CHAPTER 3
BENTHIC INVERTEBRATES

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3.1 Introduction

In the early 1960s much of the Buffalo River was considered biologically "dead", and few if any benthic (bottom-dwelling) organisms could be collected from its sediments (Blum 1964). By 1965 the Federal Water Pollution Control Agency listed the Buffalo River AOC as one of the three most polluted rivers in the United States (Sweeney 1973). With continuous recycling of water for industrial cooling, summer surface temperatures often exceeded 40°C, and discharged contaminants accumulated to shocking levels (Sweeney and Merckel 1972). Thick oil slicks covered the river's surface and caught fire on at least four occasions (Boyer 2002). Increased precipitation in the fall often flushed this grossly polluted water into the Niagara River in a concentrated "slug", causing widespread harm to wildlife downstream (Sweeney and Merkel 1972).

As environmental conditions grew intolerable even for commerce and industry, the City of Buffalo and the river's major industries established the Buffalo River Improvement Corporation to combat thermal pollution and contaminant accumulation (Oleszko 1977). Starting in 1967 a minimum of 400 million L of water daily (later reduced to ~ 60 million L following industrial closings) were pumped from Lake Erie to the river to provide cooling water and to augment low summer flows (Sweeney and Merckel 1972, Oleszko 1977).

Three of the river's major industries (Republic Steel, Donner-Hannah Coke, and Mobil Oil) have since closed or curtailed operations for economic reasons, decreasing industrial discharges. However, the Buffalo River continues to face environmental risks from residual sediment contamination (Stewart and Diggins 2002), and from combined sewer overflows (Loganathan et al. 1997), municipal wastewater treatment plants (Rossi 1995), smaller extant industries, leaking disposal facilities, and various non-point sources (NYS DEC 1989, Lee et al. 1991). The Buffalo River AOC currently suffers sediment and water quality impairments that have led to restrictions on recreation, fish consumption, water consumption, and to loss of wildlife habitat (NYS DEC 1989).

In a review of mostly unpublished historical Buffalo River benthic invertebrate data (1964 – 1993), Diggins and Snyder (2003) documented marked recolonization and expansion of the benthos from the barren conditions seen in 1964. While these developments were encouraging, biological recovery was far from complete. New taxa often occurred as scattered individuals, and the benthic community remained 70 – 99% tubificid oligochaetes (very pollution-tolerant) in terms of abundance as recently as 1993 (Diggins and Snyder 2003). Also, Diggins and Stewart (1998) reported 10 – 46% occurrence of mouthpart deformities in the chironomid (midge) genus *Chironomus* during 1990 – 1993, far exceeding the Great Lakes reference condition of 2.15% (Burt et al. 2003).

The objective of this portion of our comprehensive assessment of the Buffalo River was to evaluate the condition of benthic invertebrate communities at potential habitat restoration sites. As relatively local and sedentary components of the biota, benthic invertebrates must tolerate water and sediment conditions (i.e., they do not readily move away), and so provide an integrated metric of environmental health. Benthic communities have been well studied at a number of Great Lakes AOCs (Thornley 1985, Hart et al. 1986, Krieger and Ross 1993), including the Buffalo River, where detailed historical data are available (Diggins and Snyder 2003).

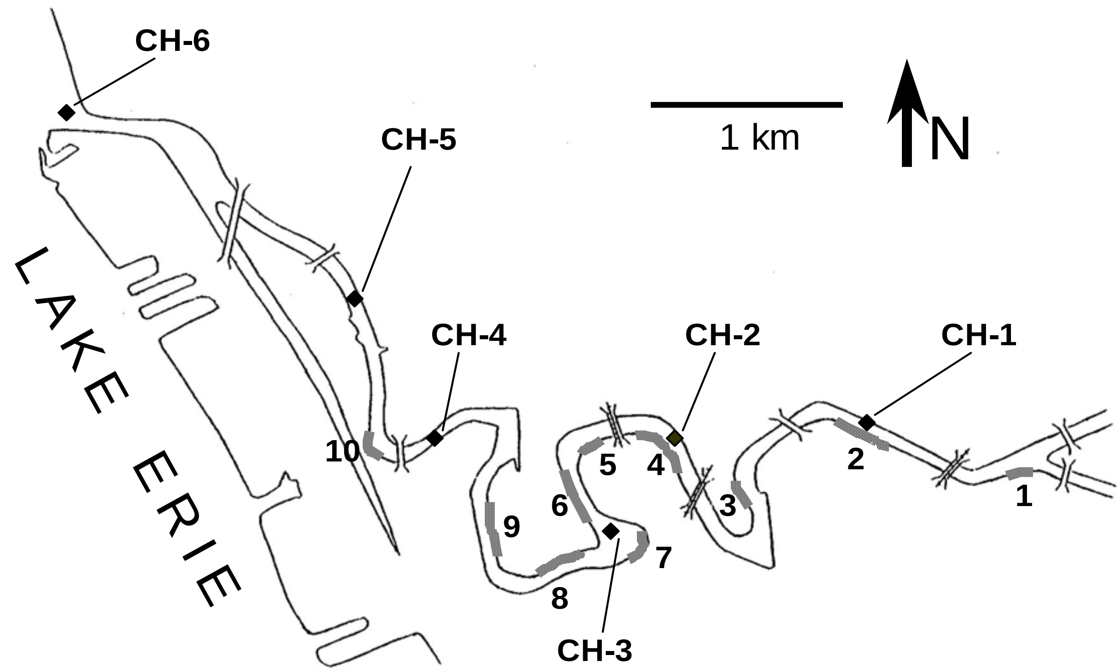

Figure 3.1 Location of shoreline habitat restoration (hatched lines) and mid-channel (diamonds) sites from which benthic invertebrates were sampled during 2003 – 2004.

3.2 Benthic sampling

In addition to the ten potential habitat restoration sites described in Chapter 1, benthos at six stations within the dredged navigation channel (Figure 3.1) were sampled for comparison with long-term trends that are better documented here than in the shallows (Diggins and Snyder 2003). Bottom sediments were sampled from a boat with a 15 x 15-cm Ponar grab. Nearshore habitat restoration sites were sampled at 0.5 – 2.0 m depth, and typically within 5 m of shore. In-channel sites were sampled at the 6 – 8-m depth that is maintained for navigation. Benthic samples were collected three times in 2003 (16 June, 18 August, and 30 October) and twice in 2004 (26 June and 27 September). Three replicate grab samples were taken at each site on each date. Samples were sieved in the field (500 micron), and retained material was preserved upon return to the lab (10% formalin and/or 70% ethanol). Habitat restoration site #5 was sampled only once, on 16 June 2003, with great difficulty. The decision was made henceforth to drop this site from the benthic sampling plan, especially in light of its maze of underwater steel pilings and cables that threatened to damage a boat on approach.

Invertebrates were identified to lowest practical taxon (always at least to family, but usually to genus) and enumerated. Gastropoda were identified following Jokinen (1992). Chironomid larvae were slide-mounted (Simpson and Bode 1980) for genus/species identification according to Simpson and Bode (1980), Peckarsky et al. (1990), and/or Merritt and Cummins (1996). Presence of mentum (mouthpart) abnormalities in larvae of the genus *Chironomus* was assessed as described by Diggins and Stewart (1993, 1998).

3.3 Data analysis

Due to their broad taxonomic and ecological diversity, benthic invertebrate communities are typically assessed by multimetric analytical approaches, e.g., as followed by Greer et al. (2002) in a study of the Buffalo River tributary Cazenovia Creek. Such analyses may incorporate measures of species richness, EPT (Ephemeroptera [mayfly], Plecoptera [stonefly], and Trichoptera [caddisfly]) richness, and one or more pollution tolerance-based biotic indices (e.g., Hilsenoff Biotic Index). In this study of the Buffalo River AOC we likewise followed a multimetric approach, but we have selected variables that are the most appropriate for the river's organically enriched, oxygen stressed, and likely still contaminated sediment environment. For example, EPT richness is not useful for comparison among Buffalo River sites, as few of these pollution sensitive organisms are found here, and all sites score uniformly low for this metric.

Also, we have explored a number of taxon-specific indicators, focusing on the Chironomidae (aquatic midges), which are typically the dominant insects in stressed systems (including the Buffalo River). In addition to the assessment of mouthpart deformities as mentioned above, we catalogued chironomid genus/species richness and applied a tolerance-based index of biotic integrity to the Chironomidae at the genus/species level. Diggins and Stewart (1998) found that during 1990 – 1993 such metrics were significantly associated with a gradient in trace metal contamination in the dredged channel of the Buffalo River AOC. These correlations between biotic health and sediment quality were not evident until detailed analyses of the Chironomidae were performed. Unfortunately, chironomids are too often reported only to the family level.

Most of the data reported here are presented both as figures, to allow visualization of spatial trends, and in tabular form, for possible inclusion in future biomonitoring efforts.

3.3.1 Benthic community metrics

1. Number of families per sample/site. The invasive Dreissenidae (zebra and quagga mussels) are excluded from this calculation to avoid characterizing their presence as an "improvement".
2. Oligochaete (nearly all family Tubificidae) density per m^2.
3. Chironomid density per m^2.
4. Percent contribution of tubificid oligochaetes to overall invertebrate density
5. Number of genera of Chironomidae per sample/site.
6. Genus/species Biotic Index for the Chironomidae, in which chironomid community pollution tolerance scores are generated.
7. Incidence of mouthpart deformities in larvae of the chironomid genus *Chironomus* (see Figure 3.2).

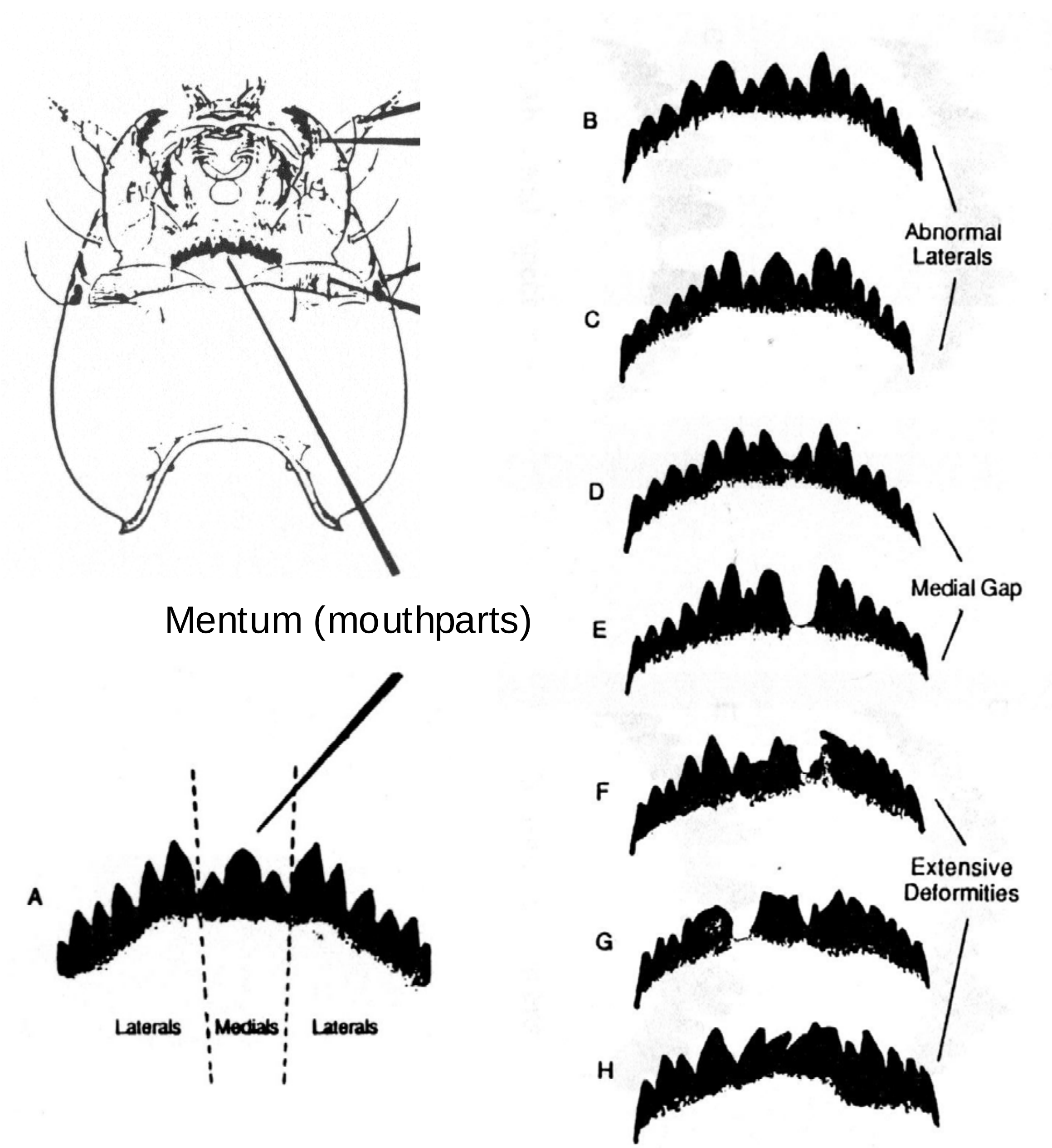

Figure 3.2 Larval head capsule morphology (modified from Oliver and Roussel 1983) and examples of mentum (mouthpart) deformities. A) Normal mentum. B – H) Deformities as observed in the Buffalo River during 1990 – 1993. Figure modified from Diggins (1997).

3.4 Results and Discussion

3.4.1 Benthic invertebrate families

Sixteen families of benthic invertebrates, including the invasive Dreissenidae, were collected from the Buffalo River during 2003 – 2004 (Table 3.1). Tubificidae (annelid oligochaete "sludge worms") and Chironomidae (insect "midge" larvae) dominated numerically. Other taxa consistently encountered included several families of gastropod mollusks, sphaerid "fingernail" clams, small leeches, and the dreissenids. Occurring as rare and scattered individuals were juvenile stages of several other insect groups usually found in streams with more heterogeneous sediments (i.e., sand and gravel in addition to mud and silt) than those of the Buffalo River. Notably absent were nymphs of mayflies and stoneflies, two groups generally considered pollution sensitive.

Nearshore habitat restoration sites consistently (with the exception of upstream site 1) yielded more invertebrate families than channel sites (Figure 3.3, Table 3.2). Up to 11 families were collected from nearshore sites, whereas only channel site CH-5 (above Michigan Avenue) yielded more than five. A plausible speculation is that river edge sediments may be more structurally heterogeneous, and oxygen stress may be less severe in shallower water, both of which could allow persistence of more invertebrate families. However, shoreline habitat restoration sites were still solidly dominated by oligocheates and chironomids (discussed below).

Disappointingly, invertebrate community richness during 2003 – 2004 was not only no better than during the early 1990s (Diggins and Snyder 2003), it had actually declined (Figure 3.4.A). In retrospect, collecting and enumerating the channel samples was very informative indeed, as it showed very clearly how historical trends of increasing taxonomic richness have reversed in the last decade. The reasons for this are not readily apparent, but this finding suggests that post-industrial biological recovery of the Buffalo River in its present state may remain stalled without active remediation.

Table 3.1 Occurrence of invertebrate families in the Buffalo River

A. Habitat restoration sites

Phylum	Class/Order/Suborder	Family	Common name	1	2	3	4	5	6	7	8	9	10
Annelida	Oligochaeta	Tubificidae	sludge worms	X	X	X	X	X	X	X	X	X	X
Annelida	Hirudina		leeches			X					X	X	X
Arthropoda	Insecta/Diptera	Chironomidae	midges	X	X	X	X	X	X	X	X	X	X
	Insecta/Diptera	Ceratopogonidae	biting midges										
	Insecta/Odonota/Zygoptera		dragonflies										
	Insecta/Trichoptera		caddisflies			X							
	Insecta/Coleoptera	Psephenidae	water penny beetles	X									
	Insecta/Coleoptera	Elmidae	riffle beetles								X	X	
Arthropoda	Amphipoda		scuds		X								
Mollusca	Gastropoda	Bythinidae	faucet snails				X	X	X	X	X	X	X
		Valvatidae	valve snails			X	X		X	X	X	X	X
		Planorbidae	rams horn snails										
		Physidae				X	X		X	X	X	X	X
Mollusca	Bivalvia	Sphaeridae	fingernail clams			X				X	X	X	X
		Unionidae	native clams		X		X						
		Dreissenidae	zebra/quagga mussels	Z	Z	Z/Q	Z		Z/Q	Z/Q	Z	Z	Z

B. Channel sites

Phylum	Class/Order/Suborder	Family	Common name	CH-1	CH-2	CH-3	CH-4	CH-5	CH-6
Annelida	Oligochaeta	Tubificidae	sludge worms	X	X	X	X	X	X
Annelida	Hirudina		leeches		X			X	X
Arthropoda	Insecta/Diptera	Chironomidae	midges	X	X	X	X	X	X
	Insecta/Diptera	Ceratopogonidae	biting midges		X				
	Insecta/Odonota/Zygoptera		dragonflies		X				
	Insecta/Trichoptera		caddisflies						
	Insecta/Coleoptera	Psephenidae	water penny beetles						
	Insecta/Coleoptera	Elmidae	riffle beetles						
Arthropoda	Amphipoda		scuds						
Mollusca	Gastropoda	Bythinidae	faucet snails			X		X	
		Valvatidae	valve snails					X	
		Planorbidae	rams horn snails					X	
		Physidae						X	
Mollusca	Bivalvia	Sphaeridae	fingernail clams					X	
		Unionidae	native clams						
		Dreissenidae	zebra/quagga mussels	Z	Z	Z	Z/Q	Z/Q	Z

Table 3.2 Site-mean benthic invertebrate parameters in the Buffalo River

A. Habitat restoration sites

	1	2	3	4	5	6	7	8	9	10
Families/sample	3	5	8	7	3	6	7	10	11	9
Oligochaetes per sq. meter	3802	12356	9758	8795		12390	11699	4811	8033	5951
Chironomids per sq. meter	370	573	291	351		281	583	178	522	262

B. Channel sites

	CH-1	CH-2	CH-3	CH-4	CH-5	CH-6
Families/sample	4	5	4	2	8	3
Oligochaetes per sq. meter	12217	14484	11230	15889	13970	12267
Chironomids per sq. meter	894	350	400	328	333	378

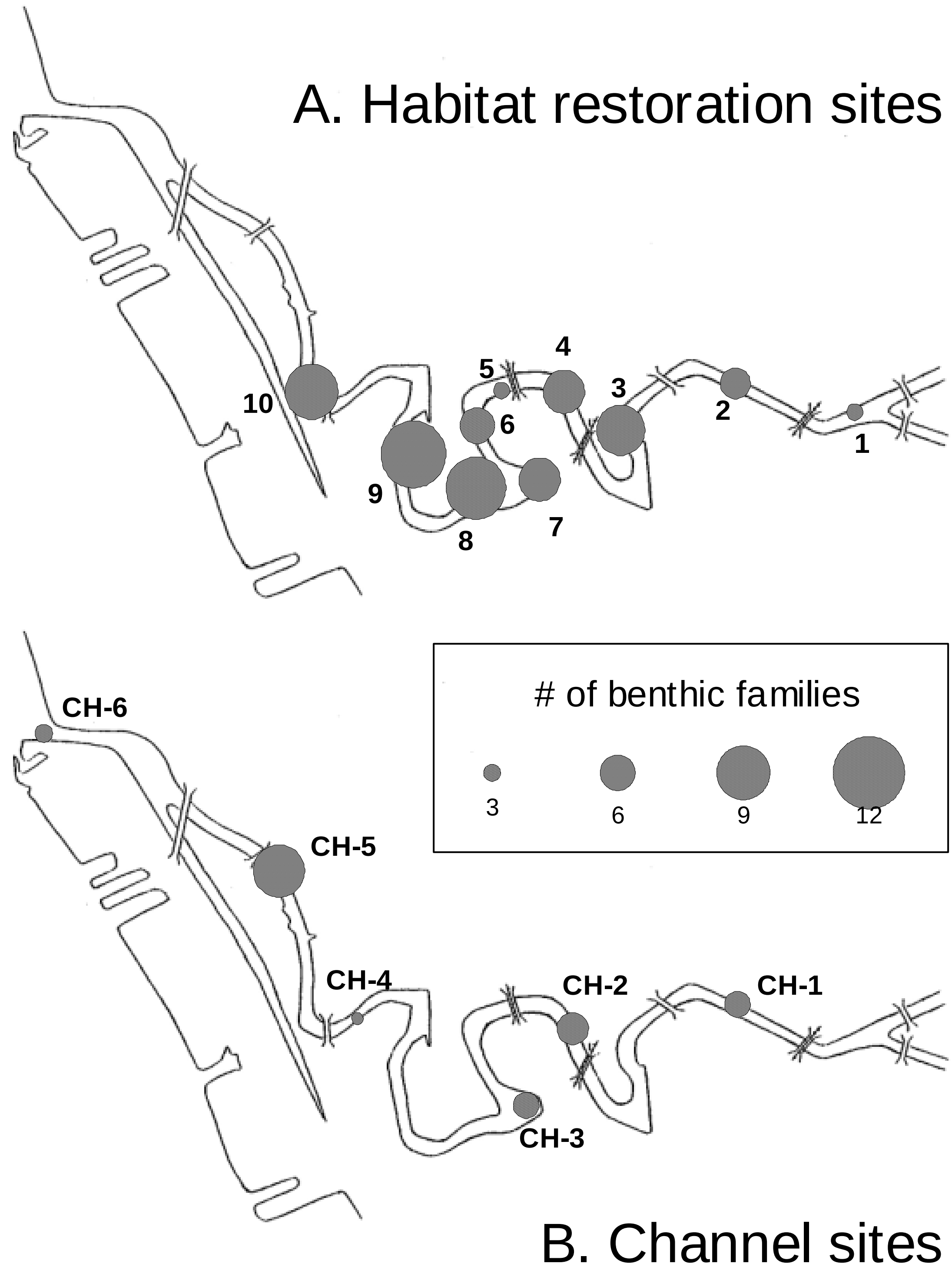

Figure 3.3 Site-mean richness of benthic invertebrate families during 2003 – 2004 at A) shoreline habitat restoration, and B) mid-channel sites.

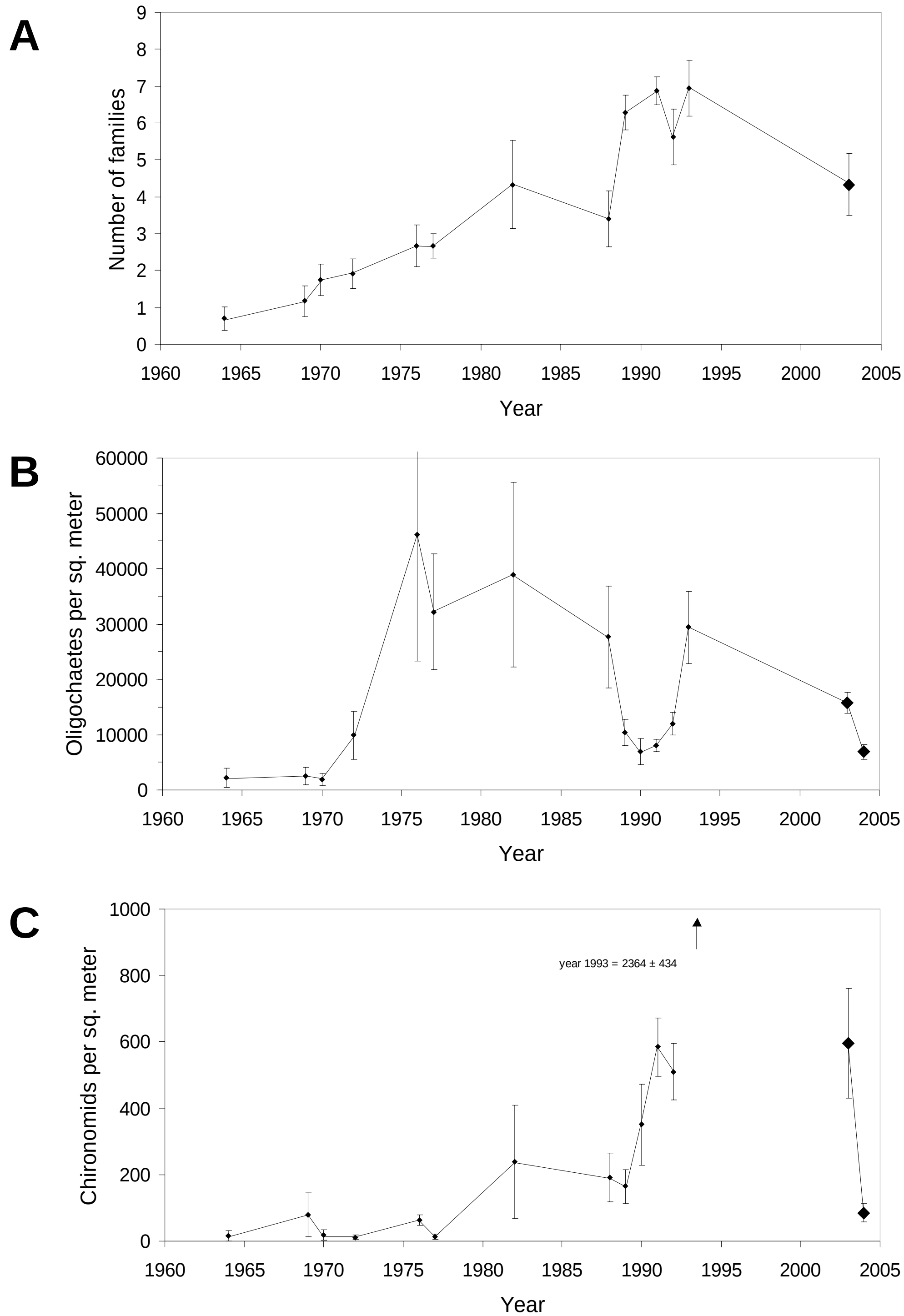

Figure 3.4 Whole river temporal trends in A) invertebrate family richness, B) Oligochaete density, and C) chironomid density.

3.4.2 Oligochaetes

Oligochaete density regularly exceeded 10,000/m^2 during 2003 – 2004, with only the habitat restoration sites 1 and 8 yielding average densities below 5000/m^2 (Table 3.2). Site-mean oligochaete densities were typically higher in the dredged channel than at shoreline sites (Figure 3.5). Oligochaete densities were also much lower in 2004 than in the preceding year – combined averages of 10,639 and 5153 for channel and shoreline sites, respectively, vs. 15,717 and 6893 during 2003. This may have been partially the result of the temporal proximity of our 27 September 2004 sampling date to the 09 September flood described in Chapter 5, which may have scoured bottom sediments. Oligochaete (and chironomid) from habitat restoration site 5 densities are not included in our site characterization matrix because sampling was not conducted here on the 27 September 2004 date, potentially biasing the data from this site.

Oligochaete densities during this study were generally similar to those recorded during the early 1990s (see Figure 3.4.B), with the exception of the very high densities from 1993 that were based on only one sampling date (Diggins and Snyder 2003). While these densities of 7 – 15,000/m^2 are much lower than the 30 – 50,000+/m^2 recorded during the late 1970s (Figure 3.4.B, also Diggins and Snyder 2003), tubificid oligochaete abundance still exceeds a long-held threshold of 5000/m^2 that signifies organic pollution (Nalepa and Thomas 1976). Additionally, the benthic invertebrate community was consistently >95% tubificid oligochaetes numerically at both channel and shoreline sites. Only at the habitat restoration sites 1 and 9 was the invertebrate community less than 90% oligocheates, and at 89% for each, barely so. Clearly, the entire Buffalo River AOC continues to be dominated by abundant and very pollution tolerant tubificid oligochaetes.

3.4.3 Chironomid densities

Site-mean chironomid densities during 2003 – 2004 ranged between 200 and 900/m^2 (Table 3.2), with no obvious trends along the river, or between channel and shoreline sites (Figure 3.6). River-wide chironomid densities during 2003 were in the range of those recorded in the early 1990s, again with the exception of a very high density from 1993's single sample date (Figure 3.4.C). As with the oligochaete data discussed above, chironomid densities were much lower in 2004 than in 2003 (585 vs. 85/m^2). Again, we speculate this may have resulted from bottom scouring during the 09 September 2004 storm event.

3.4.4 Chironomid richness and pollution tolerance

Twenty-two chironomid taxa (species or genera, depending on whether specific identification can be made based only on larval characteristics) were collected from the Buffalo River during 2003 – 2004 (Table 3.3). This is slightly fewer than the 27 taxa encountered during 1990 – 1993 (Diggins 2000). However, if only channel samples from 2003 – 2004 are considered (all 1990 – 1993 data are from the channel), chironomid richness appeared very poor during the present study – only six taxa. While the present study represents less than 1/6 of the sampling effort of studies in the early 1990s (Singer et al. 1994, Diggins and Stewart 1998, Diggins 2000), and thus may have missed rare species, 2003 – 2004 results still may reveal an actual decline in mid-channel chironomid richness over the past decade. Unfortunately, very few historical shoreline invertebrate data are available for comparison with present results from habitat restoration sites.

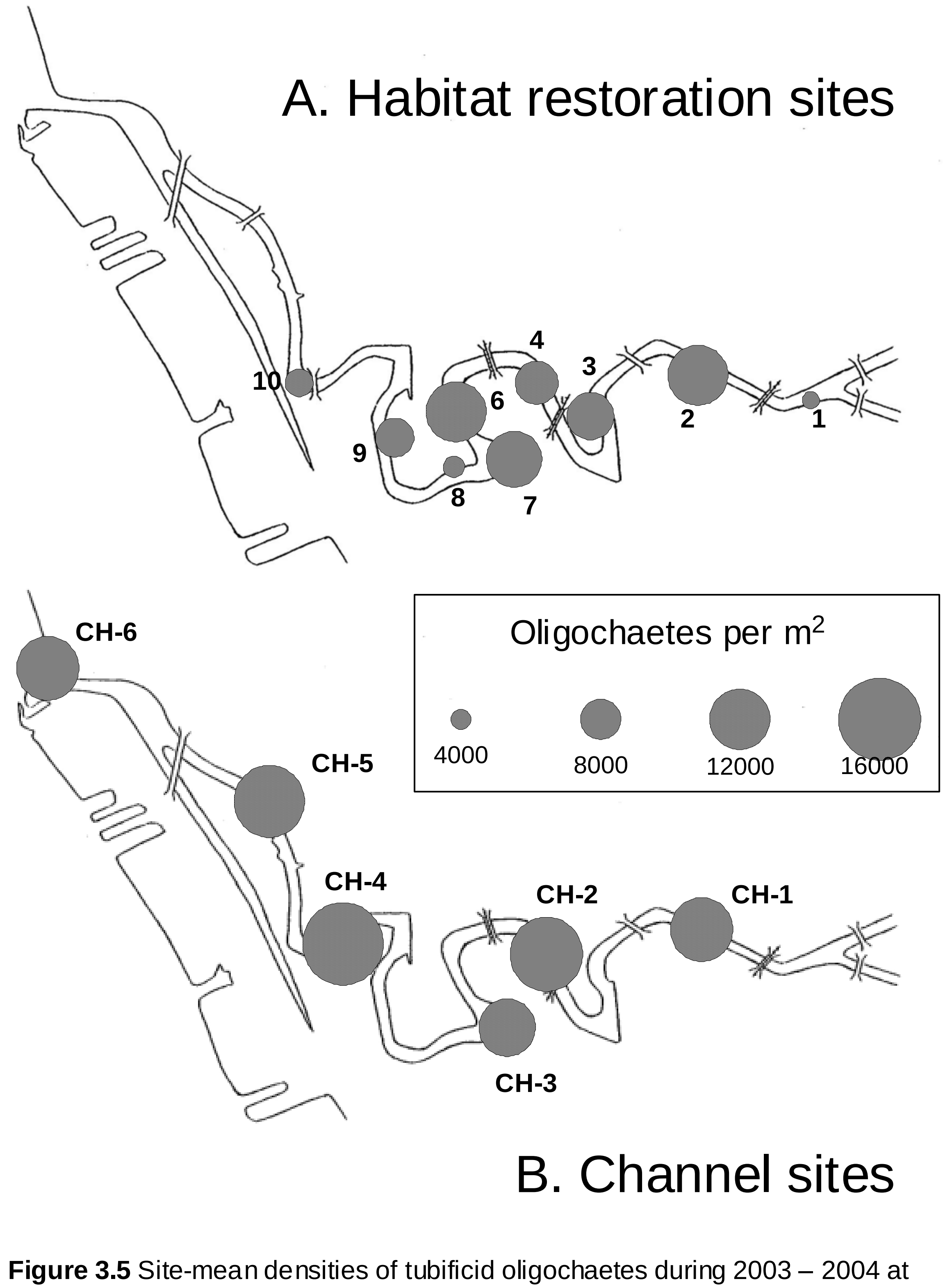

Figure 3.5 Site-mean densities of tubificid oligochaetes during 2003 – 2004 at A) shoreline habitat restoration, and B) mid-channel sites.

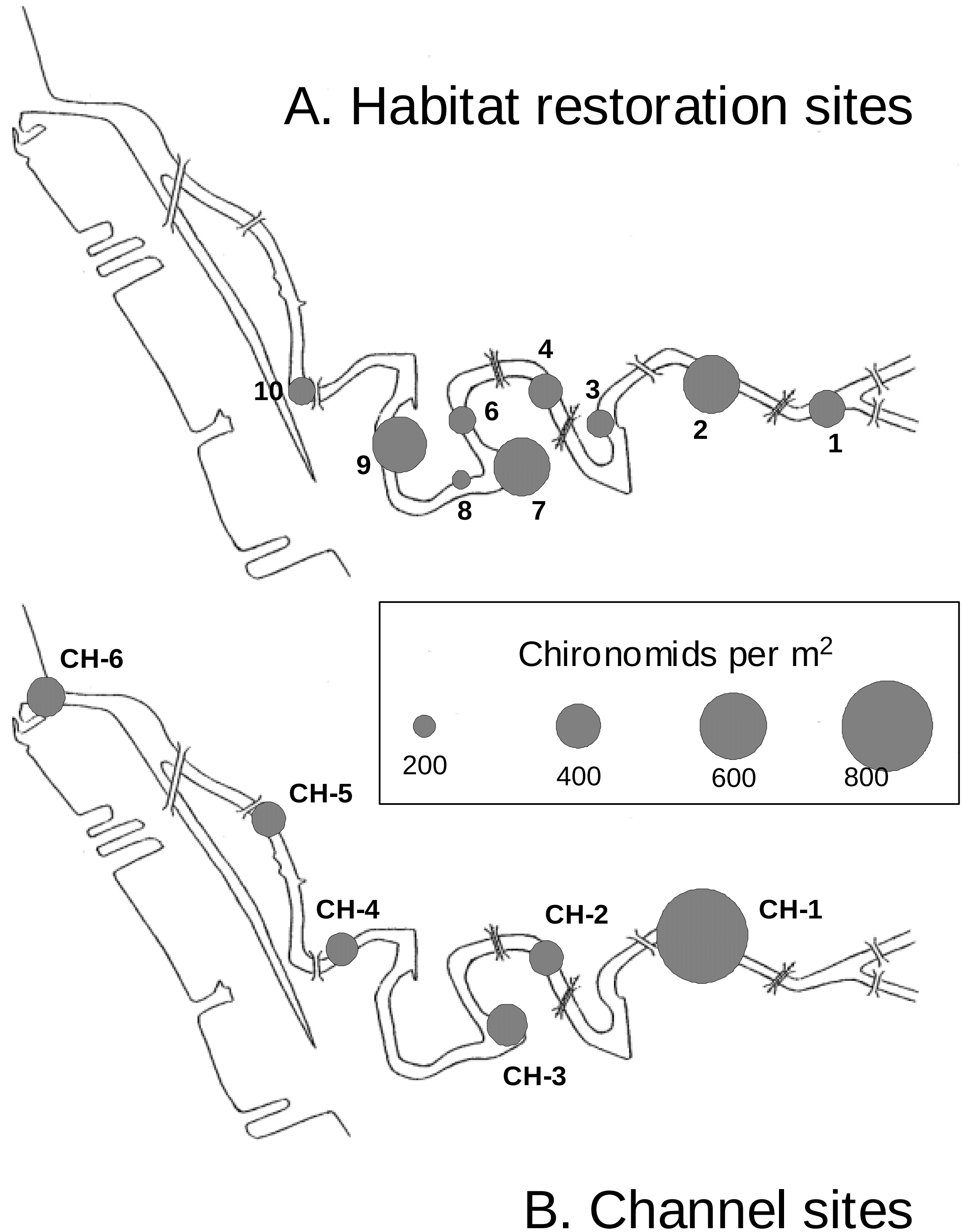

Figure 3.6 Site-mean densities of chironomid larvae during 2003 – 2004 at A) shoreline habitat restoration, and B) mid-channel sites.

Table 3.3 Occurrence of chironomid taxa in the Buffalo River

A. Habitat restoration sites

Chironomid taxon	1	2	3	4	5	6	7	8	9	10
TANYPODINAE										
Ablabesmyia	X									
Procladius		X		X	X	X	X	X	X	X
ORTHOCLADINAE										
Cricotopus sp.		X								
Cricitopus bicinctus									X	
Cricotopus silvestris	X									X
Nanocladius						X				
Psectrocadius	X	X								X
TANYTARSINI										
Paratanytarsus		X				X			X	
Rheotanytarus exiguus		X								
Tanaytarsus glabrescens		X								
Tanytarsus guerlus		X			X	X	X		X	
CHIRONOMINI										
Chironomus	X	X			X		X			
Cladopelma		X	X	X	X	X	X		X	
Cryptochironomus		X			X		X		X	
Crytptotendipes									X	
Dicrotendipes neomodestus	X				X	X	X		X	X
Endochironomus subtendens						X	X			
Glyptotendipes	X									
Parachironomus aborticus										
Paratendipes									X	
Polypedilum	X	X	X		X	X	X		X	
Tribelos										

B. Channel sites

Chironomid taxon	CH-1	CH-2	CH-3	CH-4	CH-5	CH-6
TANYPODINAE						
Ablabesmyia						
Procladius	X	X	X	X	X	X
ORTHOCLADINAE						
Cricotopus sp.						
Cricitopus bicinctus						
Cricotopus silvestris						
Nanocladius				X		
Psectrocadius						
TANYTARSINI						
Paratanytarsus						
Rheotanytarus exiguus						
Tanaytarsus glabrescens						
Tanytarsus guerlus						
CHIRONOMINI						
Chironomus						
Cladopelma				X	X	
Cryptochironomus	X			X		
Crytptotendipes						
Dicrotendipes neomodestus						
Endochironomus subtendens						
Glyptotendipes						
Parachironomus aborticus						
Paratendipes						
Polypedilum			X			
Tribelos	X					

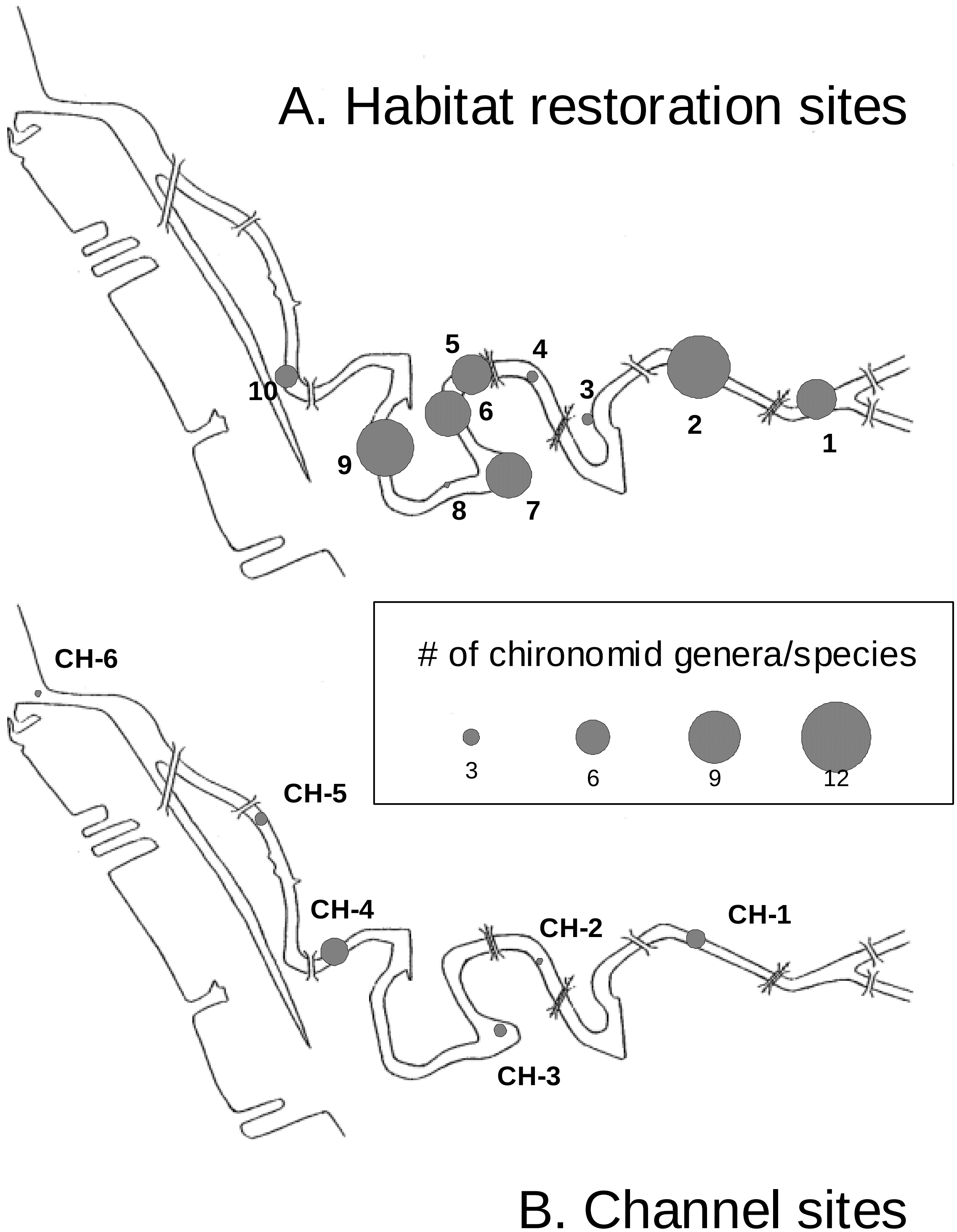

Figure 3.7 Number of chironomid genera/species collected during 2003 – 2004 at A) shoreline habitat restoration, and B) mid-channel sites.

The very pollution-tolerant genus *Procladius* (“Hilsenhoff” tolerance 10 [i.e., maximum]) was the most abundant chironomid collected during 2003 – 2004. Other abundant taxa included *Cladopelma* (tolerance 9), *Dicrotendipes neomodestus* (tolerance 8), *Tanytarsus guerlus* (tolerance 6), *Polypedilum* (tolerance 6), *Cryptochironomus* (tolerance 8), and *Chironomus* (tolerance 10). Tolerance values are reported from Mandaville (2002), summarizing a large number of sources.

Chironomid richness differed markedly between nearshore habitat restoration sites and channel sites (Figure 3.7), with none of the less diverse channel sites exceeding four taxa. Shoreline sites yielded up to 11 taxa, but were highly variable, with sites 3, 4, and 8 as species-poor as the channel sites.

Chironomid Biotic Index scores (i.e., tolerance score averaged among all individuals in a sample) at habitat restoration sites ranged from 6.60 (site 3) to 10.00 (site 8), with 10 representing a community composed entirely of the most pollution tolerant taxa. According to standards presented in Table 3.4, sites 2, 3, 5, 7, 9, and 10 were categorized as either “poor” or “impacted”, while sites 1, 4, 6, and 8 were “very poor”. All of the channel sites were characterized as “very poor”. It should be noted that habitat site 3, with its least tolerant Biotic Index, also yielded only two taxa, one of which (*Polypedilum*) happened to be only moderately tolerant. As such, it does not offer very convincing evidence of substantially greater environmental health than the five other “poor” sites.

Table 3.4 Ranges and interpretations of Biotic Index scores (modified from Mandaville 2002).

Biotic Index	Water/sediment quality	Degree of pollution
0.0 – 4.5	Excellent/very good	None to slight
4.51 – 6.5	Good/fair	Some to moderate
6.51 – 7.5	Impacted	Fairly substantial
7.51 – 8.5	Poor	Very substantial
8.51 – 10.0	Very poor	Severe

3.4.5 Chironomid mouthpart deformities

Mouthpart deformities (see Figure 3.2) in larvae of the chironomid genus *Chironomus* were not a useful metric of environmental health at habitat restoration sites, simply because we did not encounter sufficient numbers of this indicator genus in nearshore sediments to make site-to-site comparisons. However, more reliable deformity data were generated at channel sites, especially after taking extra grab samples dedicated to collecting large (>1 cm) red chironomids that often include *Chironomus*. Thus, we were at least able to compare 2003 – 2004 results with deformity frequency data from the early 1990s (Diggins and Stewart 1993, 1998). Unfortunately, this comparison yielded essentially the same trend as for other benthic invertebrate data – no improvement over the last decade, and some evidence of a decline in environmental health. In 2003 – 2004, 54.5% of *Chironomus* larvae (12 of 22) from in-channel sites displayed obvious mouthpart deformities. This percentage is at the high end of the range of deformity frequencies reported by Diggins and Stewart (1993, 1998) at channel sites during 1990 – 1993. (Reference populations at Great Lakes sites free of industrial impact display mouthpart deformities in only 2.15% of larvae [Burt et al. 2003].) Interestingly, however, *all* of the more limited number of *Chironomus* larvae (n = 12) collected at Buffalo River shoreline sites in 2003 – 2004 had normal mouthparts. This indicator genus was consistently less common in the Buffalo River during the present sampling than it had been a decade earlier, so an intensive study dedicated only to mouthpart deformities is recommended to help clarify the implications of this dichotomy between the shore and the channel. A preliminary, and tentative, interpretation is that shoreline chironomid larvae might not be exposed to or influenced by teratogenic (i.e., disrupting development) concentrations of sediment contaminants, whereas in-channel populations are.

3.5 Conclusions

Data collected during the present study indicate the Buffalo River AOC continues to be dominated by a rather low-diversity benthic invertebrate community broadly tolerant of pollution and environmental detrioration. High densities of tubificid oligochaetes (though lower than historical maxima), and their numerical dominance of the benthos, reveal poor environmental health. Oligochaete densities were higher in the channel than at shoreline habitat restoration sites. Fewer invertebrate families were collected during 2003 – 2004 than in the early 1990s, possibly even indicating some reversal of biotic recovery. Substantially more families occurred at shoreline sites than in the channel, although the habitat restoration sites were still dominated by pollution-tolerant oligochaetes and chironomids. Likewise, chironomid taxonomic richness was markedly higher at habitat restoration sites than in the channel, but samples largely constituted pollution-tolerant species and genera. Chironomid mouthpart deformities remain very high at channel sites (as they were during 1990 – 1993), but, interestingly, all of the rather limited number of larvae from shoreline sites had developed normally.

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