

**ASSESSMENT OF BENTHIC
INVERTEBRATE POPULATIONS IN THE
WHITE LAKE AREA OF CONCERN**

Michigan Department of Environmental Quality

Tracking Code: #488138/09

prepared by

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January 2012

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Introduction

White Lake (Muskegon County, Michigan) is a 10.4 km² drowned river mouth lake located in western Michigan. The lake was listed as an Area of Concern (AOC) by the International Joint Commission (IJC) in 1987 because of severe environmental impairments related to the historic discharge of municipal and industrial wastes. The Beneficial Use Impairment (BUI), Degradation of Benthos, was listed because sediment toxicity related to heavy metals and organic chemicals and impacts to species diversity from the discharge of municipal sewage. Data from 1972 showed that pollution tolerant oligochaete worms comprised 95% of the total benthic population, chironomid numbers were low (< 100/m²), and Shannon Weaver species diversity (SW) only was 0.68 (Evans 1976). In 1974, the direct discharge of municipal and industrial wastewater to White Lake was eliminated by the construction of an advanced tertiary treatment facility. In addition, industrial pretreatment programs, hazardous waste site remediation projects, and numerous conservation and non point source reduction efforts have resulted in large improvement in water quality. By 2001, Shannon Weaver diversity improved to 1.37, oligochaetes were reduced to 82% of the total population, and chironomid numbers increased to over 500/m² (Rediske et al. 2004).

In consideration of the improvements to the benthic community in the lake and the remediation/restoration of Tannery Bay and Hooker Chemical, the White Lake Public Advisory Council (WLPAC) voted in 2008 to establish numerical criteria to delist the Degradation of Benthos BUI (WLPAC 2008). The targets are summarized below:

The **Degradation of Benthos BUI** will be considered restored when:

1) All remedial actions for known contaminated sediment sites with degraded benthos are completed (except for minor repairs required during operation and maintenance) and monitored according to the approved plan for the site. Remedial actions and monitoring are conducted under authority of state and federal programs, such as Superfund, Resource Conservation and Recovery Act, Great Lakes Legacy Act, or Part 201 of Michigan's National Resource and Environmental Protection Act (NREPA) of 1994.”; and

2) All remedial actions for known contaminated sediment sites with degraded benthos are completed (except for minor repairs required during operation and maintenance) and monitored according to the approved plan for the site. Remedial actions and monitoring are conducted under authority of state and federal programs. The known contaminated sediment sites with degraded benthos are Tannery Bay and the Hooker/Occidental Outfall. In addition, average benthic macroinvertebrate populations in White Lake should reflect the following conditions in Table 1 (Rediske et al., 2004):

TABLE 1. RESTORATION TARGET CONDITIONS FOR DELISTING THE DEGRADATION OF BENTHOS BUI.

Indicator	Target
1. Sediment Toxicity	Amphipod Survival >60%
2. <i>Hexagenia</i>	Present in river mouth littoral zone with an increasing trend over 3 yrs
3. Amphipods	Present in river mouth littoral zone with an increasing trend over 3 yrs
4. % Oligochaeta	< 75% or a decreasing trend
5. Chironomidae (#/m ²)	> 500 or an increasing trend
6. Diversity (SW)	1.5 or an increasing trend

Compliance with the sediment toxicity indicator in White Lake will be determined by review of pre and post remediation data for Tannery Bay and Occidental Chemical, with additional testing of two sites in the northwestern (deep) basins near the channel. Compliance with the Oligochaete, Chironomid, and Diversity indicators will be based on a one time benthic survey conducted at all eight areas (Figure 1) examined by Evans (1976) and Rediske et al. (2004); both before and after remediation, respectively. Compliance with the *Hexagenia* and amphipod targets will be based on three years of post-remediation monitoring at one station that was established in the littoral zone near the mouth of the White River where it enters White Lake (Area #6, Figure 1). If any station shows an indication of statistically significant degradation (as listed in criteria above) from the previous sampling event, the area will require re-sampling and analysis to determine the source of the problem.

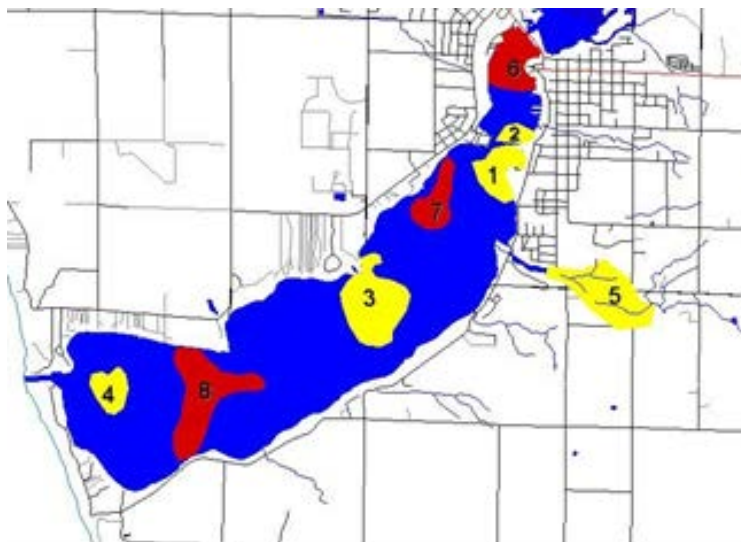


FIGURE 1. PROPOSED WHITE LAKE SAMPLING AREAS FOR BENTHIC SURVEY (WLPAC 2008).

Benthic surveys of White Lake were conducted in 1996 (Rediske et al. 1998) and 2001 (Rediske et al. 2004). The results of the 1996 and 2001 investigations indicated that macroinvertebrate populations had improved from historical conditions (Evans 1976). We conducted a monitoring program of the benthic macroinvertebrate communities in White Lake that provided sufficient information for the PAC to determine if the numerical targets have been achieved. Benthic macroinvertebrates from Area 5 (Mill Pond Creek) were not collected as part of this project. The WLPAC will be completing this task during Spring 2012.

Methods

AWRI collected triplicate samples at each site shown in Figure 2 with a petite Ponar in 2009. Station WL-24 was added to provide coverage in Area 1 and the samples were collected in 2011. In 2010 and 2011, samples were collected at stations WL-18, WL-19, and WL-20 for amphipods and *Hexagenia*. Station coordinates and depths are provided in Table 1. The recommend sampling regions were included in Figure 2 to show that the sampling plan provided coverage in all the proposed areas of White Lake. Samples were washed into a large tub and then into an elutriation device with a 0.5-mm, nitex-mesh sleeve to remove silt and other fine particles. Retained materials were preserved in 10% buffered formaldehyde with rose bengal stain. The samples from 2009 and WL-24 were analyzed to the lowest possible taxonomic level.

Comparisons of the between 2009 and 2010 were made with respect to the restoration target conditions 4, 5, and 6 listed in Table 1. A separate comparison between the 1996 and 2011 data for Station WL-24 also was made.

TABLE 2. SAMPLING STATION COORDINATES AND DEPTHS FOR WHITE LAKE 2009-2011.

Station	Lat	Long	Depth ft
WL-1	43.37633	-86.4092	49.3
WL-2	43.37417	-86.4025	65.7
WL-3	43.37350	-86.4128	55.1
WL-6	43.38250	-86.3810	70.3
WL-7	43.37683	-86.3878	35.2
WL-9	43.38783	-86.3738	31.6
WL-11	43.39233	-86.3708	46.9
WL-12	43.39367	-86.3662	53.0
WL-13	43.38467	-86.3722	35.8
WL-15	43.39783	-86.3638	27.8
WL-16	43.40267	-86.3525	11.3
WL-17	43.40333	-86.3542	13.6
WL-18	43.40650	-86.3543	10.4
WL-19	43.40533	-86.3523	12.4
WL-20	43.4085	-86.3537	9.0
WL-21	43.38583	-86.3762	49.6
WL-24	43.40033	-86.3550	10.4

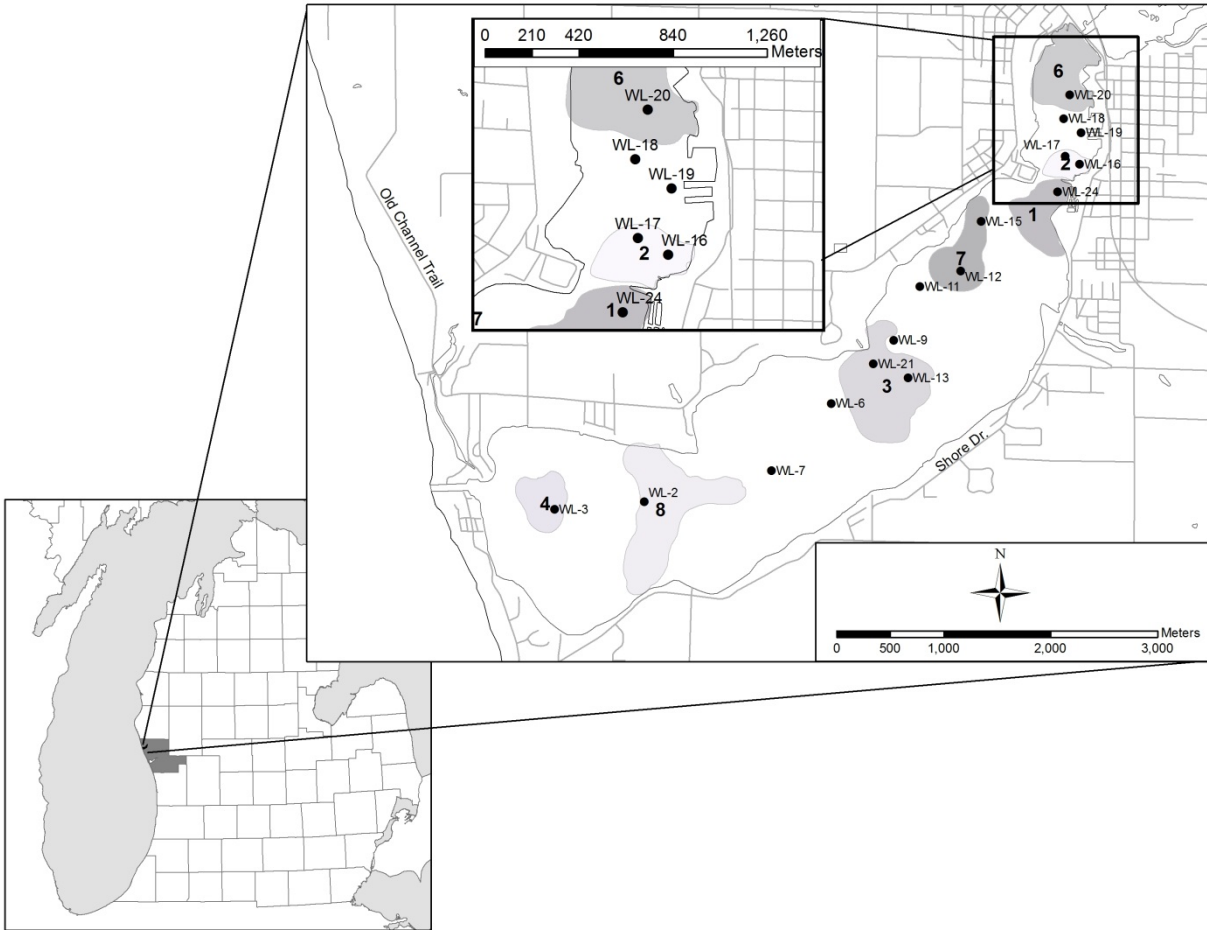


Figure 2. White Lake Sampling Stations 2009-2011.

Results and Discussion

The results of benthic macroinvertebrate collections in White Lake for 2001 and 2009 are shown in Tables 1 and 2, respectively. Comparison graphs of Shannon Weaver Diversity, % Oligochaeta, and Chironomidae/m² between 2001 and 2009 are shown in Figures 2, 3, and 4, respectively. Shannon Weaver Diversity scores (Figure 2) were greater than or equal to the target of 1.5 for all locations except WL-19 (1.45). Station WL-19 had a Shannon Weaver Diversity score of 1.44 in 2001. The % Oligochaeta (Figure 3) was less than the target of 75% for all locations except WL-11 (76%) and WL-19 (79%). Stations WL-11 and WL-19 had % Oligochaeta values of 78% in 2001. The Chironomidae/m² (Figure 4) was greater than the target of 500/m² for all locations except WL-7, WL-9, WL-12, WL-13, WL-16, and WL-17. All of these stations showed an increase in chironomid densities from 2001 levels.

Table 3. Quantitative Aquatic Macroinvertebrate Results Obtained from White Lake October 2001.

Organism Description	WL-2	WL-3	WL-6	WL-7	WL-9	WL-11	WL-12	WL-13	WL-15	WL-16	WL-17	WL-18	WL-19	WL-20	WL-21	Mean
Oligochaeta																
Tubificidae																
Aulodrilus limnobius	14	57	230	144	129	72	14	72	100							287
Aulodrilus pigueti	0	43	57	29	29	29			14		100					72
Ilyodrilus templetoni	144	72	158	29	57	359	29		14	14				86		388
Limnodrilus hoffmeisteri	215	560	789	488	301	732	43	402	818	172	230		100	158		2239
Limnodrilus claparianus					100						43					
Quistadrilus mitisetosus					72											
Immatures w/o capilliform chaetae	1019	129	1421	29	1134	1909	646	1837	660	890	2411	230	330	215	10363	
Immatures with capilliform chaetae	2340	1521	2612	1234	1694	7650	1421	2110	1852	2225	2038	1306	1837	1521	18444	
Nematoda	14	14	646		3804	1277	7780	574	617	14		14	14		2268	
Turbellaria																
Planariidae sp.			14							29					431	
Amphipoda																
Gammarus	14	14	14	29	29	14		43	14	29	57	43	43	2483	100	
Hyalolela	14													230		
Insecta																
Ephemeroptera																
Caenis																14
Ephemera																14
Hexagenia												29	29			129
Isonychia																14
Odonata																
Zygoptera																57
Diptera																
Ceratopogonidae							14		43	14		14			115	
Chaoboridae																
Chaoborus punctipennis	2497	1565	1077	330	158	416	129	201								976
Chironomidae	129		230			301	43	72	115	86		187	172	560		258
Ablabesmyia sp.														29		
Chironomus sp.	646	72	1435	43	230	904	172	144	359	115	29	43	43	86	976	
Clinotanypus sp.														57		
Coelotanypus sp.										43						
Cryptochironomus sp.			14	14						72			144		14	
Dicrotendipes sp.	100		43			29									57	14
Heterotrissocladius sp.																
Paraphaenocladus sp.																
Paratendipes sp.		14	14		14											
Phaenopsectra sp.															14	14
Polypedilum sp.														0	0	
Procladius sp.	14			14	144		115	115	172	57	43	57	57	301	316	
Pseudochironomus sp.																
Tanytus sp.										29						
Mollusca																
Amnicola	43	72	57	43	43	14	57	129	172	43	72	14	57	144	86	
Physa							14				29			14	14	
Valvata tricarinata																
Viviparus												14				
Pelecycboda																
Dreissena polymorpha		14		144	86		43	29	57	244	72	86		201	43	
Pisidium	100	129	14	29	100						43			144	144	
Hirudinia																
Haemonais waldvogeli						14									14	14
Helobdella																
Trichoptera																
Polycentropodidae															14	
Pseudostenophylax																
Sialis										14						
Total Organisms per site	7306	4277	8856	2598	8038	13794	10521	5727	5124	3947	5339	2038	2899	6890	37003	8290
Shannon- Weaver	1.68	1.60	2.03	1.69	1.66	1.54	0.97	1.70	1.98	1.40	1.40	1.35	1.44	2.16	1.48	1.61
# Chironomidae/m²	890	86	1765	72	388	1234	330	330	761	258	244	287	488	1019	1579	649
% Oligochaeta	51%	56%	59%	75%	43%	78%	20%	77%	68%	84%	90%	75%	78%	29%	86%	65%
# of Hexagenia												29	29	129	62	
# of Amphipods												43	43	2942	1010	

A summary of the status of the restoration targets for White Lake benthic macroinvertebrates is presented in Table 3. The lake wide means for Shannon Weaver Diversity and #Chironomidae/m² all increased from 2001 levels and exceed the restoration targets. The %Oligochaeta decreased from 2001 levels and was below the restoration target. Amphipod and *Hexagenia* densities increased from 2001 to 2009 and continued to increase in 2010. White Lake will meet the restoration targets for benthic macroinvertebrates if the 2001 results continue to show an increasing trend in population numbers.

Table 4. Quantitative Aquatic Macroinvertebrate Results Obtained from White Lake October 2009.

Organism Description	WL-2	WL-3	WL-6	WL-7	WL-9	WL-11	WL-12	WL-13	WL-15	WL-16	WL-17	WL-18	WL-19	WL-20	WL-21	Mean
Oligochaeta																
Lumbriculidae																
Lumbriculus sp.														14		
Tubificidae																
Limnodrilus hoffmeisteri	350	54	86	59	90	180	73	155	43	133	140	86	187	101	29	
Ilyodrilus templetoni	224	71		61	59	210	86	14	43						29	
Quistadrilus mlrtisetosus		14						14								
Immatures w/o capilliform chaetae	1733	1067	1192	540	450	970	717	808	244	312	550	330	1322	345	1595	
Immatures with capilliform chaetae	3799	1452	1379	14	516	1056	532	331	58	29	640	290	11134	43	934	
Naididae																
Pristina osborni	29															
Nematoda	29	57								86			43		14	
Turbellaria														29		
Planariidae sp.										101						
Amphipoda																
Hyalella azteca	14				14					14		1457	11939	129		
Isopoda																
Asellus sp.				14						14		72	216	29		
Ephemeroptera																
Hexagenia sp.										29				359		
Odonata																
Anisoptera																
Pachidiplex sp.													29	72		
Zygoptera																
Amphigrion sp.													14			
Diptera																
Ceratopogonidae																
Stilobezzia sp.									29				101			
Chaoboridae																
Chaoborus punctipennis	1896	575	532	72	86	86	230	29	14						388	
Chironomidae																
Ablabesmyia sp.										14			72		158	
Chironomus sp.	474	372	322	225	336	560	414	357	376	293	238	327	3261	460	417	
Cryptochironomus sp.		14	29	29		14		14	43	57	14					
Epoicladius sp.														14		
Kiefferulus sp.	29	129	86		57	57	43	43	129		58	167	1192	488		
Microtendipes sp.													14			
Paracladopalma sp.	14															
Polypedilum sp.			14													
Procladius sp.			57	14	29	14		29		29	29		14	603	101	
Tribelos sp.			14							29			14	1164		
Zavrelimyia sp.																
Mollusca																
Gastropoda																
Bulinus sp.														43		
Pelecypoda																
Dreissena polymorpha			86	86	14	29		43	14	43	14	29	330		14	
Sphaerium sp.	29	101	29										201	101	86	
Total Organisms per site	8620	3906	3827	1115	1652	3177	2095	1836	993	1184	1683	2758	30084	3994	3764	4713
Shannon Weaver	1.50	1.67	1.65	1.63	1.74	1.64	1.61	1.62	1.78	1.79	1.48	1.50	1.45	2.16	1.62	1.66
# Chironomidae/m ²	517	516	523	268	422	646	457	443	548	422	339	494	4569	2730	675	905
% Oligochaeta	71%	68%	69%	60%	67%	76%	67%	72%	39%	40%	79%	26%	42%	13%	69%	57%
# of Hexagenia											0	0	359	129	120	
# of Amphipods											1457	11939				4508

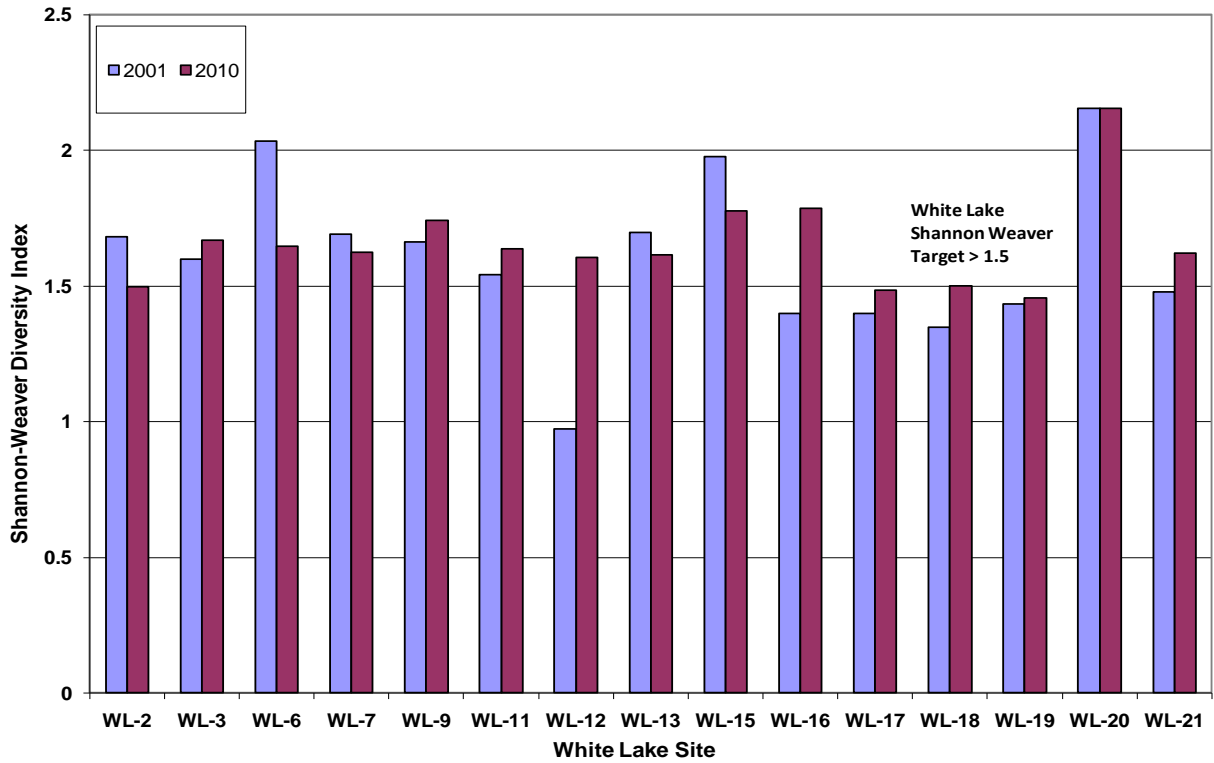


Figure 2. Comparison of 2001 and 2009 Shannon Weaver Diversity Scores for White Lake Benthic Macroinvertebrates.

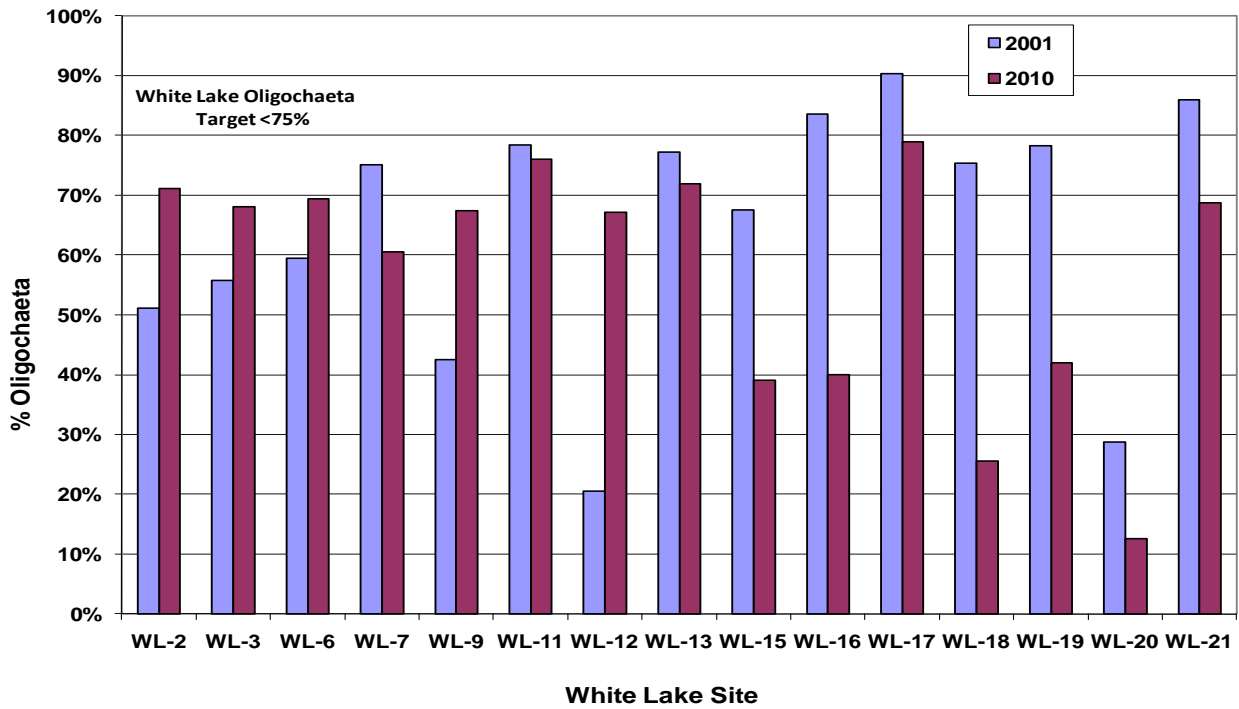


Figure 3. Comparison of 2001 and 2009 % Oligochaeta for White Lake Benthic Macroinvertebrates.

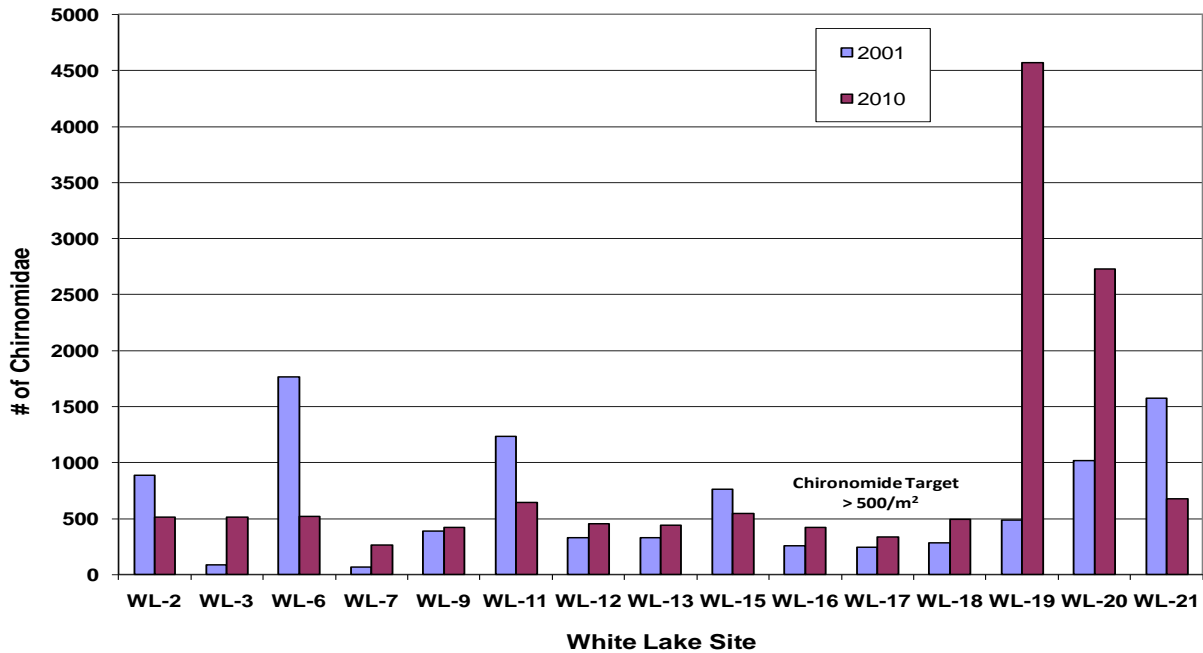


Figure 4. Comparison of 2001 and 2009 #Chironomidae/m² for White Lake Benthic Macroinvertebrates.

Table 5. Comparison of White Lake Targets.

Summary of Aquatic Macroinvertebrate Results White Lake					
Mean	Target	2001	2009	2010	2011
Shannon_Weaver	1.50	1.61	1.67	na	na
% Oligochaete	<75%	65	59	na	na
# Chironomidae/m ²	>500	649	729	na	na
# Hexagenia	Increasing Trend	62	120	145	
# Amphipods	Increasing Trend	1011	4842	5612	

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