11-3	49.61	4	0
L. siliquoidea	11-3	49.61	1	0
O. olivaria	11-3	49.61	7	0
P. alatus	11-3	49.61	2	0
S. u. undulatus	11-3	49.61	4	0
T. truncata	11-3	49.61	1	0
A. marginata	11-4	49.48	3	0
F. flava	11-4	49.48	10	0
L. c. complanata	11-4	49.48	1	0
L. cardium	11-4	49.48	7	0
L. costata	11-4	49.48	1	0
L. fragilis	11-4	49.48	4	0
L. recta	11-4	49.48	5	0
L. siliquoidea	11-4	49.48	1	0
O. olivaria	11-4	49.48	12	0
O. reflexa	11-4	49.48	1	0
P. alatus	11-4	49.48	4	0
P. sintoxia	11-4	49.48	3	0
T. truncata	11-4	49.48	7	0
O. olivaria	11-2	48.75	1	0
A. marginata	11-5	48.56	3	0
L. cardium	11-5	48.56	1	0
L. costata	11-5	48.56	1	0
P. alatus	11-5	48.56	2	0
S. ambigua	11-5	48.56	1	0
A. marginata	12-2	47.23	5	1
A. p. plicata	12-2	47.23	3	0
F. flava	12-2	47.23	1	0
L. cardium	12-2	47.23	11	0
L. costata	12-2	47.23	2	0
L. fragilis	12-2	47.23	5	2
L. recta	12-2	47.23	9	1
L. siliquoidea	12-2	47.23	3	1
O. olivaria	12-2	47.23	12	0
O. reflexa	12-2	47.23	1	0
P. alatus	12-2	47.23	7	0
P. cyphyus	12-2	47.23	1	0
Q. pustulosa pustulosa	12-2	47.23	2	0
S. u. undulatus	12-2	47.23	0	1

T. donaciformis	12-2	47.23	1	0
T. truncata	12-2	47.23	3	1
A. p. plicata	13-3	46.98	1	0
F. flava	13-3	46.98	1	0
L. cardium	13-3	46.98	3	1
L. fragilis	13-3	46.98	0	3
L. recta	13-3	46.98	3	0
O. olivaria	13-3	46.98	5	0
S. u. undulatus	13-3	46.98	1	0
L. cardium	13-4	46.82	4	0
L. recta	13-4	46.82	2	0
O. olivaria	13-4	46.82	2	0
Q. pustulosa pustulosa	13-4	46.82	1	0
T. parvus	13-4	46.82	1	0
E. dilatata	13-5	45.99	1	0
L. cardium	13-5	45.99	1	0
L. recta	13-5	45.99	1	0
O. olivaria	13-5	45.99	1	1
T. truncata	13-5	45.99	0	1
L. cardium	13-6	45.7	3	0
A. p. plicata	13-7	45.31	0	2
P. sintoxia	13-7	45.31	1	0
A. marginata	14-3	44.53	5	3
A. p. plicata	14-3	44.53	1	0
F. flava	14-3	44.53	4	0
L. c. complanata	14-3	44.53	2	0
L. cardium	14-3	44.53	1	0
L. costata	14-3	44.53	0	1
L. fragilis	14-3	44.53	2	0
L. recta	14-3	44.53	1	0
O. olivaria	14-3	44.53	5	0
O. reflexa	14-3	44.53	1	0
P. alatus	14-3	44.53	1	0
S. u. undulatus	14-3	44.53	0	1
T. verrucosa	14-3	44.53	0	1
A. g. form corpulenta	15-2	43.1	1	0
A. marginata	15-2	43.1	5	0
A. p. plicata	15-2	43.1	2	0
F. flava	15-2	43.1	26	0
L. c. complanata	15-2	43.1	3	0
L. cardium	15-2	43.1	23	0
L. costata	15-2	43.1	4	0
L. fragilis	15-2	43.1	6	0
L. recta	15-2	43.1	18	0

L. siliquoidea	15-2	43.1	2	0
O. olivaria	15-2	43.1	15	2
O. reflexa	15-2	43.1	3	0
P. alatus	15-2	43.1	72	6
Q. pustulosa pustulosa	15-2	43.1	3	0
S. u. undulatus	15-2	43.1	2	0
T. truncata	15-2	43.1	12	0
L. cardium	16-1	41	1	0
P. alatus	16-1	41	1	0
S. ambigua	16-1	41	1	0
L. c. complanata	21-2	34.3	0	1
L. cardium	21-2	34.3	1	0
P. alatus	21-2	34.3	1	0
A. l. carinata	21-3	33.5	1	0
A. marginata	21-3	33.5	12	1
F. flava	21-3	33.5	21	0
L. c. complanata	21-3	33.5	6	0
L. cardium	21-3	33.5	9	1
L. costata	21-3	33.5	1	0
L. recta	21-3	33.5	15	0
O. olivaria	21-3	33.5	6	1
P. alatus	21-3	33.5	3	0
P. cyphyus	21-3	33.5	4	0
P. sintoxia	21-3	33.5	1	0
S. u. undulatus	21-3	33.5	7	0
T. truncata	21-3	33.5	1	0
T. verrucosa	21-3	33.5	1	0
unidentified	21-3	33.5	1	0
L. cardium	22-2	32.2	3	0
A. marginata	23-2	30.92	0	1
F. flava	23-2	30.92	0	1
S. u. undulatus	23-2	30.92	0	1
F. flava	24-2	29.66	1	0
L. recta	24-2	29.66	1	0
P. alatus	24-2	29.66	1	0
P. alatus	25-3	28.47	1	1
F. flava	27-3	24.08	1	0
L. fragilis	27-3	24.08	1	0
P. alatus	27-3	24.08	2	0
P. ohiensis	27-3	24.08	1	0
S. ambigua	27-3	24.08	9	0
T. truncata	27-3	24.08	1	0
P. alatus	28-4	23.8	1	0
S. ambigua	28-4	23.8	2	0