



# A Biological Study of the Newburgh Pool of the Ohio River



## **Executive Summary**

- Since 2004, ORSANCO has been using a probabilistic (random) design for monitoring fish communities in the Ohio River and conducting biological assessments.
- The Ohio River was divided into 20 assessment units based primarily on the locations of navigational dams. Using the random design, each assessment unit was assigned 15 sampling locations.
- Once sampled, each site is graded as passing or failing. For an assessment unit to meet its aquatic life use designation, more than 75% of the sites assessed must be in passing condition.
- In 2007, 87% of the sites assessed in Newburgh pool were in passing condition. This percentage indicates the pool is passing; however the confidence and precision (14%) of the measurement is not at the desired level of the current protocol.
- After considering the results and additional relevant information about the pool, Newburgh was listed as passing. Since no other data indicated impairment, the Biological Water Quality Subcommittee decided that reassessing the pool is lower priority compared to assessing other areas of the Ohio River.
- Previous analyses have indicated that increased flows may cause lower ORFIn scores due to decreased sampling efficiency and changes in fish behavior.
- Increased flows were not an issue in 2007. Flows were stable and not elevated when sampling was conducted.
- Recommendations include:
  - Accepting the assessment of Newburgh pool as meeting its aquatic life use designation.
  - Resources would be better spent assessing another pool rather than reassessing a pool that appears to be passing.
  - Continue to monitor flow and its influence on assessment results.

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# **A Biological Study of the Newburgh Pool of the Ohio River (2007)**

## **1.0 Introduction**

The Ohio River Valley Water Sanitation Commission (ORSANCO) is an interstate water pollution control agency created in 1948 by an act of Congress to monitor and improve the water quality of the Ohio River. Until that time, water quality issues on the Ohio River had been charged to state water quality agencies. However, due to large-scale interstate implications and large pollution loads received by the Ohio River, these agencies were not sufficiently equipped to work with such a system. ORSANCO's role is to work in conjunction with state agencies to develop a set of pollution control standards exclusive to the Ohio River. The creation of these standards requires the establishment of monitoring programs that can efficiently be used on the Ohio River.

The routine ambient monitoring programs of ORSANCO are primarily directed at three monitoring and assessment priorities: spill detection (through an organics detection system), trend assessment (manual sampling system), and aquatic resource characterization (macroinvertebrate and fish studies). Another priority, water quality impacts assessment, is achieved through entire watershed intensive surveys.

In 1993, following direction from state and federal agencies, ORSANCO staff developed and implemented an intensive survey design that used electrofishing methods designed for the navigational pools of the Ohio River. This entailed extensive sampling of fish communities throughout the entire length of a particular pool. The surveys were intended to provide background information on fish populations and lay a foundation for establishing biological criteria (biocriteria) for the Ohio River. With appropriate biocriteria in place, information on the biological community provides insight into the health of the Ohio River.

After several years of collecting background data on the fish population of the Ohio River, ORSANCO developed the Ohio River Fish Index (ORFI<sub>n</sub>, Emery et al. 2003). The ORFI<sub>n</sub> incorporates 13

attributes, or metrics, of the fish community that when compiled provide an accurate representation of the overall condition of the Ohio River fish community. These 13 metrics take into account several different aspects of the fish population, including diversity, abundance, feeding and reproductive guilds, pollution tolerance/intolerance, and fish health.

An important aspect of biological monitoring is the reduction of human induced bias in the samples. The use of probability-based sample site selection was designed to reduce this bias. Within this design, sample sites are randomly selected by computer generation, eliminating the tendency to sample only in the best or worst locations. Many states already have programs in place that use this design for sampling on smaller streams, and it is also used by the U.S. Environmental Protection Agency's (USEPA) Environmental Monitoring and Assessment Program (EMAP). ORSANCO has now begun using this approach on the Ohio River for its biological monitoring. In 2007, the Emsworth, Pike Island, Meldahl, Cannelton and Newburgh pools were sampled as part of ORSANCO's normal monitoring. This report presents the 2007 survey of the Newburgh pool including the data collected and assessment results based on the fish population surveys.

## **2.0 Study Area**

### *2.1 Ohio River*

The Ohio River (Figure 1) begins at the confluence of the Monongahela and Allegheny rivers and flows 981 miles in a southwesterly direction to the confluence with the Mississippi River. Twenty navigational dams maintain a nine-foot minimum depth for commercial navigation throughout the entire length of the river. There are over 600 permitted discharges to the Ohio River, 49 of which are power-generating facilities. The Ohio River Basin contains nearly ten percent of the nation's population, more than 25 million people, and serves as an avenue for transportation of approximately 250 million tons of cargo each year (ORSANCO 1994). The Ohio River dissects four ecoregions: the Western Allegheny Plateau, the Interior Plateau, the Interior River Lowland, and the Mississippi Alluvial Plain (Omernik 1987).



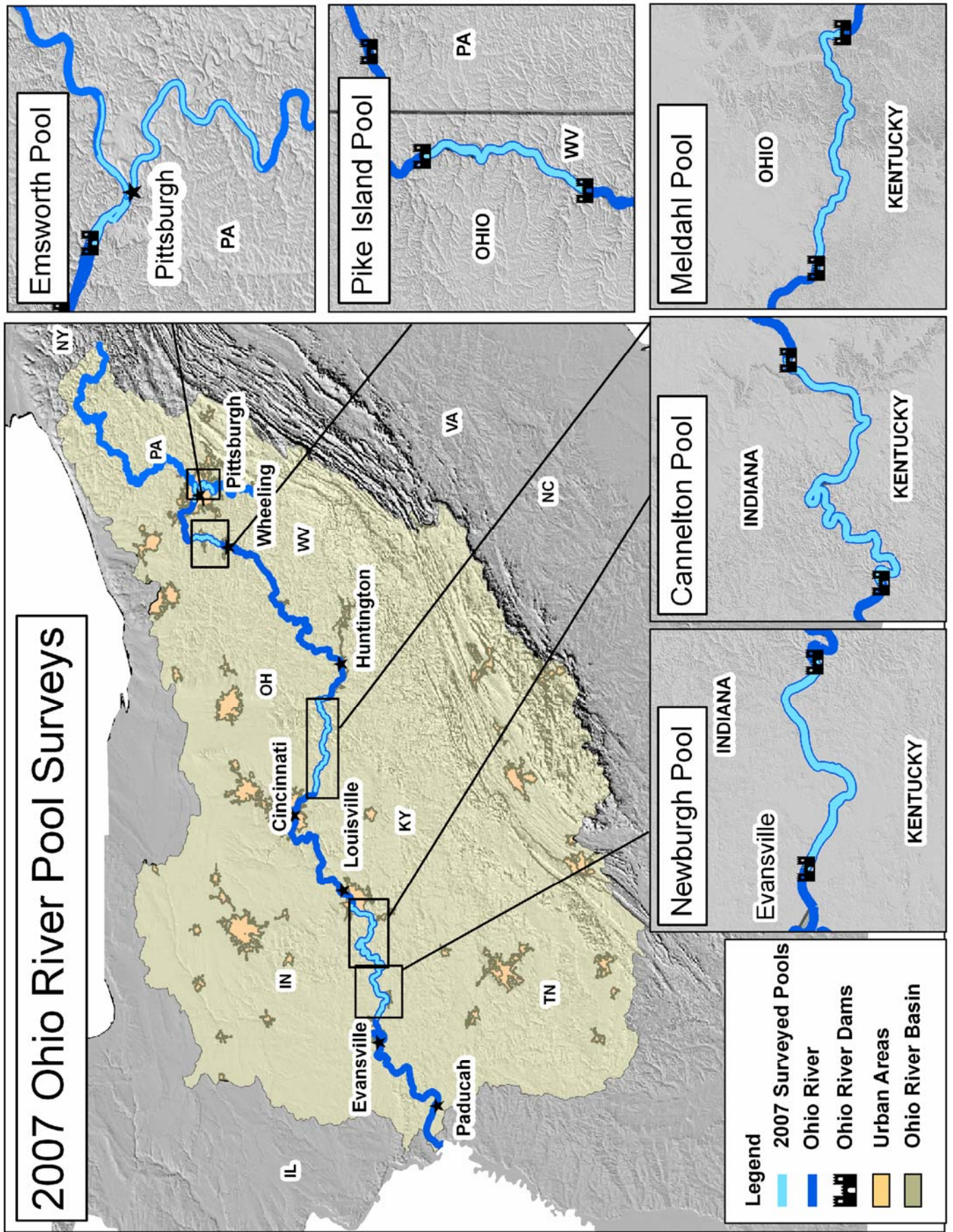


Figure 1. The Ohio River basin and the five pools selected for 2007 sampling.



## 2.2 Newburgh Pool

The Newburgh pool is 55.4 miles long, extending from Cannelton Locks and Dam (ORM 720.7) to Newburgh Locks and Dam (ORM 776.1). The pool has a gradient of 0.3 feet per mile and averages 2,477 feet wide and 28 feet deep. The pool is bordered by the states of Indiana and Kentucky. The Newburgh pool receives water from the following tributaries: Anderson River at mile point 731.5 with a drainage area of 276 square miles, Blackford Creek at mile point 742.2 with a drainage area of 124 square miles and Little Pigeon Creek with a drainage area of 415 square miles (ORSANCO 1994).

## 2.3 Newburgh Pool Land Use

Newburgh pool lies in a portion of the Ohio River

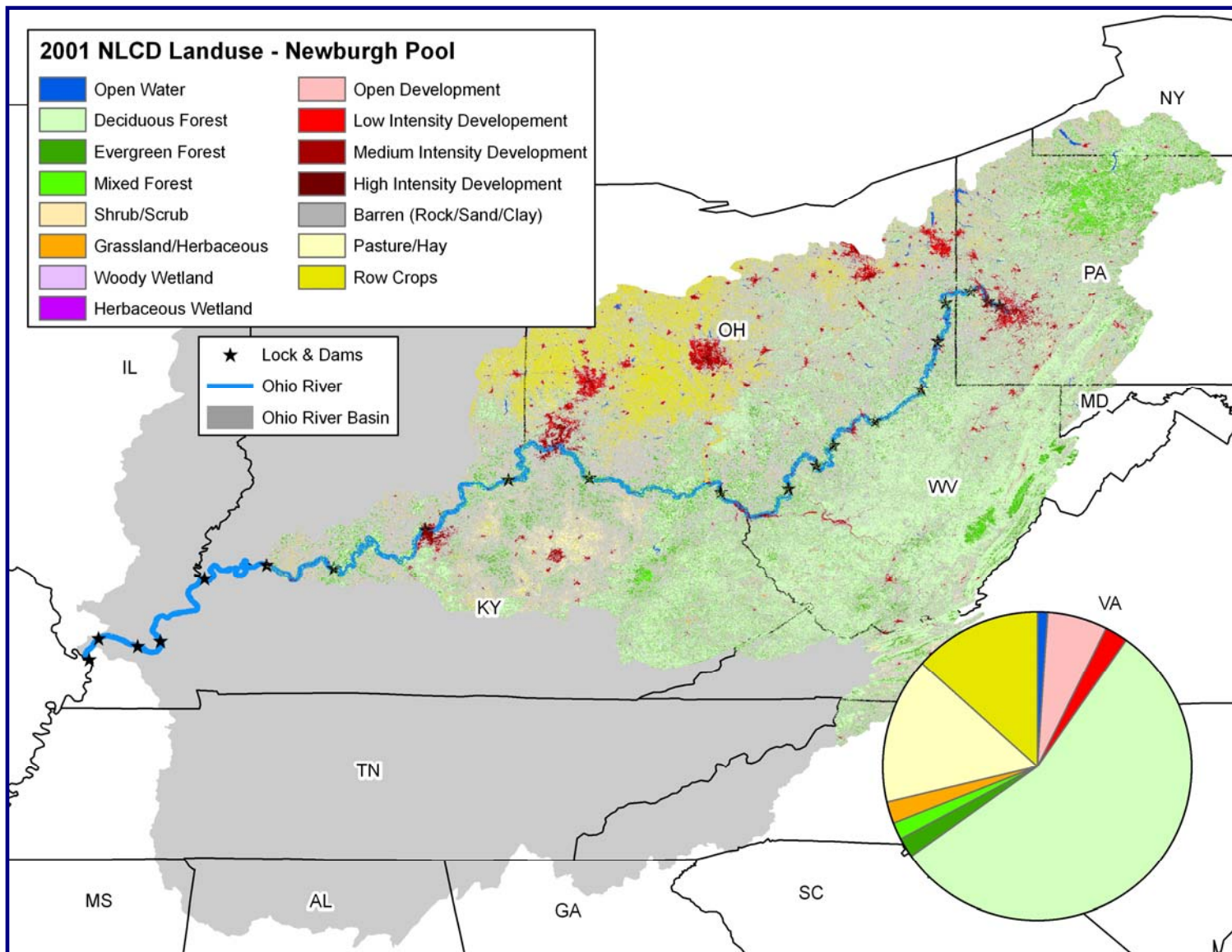
forest (53.9%), but also has a considerable amount of row crops (13.1%) and pasture lands (14.9%) (Figure 2).

## 3.0 Methods

### 3.1 Survey Design and Site Location

A random, probability-based survey design was used to select sampling site locations within each Ohio River survey pool. The USEPA National Health and Environmental Effects Laboratory, Western Ecology Division provided assistance by generating the survey design for this project. The target population was the linear shorelines of the Newburgh pool of the Ohio River from mile marker

720.7 (Cannelton Locks and Dam) to 776.1



**Figure 2.** Land use in the Newburgh pool catchment area. where the land use consists primarily of deciduous

(Newburgh Locks and Dam). The total linear extent

of the target population was approximately 110.8 miles. The sample frame was generated using RF3 river double lines for the Ohio River and river mile coverage provided by ORSANCO. A generalized random tessellation stratified (GRTS) survey design for a linear network with reverse hierarchical randomization (RHR) was used to select all sampling locations. This survey design provided coordinates for 15 sampling sites in each of the selected pools. The data collected from these sites were used to make an assessment of the pool (see Section 3.6 and Appendix A).

Sites were sampled as closely as possible to the location generated from the design, but in cases of restricted access or unsafe sampling conditions (e.g. barge loading/mooring area), sampling zones were shifted if possible (up to a maximum of 500m up- or downstream). The survey design supplied additional sampling sites to be used if a site could not be placed within 500m of the original location.

### 3.2 Index Period and Sampling Restrictions

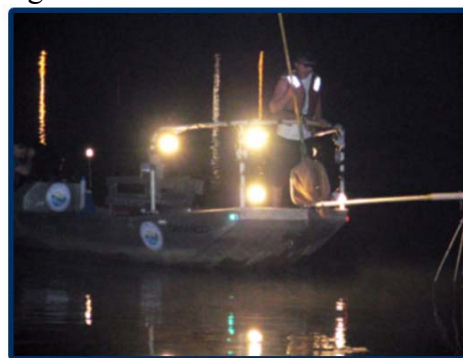
All sampling was conducted under the required conditions as described by Emery et al. (2003). This included sampling between July 1 and October 31 when water levels were within one meter of “normal flat pool” and Secchi depths were greater than 0.3m. These sampling restrictions were used to reduce community variability by increasing the likelihood that samples were collected during the stable, low-flow conditions usually present on the Ohio River during the summer and early fall months.

### 3.3 Fish Collections

Standard collection techniques were employed throughout the surveys as described by Emery et al. (2003). Fish were collected using boat electrofishing techniques at night because nighttime electrofishing typically yields samples of increased diversity and richness (Sanders 1992).

A sampling crew consisted of a three-person team working from an 18-foot aluminum johnboat. Each boat was equipped with a 5000-watt generator and a Smith-Root Type VI-A

electrofishing unit. Sampling was conducted over a 500m long section



*ORSANCO crew conducting night-time electrofishing*

of near-shore habitat (shoreline out to a maximum distance of 100 ft or a depth of 20 ft.) and was sampled for a minimum of 1800 seconds (Gammon 1998). Time could vary depending upon the complexity of the habitat within a given zone. Stunned fish were captured with nets and placed into large, aerated tubs for processing. Each fish was measured, inspected for anomalies, and identified to lowest possible taxonomic level (species) before being returned to the water. Fish that could not be confidently identified in the field (e.g. minnows) were preserved in a ten percent formalin solution and identified in the laboratory.



*Typical 500 meter electrofishing reach*

### 3.4 Habitat Characterizations

Large rivers have distinct habitat types, including unique microhabitats (Reash 1999). Therefore, extensive habitat surveys were conducted for each electrofishing zone, including thorough substrate and depth measurements. Descriptions of the riparian corridor adjacent to the sampling zone and the presence of woody material available as fish cover were also recorded. Depth and substrate composition were measured at 66 points throughout each 500m zone. Six points along the shoreline

were selected throughout the length of the zone, at 0, 100, 200, 300, 400 and 500m. From each of these points, depth was recorded at 10ft intervals beginning at the shore/water interface and moving away from the shore for 100ft. Woody cover, which included submerged brush, logs, and stumps, was estimated visually. Using these data, each site, or electrofishing zone, was assigned to one of three existing classes of habitat: 'A', 'B', or 'C'. By assigning each sampling site to one of three habitat categories, biologists can reduce the amount of assessment variability, or 'noise', because each habitat class has a slightly different expectation. Sites assigned to habitat class 'A' are characterized by the presence of large substrates such as cobble and boulders. Sites that fall in habitat class 'C' are dominated by sand and other small substrates, and habitat class 'B' describes sites that fall between 'A' and 'C' with a mix of large and small substrate materials.

### 3.5 Water Quality and Flow Condition Data

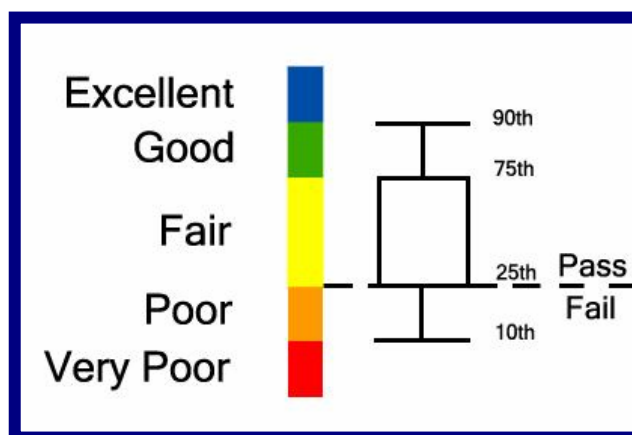
Basic measures of water quality were collected at each site prior to sampling. The following parameters were measured with a YSI meter: water temperature, pH, dissolved oxygen (DO), and conductivity. Water samples were also collected using a Kemmerer and consisted of a single-point, mid-depth grab sample at the downstream end of each 500m zone. Samples were collected approximately 100 ft from shore at each site on three separate occasions throughout the field season. Samples were kept at or below 4°C until sent off for laboratory analyses. Water quality parameters analyzed included: ammonia nitrogen, chloride, hardness, nitrate-nitrite, total Kjeldahl nitrogen (TKN), phenolics, sulfate, total suspended solids (TSS), total phosphorus, and total organic carbon (TOC).

Secchi depth was measured using a standard Secchi disk. Flow data were obtained from the U.S. Army Corps of Engineers. These included daily average flow volumes and velocities from the sampling station within or nearest to the sampled pool. Harmonic mean flow (HMF) values were determined by ORSANCO using 30-year means for the flow data obtained from the U.S. Army Corps of Engineers (ORSANCO 2003).

### 3.6 Pool Assessment

In 2007, ORSANCO employed a probability-based sampling and assessment approach to provide a thorough assessment of biological condition. For the purpose of assessment, individual navigational pools served as the primary assessment units. Therefore, the Newburgh pool served as one distinct assessment unit (AU) and will be reported on as such in the 305(b) report issued to EPA. The approach to assessing each AU involved sampling a statistically determined number of sites (15) and comparing observed ORFIn scores to habitat derived expectations for each site (Emery et al. 2003).

The three distinct habitat classes ('A', 'B', and 'C') each exhibit different levels of ORFIn performance. Performance expectations for each habitat class were determined based on the statistical distribution of data (ORFIn scores) gathered from 'least impacted' (reference) sites within each habitat class. The 25<sup>th</sup> percentile value for each habitat class was established as the criterion for determining whether an individual site 'passes' (meets its aquatic life use designation) or 'fails' (does not meet its aquatic life use designation, Figure 3).



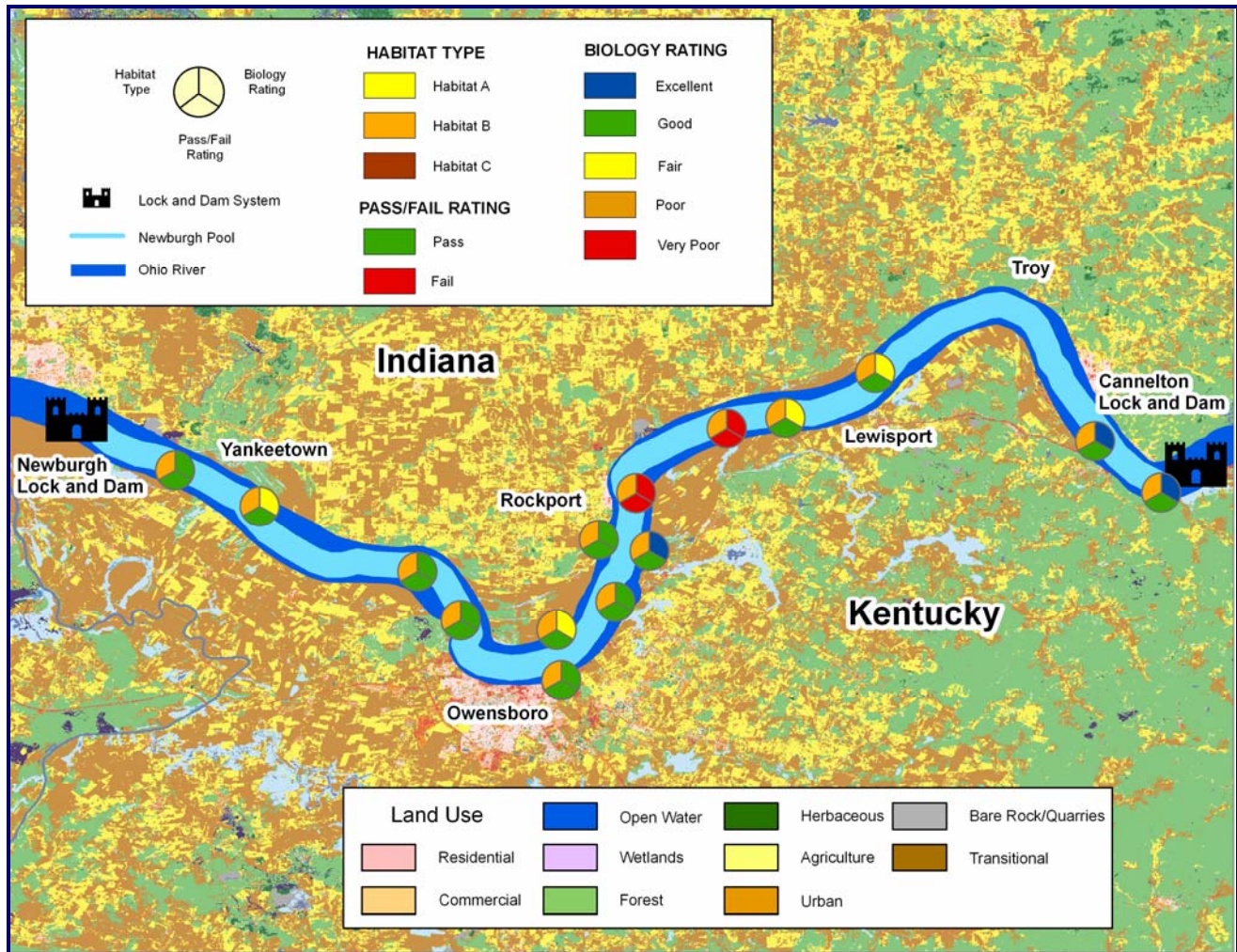
**Figure 3.** Approach used to assign habitat condition ratings.

Individual site scores were compared to expected values and the percentage of failing sites in the pool was then calculated. A precision estimate for the percentage of sites failing was also calculated (see Appendix A for a detailed explanation). The precision estimate was used to create a 90% confidence interval around the percentage of sites failing. The threshold for the pool assessment was



set at 25% failure. The pool passed the assessment if the entire confidence interval fell below 25%. If the whole confidence interval was greater than 25%, the pool was assessed as failing. If the confidence interval overlapped the 25% threshold, the assessment required additional sampling to determine the result. To further characterize the condition of each pool, sites were given individual condition ratings. These ratings

were based on the same distribution of data from ‘least impacted’ sites used to determine expectations and consisted of Excellent, Good, Fair, Poor and Very Poor. The 90<sup>th</sup>, 75<sup>th</sup>, 25<sup>th</sup>, and 10<sup>th</sup> percentiles were used as cutoff points for the different ratings. Any sites that were classified as Poor or Very Poor were also sites that failed to meet expectations (Figures 3 and 4).



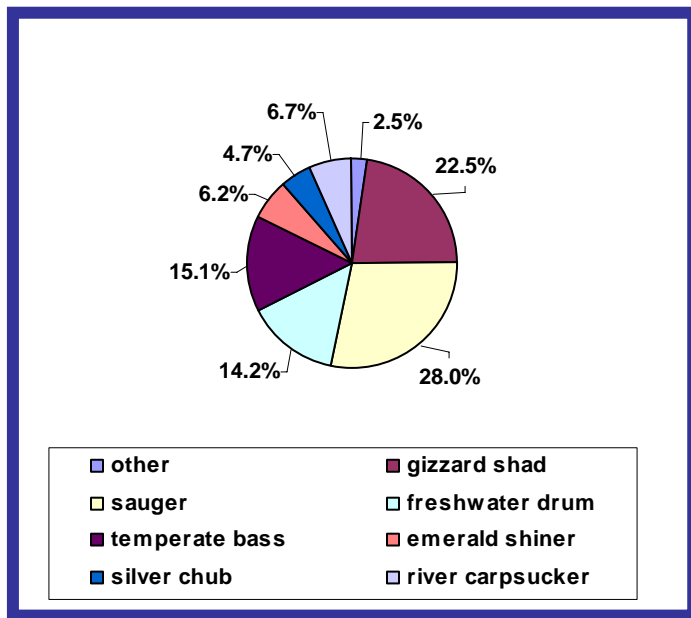
**Figure 4.** Locations and results of sampling at 15 sites within the Newburgh pool.

## 4.0 Results

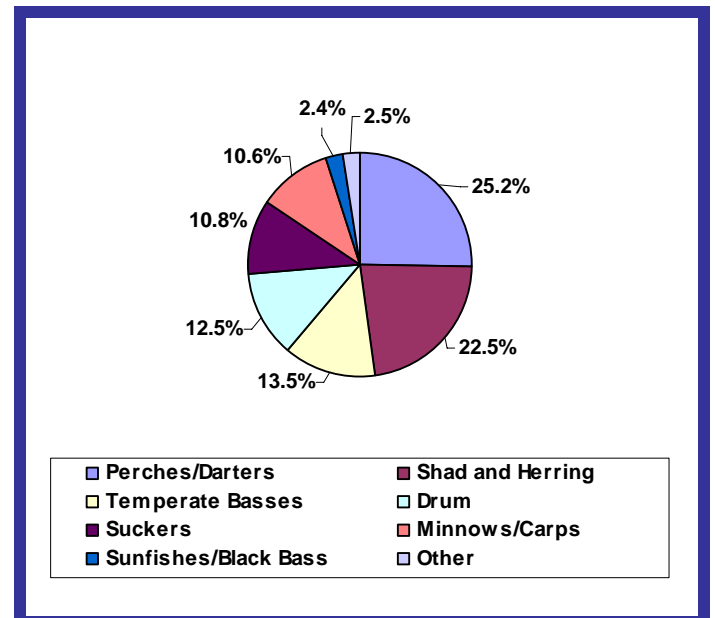
### 4.1 Fish Population

In 2007, fish population data (Appendix B) were collected from 15 randomly selected locations throughout the length of the Newburgh pool (Table 1). These collections produced 44 species, representing 12 different families (Table 2). Two of the 44 taxa are listed in IN and KY as special concern. These include river redhorse (*Moxostoma carinatum*) in IN and black buffalo (*Ictiobus niger*)

in KY. No federally listed taxa were collected from the Newburgh Pool. The two most abundant species were sauger (*Sander canadensis*) and gizzard shad (*Dorosoma cepedianum*), which comprised 28.0% and 22.5% of the catch respectively (Figure 5). The three dominant families were the perches and darters family (Percidae), the shad and herring family (Clupeidae), and the temperate bass family (Moronidae), which comprised 25.2%, 22.5% and 13.5% of the catch respectively (Figure 6).



**Figure 5.** Species composition of fish sampled in Newburgh pool.



**Figure 6.** Fish composition by family in Newburgh pool.

**Table 1.** Electrofishing site list for the Newburgh pool, including habitat designation, ORFIn scores and status.

Site #	River Mile	Bank	Date	Latitude	Longitude	Habitat Class	ORFIn Expectation	Observed ORFIn	Site Result	Rating
1	721.2	LDB	31-Jul-07	37.89183	86.70759	B	33	55	PASS	EXCELLENT
2	724.8	LDB	31-Jul-07	37.91494	86.76125	B	33	49	PASS	EXCELLENT
3	736.7	RDB	30-Jul-07	37.95587	86.89375	B	33	41	PASS	FAIR
4	740.4	LDB	01-Aug-07	37.92884	86.94792	B	33	41	PASS	FAIR
5	742.4	LDB	01-Aug-07	37.92246	86.98325	B	33	17	FAIL	VERY POOR
6	747.3	LDB	01-Aug-07	37.88353	87.03789	B	33	21	FAIL	VERY POOR
7	748.8	LDB	07-Aug-07	37.86047	87.03876	B	33	49	PASS	EXCELLENT
8	749.3	RDB	07-Aug-07	37.85440	87.04955	B	33	43	PASS	GOOD
9	752.0	LDB	08-Aug-07	37.81766	87.05035	B	33	45	PASS	GOOD
10	754.3	RDB	08-Aug-07	37.79184	87.07894	B	33	41	PASS	FAIR
11	754.8	LDB	08-Aug-07	37.78226	87.08300	B	33	43	PASS	GOOD
12	759.7	LDB	07-Aug-07	37.80653	87.14359	B	33	43	PASS	GOOD
13	762.5	LDB	07-Aug-07	37.83600	87.16970	B	33	43	PASS	GOOD
14	768.9	RDB	06-Aug-07	37.87553	87.26483	B	33	35	PASS	FAIR
15	772.1	LDB	06-Aug-07	37.89724	87.31578	B	33	45	PASS	GOOD

LDB = Left Descending Bank

RDB = Right Descending Bank

**Table 2.** Species collected in the Newburgh pool during the 2007 survey

Family	Species	Latin Name	IN	KY
Polyodontidae	paddlefish	<i>Polyodon spathula</i>		
Lepisosteidae	spotted gar	<i>Lepisosteus oculatus</i>		
Lepisosteidae	longnose gar	<i>Lepisosteus osseus</i>		
Lepisosteidae	shortnose gar	<i>Lepisosteus platostomus</i>		
Hiodontidae	goldeye	<i>Hiodon alosoides</i>		
Hiodontidae	mooneye	<i>Hiodon tergisus</i>		
Clupeidae	skipjack herring	<i>Alosa chrysochloris</i>		
Clupeidae	gizzard shad	<i>Dorosoma cepedianum</i>		
Clupeidae	threadfin shad	<i>Dorosoma petenense</i>		
Cyprinidae	grass carp	<i>Ctenopharyngodon idella</i>		
Cyprinidae	spotfin shiner	<i>Cyprinella spiloptera</i>		
Cyprinidae	common carp	<i>Cyprinus carpio</i>		
Cyprinidae	silver carp	<i>Hypophthalmichthys molitrix</i>		
Cyprinidae	bighead carp	<i>Hypophthalmichthys nobilis</i>		
Cyprinidae	silver chub	<i>Macrhybopsis storeriana</i>		
Cyprinidae	emerald shiner	<i>Notropis atherinoides</i>		
Cyprinidae	river shiner	<i>Notropis blennius</i>		
Cyprinidae	mimic shiner	<i>Notropis volucellus</i>		
Catostomidae	river carpsucker	<i>Carpiodes carpio</i>		
Catostomidae	quillback	<i>Carpiodes cyprinus</i>		
Catostomidae	highfin carpsucker	<i>Carpiodes velifer</i>		
Catostomidae	northern hog sucker	<i>Hypentelium nigricans</i>		
Catostomidae	smallmouth buffalo	<i>Ictiobus bubalus</i>		
Catostomidae	bigmouth buffalo	<i>Ictiobus cyprinellus</i>		
Catostomidae	black buffalo	<i>Ictiobus niger</i>		SC
Catostomidae	smallmouth redhorse	<i>Moxostoma breviceps</i>		
Catostomidae	river redhorse	<i>Moxostoma carinatum</i>	SC	
Catostomidae	golden redhorse	<i>Moxostoma erythrurum</i>		
Ictaluridae	channel catfish	<i>Ictalurus punctatus</i>		
Ictaluridae	flathead catfish	<i>Pylodictis olivaris</i>		
Atherinopsidae	brook silverside	<i>Labidesthes sicculus</i>		
Moronidae	Morone sp	<i>Morone sp</i>		
Moronidae	white bass	<i>Morone chrysops</i>		
Centrarchidae	green sunfish	<i>Lepomis cyanellus</i>		
Centrarchidae	bluegill	<i>Lepomis macrochirus</i>		
Centrarchidae	longear sunfish	<i>Lepomis megalotis</i>		
Centrarchidae	smallmouth bass	<i>Micropterus dolomieu</i>		
Centrarchidae	spotted bass	<i>Micropterus punctulatus</i>		
Centrarchidae	largemouth bass	<i>Micropterus salmoides</i>		
Centrarchidae	white crappie	<i>Pomoxis annularis</i>		
Percidae	logperch	<i>Percina caprodes</i>		
Percidae	sauger	<i>Sander canadensis</i>		
Percidae	walleye	<i>Sander vitreus</i>		
Sciaenidae	freshwater drum	<i>Aplodinotus grunniens</i>		



#### 4.2 Metric Performance

Thirteen metrics were used to calculate ORFI scores for each electrofishing site (Emery et al. 2003). Each site's performance and scores for the ORFI metrics are shown in Table 3. The number of native species collected at each site ranged from 12 to 20, with an average of 14.7 species per site. Thirteen of the fifteen sites scored a 3 for the number of native species metric and two sites scored a 5. The number of sucker species found at each site ranged from 1 to 6. The number of centrarchid species varied from 0 to 3 and the metric scores were mostly a 1. The number of great river species ranged from 1 to 5. The number of intolerant species ranged from 0 to 4 at the sampled sites. The percentage of tolerant individuals at each site ranged between 0% and 10.3%, and thirteen of the sites scored a 5 for this metric. The percentage of simple lithophils was between 15.6% and 62.2%, and scores for this metric were mostly a 3 or 5. All sites had below 3.1% non-native individuals and thirteen of the sites scored a 5 for this metric. The percent detritivores ranged from 0.6% to 37.9% and six sites scored a 5; the remaining sites scored either a 1 or 3. The percent invertivores ranged from 0.0% to 17.1%, with fourteen sites scoring a 1. The percent piscivores ranged from 27.8% to 80.7%. Eleven sites scored a 5 and the remaining scored either a 1 or 3 for this metric. Only one site had a single DELT (deformities, eroded fins, lesions and tumors) anomaly and all sites scored a 5. The CPUE (catch per unit effort) ranged from 58 to 364 individuals per site. For this metric, only two sites scored a 5 and the remaining sites scored a 3 or 1.

#### 4.3 Habitat Surveys

Intensive habitat surveys at each of the 15 sampling locations revealed that the bottom substrate in the Newburgh pool was in nearly equal proportions of fines and sand, with a smaller percentage of gravel and hardpan (Figure 7). The percentage of fines increased as the river miles increased. There was some variation among the individual sites (Figure 8). The percentages of substrate variables were used to give each site a habitat classification of 'A', 'B', or 'C' (Table 1). All sites in the Newburgh pool were classified as class 'B' habitats.

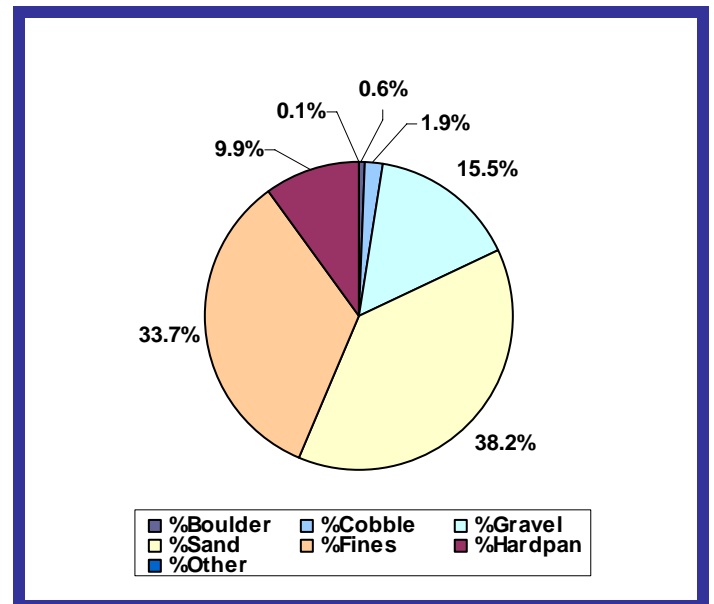


Figure 7. Substrate composition of the Newburgh pool.

Woody cover was present at 14 of the 15 sites sampled. Riparian land use was primarily natural forest with some agricultural uses present. Despite heavy barge activity throughout the pool, mooring structures were present at only one of the sites sampled (see Appendix C).

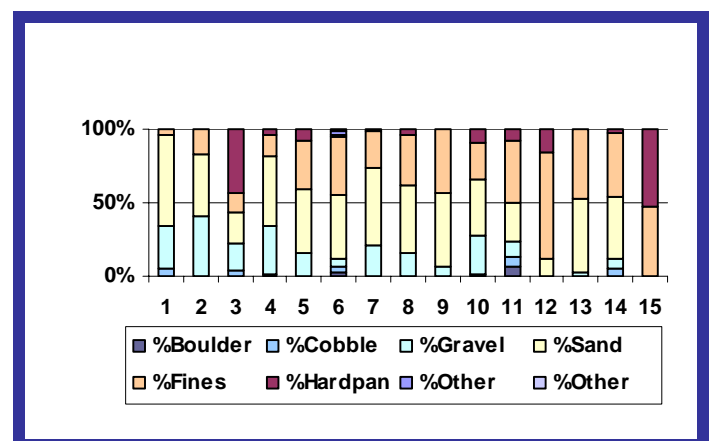


Figure 8. Substrate composition at each site sampled in the Newburgh pool.

#### 4.4 Water Quality and Flow Conditions

Rain events were sparse throughout the sampling period in 2007; therefore river levels and flows were stable. Some sampling was conducted in Newburgh pool when flows were above the harmonic mean flow (HMF) for the pool. The HMF values used for the upstream (sites 1-11) and downstream (sites 12-15) portions of this pool were 53.4 and 60.9 kcfs respectively; and sampling was conducted between 49.1% and 124.9% of the HMF (Figure 9). Measurements of water quality

**Table 3.** ORFIn metrics and scores from the 2007 Newburgh pool survey.

Site #	River Mile	Bank	# Individuals	# Individuals w/o G & E	# Individuals w/o GETHEX	# Species	# Species Score	# Suckers	Suckers Species Score	# Centrarchid Species	Centrarchid Species Score	# Great River Species	Great River Species Score	# Intolerant Species	Intolerant Species Score	% Tolerant Individuals	Tolerant Individuals Score	% Simple Lithophils	Simple Lithophils Score	% Non-native Individuals	Non-native Individuals Score	% Detritivores	Detritivores Score	% Invertivores	Invertivores Score	% Piscivores	Piscivores Score	# DELTs	DELt Score	CPUE	CPUE Score	ORFIn Expectation	Observed ORFIn	Site Result
1	721.2	L	365	322	321	20	5	6	5	3	3	3	3	2	3	0.3	5	46.9	5	0.3	5	4.7	5	3.4	1	73.6	5	1	5	364	5	33	55	PASS
2	724.8	L	282	241	241	15	3	6	5	2	1	1	1	4	5	0.0	5	62.2	5	0.0	5	3.3	5	7.5	1	79.7	5	0	5	282	3	33	49	PASS
3	736.7	R	148	72	72	14	3	1	1	1	1	2	3	1	1	0.0	5	23.6	3	0.0	5	2.8	5	6.9	1	63.9	5	0	5	148	3	33	41	PASS
4	740.4	L	136	116	116	16	3	3	3	2	1	3	3	1	1	0.0	5	26.7	3	0.0	5	8.6	5	4.3	1	62.1	5	0	5	136	1	33	41	PASS
5	742.4	L	59	32	31	12	3	2	1	1	1	1	1	0	0	3.1	1	15.6	1	3.1	1	9.4	1	0.0	0	46.9	1	0	5	58	1	33	17	FAIL
6	747.3	L	212	39	35	14	3	2	1	2	1	3	3	0	0	10.3	1	41.0	1	0.0	0	17.9	1	5.1	1	56.4	1	0	5	208	3	33	21	FAIL
7	748.8	L	159	146	144	20	5	5	5	1	1	4	5	3	3	1.4	5	35.6	5	1.4	5	24.0	1	13.0	1	45.2	5	0	5	157	3	33	49	PASS
8	749.3	R	172	161	160	16	3	5	5	0	1	3	3	1	1	0.6	5	32.9	5	0.6	5	37.9	1	10.6	1	41.0	5	0	5	171	3	33	43	PASS
9	752.0	L	236	118	117	16	3	2	1	2	1	5	5	2	3	0.8	5	61.9	5	0.8	5	9.3	3	2.5	1	79.7	5	0	5	235	3	33	45	PASS
10	754.3	R	128	97	97	13	3	3	3	2	1	2	3	1	1	0.0	5	34.0	5	0.0	5	12.4	3	2.1	1	59.8	5	0	5	128	1	33	41	PASS
11	754.8	L	152	131	128	13	3	2	1	1	1	2	3	2	3	2.3	5	51.1	5	2.3	5	9.2	3	3.1	1	67.2	5	0	5	149	3	33	43	PASS
12	759.7	L	214	170	170	13	3	1	1	1	1	3	3	1	1	0.0	5	54.7	5	0.0	5	0.6	5	17.1	1	49.4	5	0	5	214	3	33	43	PASS
13	762.5	L	148	86	86	12	3	4	3	1	1	1	1	0	1	0.0	5	52.3	5	0.0	5	7.0	5	3.5	1	69.8	5	0	5	148	3	33	43	PASS
14	768.9	R	274	217	217	12	3	3	3	2	1	1	1	1	1	0.0	5	21.2	3	0.0	5	35.9	1	4.1	1	33.2	3	0	5	274	3	33	35	PASS
15	772.1	L	328	299	299	14	3	4	3	0	1	3	3	2	3	0.0	5	32.4	5	0.0	5	16.7	3	15.1	1	27.8	3	0	5	328	5	33	45	PASS

R = Right Descending Bank

L = Left Descending Bank

w/o G & E = Individuals minus gizzard shad and emerald shiners

w/o GETHEX = Individuals minus gizzard shad, emerald shiners, tolerants, hybrids, and exotics

Centrarchid Species = black bass, sunfishes, crappie

Great River Species = fish expected to be predominant in great rivers

Intolerant Species = species with low pollution/disturbance tolerance

Tolerant Individuals = individuals with high pollution/disturbance tolerance

Simple Lithophils = fish that are sensitive to substrate disturbance based on reproductive needs

Detritivore = fish that feed primarily on detritus

Invertivore = fish that feed primarily on invertebrates

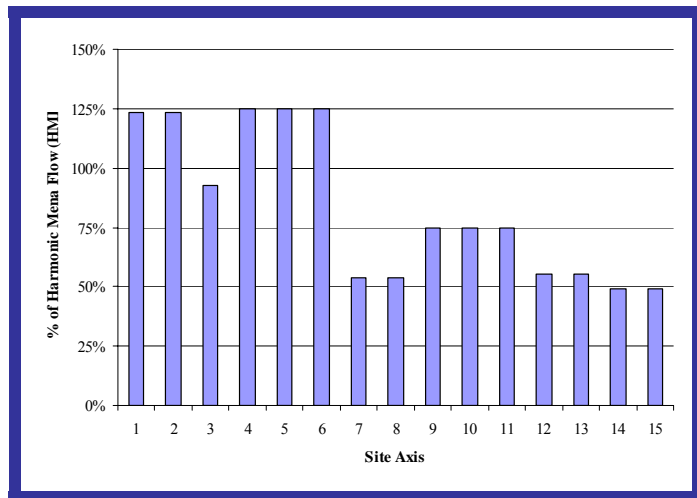
Piscivore = fish that feed primarily on other fish

DELt = individuals with Deformities, Eroded fins, Lesions, and/or Tumors

CPUE = Catch Per Unit Effort

parameters did not reveal any unusual or poor water conditions present at the time of sampling (Appendix D). Secchi depths at the time of sampling ranged from 42 to 156 inches.

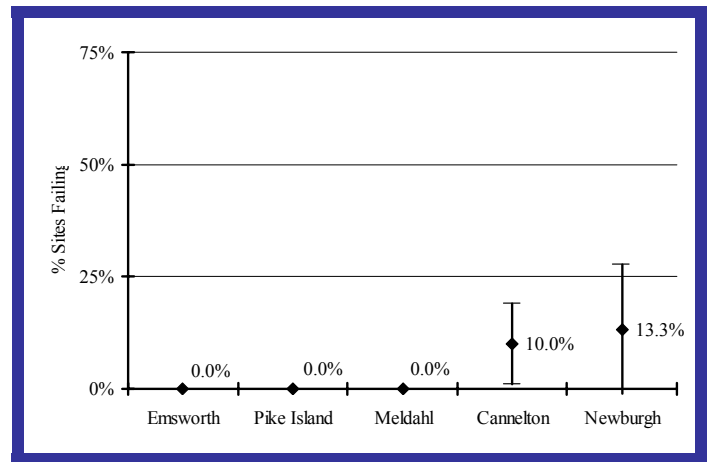
The water quality parameters measured from water samples, collected three times with Kemmerers, did not reveal any parameters exceeding water quality criteria (Appendix E).



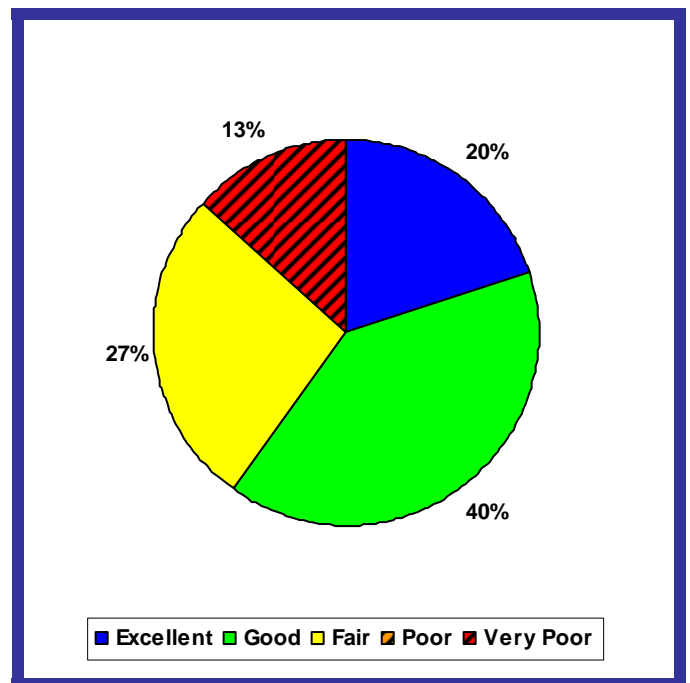
**Figure 9.** Relative flows (%HMF) at the time of sampling.

#### 4.5 Assessment of Condition

ORFIn scores were calculated for each of the sites sampled. The maximum score achieved by any site in this pool out of a possible 65 was 55 and the minimum was 17. By comparing observed and expected ORFIn scores, ORSANCO assessed each site as either passing or failing (Table 3). All but two of the 15 sites sampled in 2007 scored higher than the minimum expected scores and received passing evaluations (Table 1). Sites that were in failing condition comprised 13.3% of the total with an estimated precision of +/-14% (Figure 10). Three sites (20%) received an excellent condition rating, six sites (40%) were found to be in good condition, and four (27%) were in fair condition, and two sites (13%) were 'very poor' (Figure 11).



**Figure 10.** 2007 pool assessment results with 90% confidence intervals.



**Figure 11.** Condition of the Newburgh Pool based on ORFIn scores at 15 sites (Pass=Excellent-Fair, Fail=Poor-Very Poor).

## 5.0 Discussion

### 5.1 Fish Population

In 2007, the fish population of Newburgh pool was in fair to good condition. This was supported by the diversity and types of species collected from the pool. The largest fish collected from this pool was a paddlefish (*Polyodon spathula*). This was the only individual of its species collected in the 2007 survey. This mid-channel species is rarely collected.



Four invasive carp species were collected from the Newburgh pool including: common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*), silver carp (*Hypophthalmichthys molitrix*), and bighead carp (*H. nobilis*). Nine total individuals were collected from the survey but many more were observed. Silver and bighead carp pose a potential threat to boaters due to their skittish behavior and large sizes. Boat motors have been known to cause these fish to breach the surface of the water. Fish have been reported landing in boats and even hitting boaters. Caution is advised when boating in the Newburgh pool. Future monitoring will determine if the populations of these species are increasing.

### *5.2 Metric Performance*

Three metrics stood out as the lowest performing metrics in Newburgh pool: the % invertivorous individuals, # of intolerant species, and the # of centrarchid species. For all of these metrics, most sites scored a 1. Only four centrarchid species were collected during the survey (Table 2). Most of the invertivorous species were also considered intolerant; therefore it was understandable how both metrics produced low scores. However, there was no known reason or explanation for these low scores.

### *5.3 Habitat Surveys*

The habitat assessments show that all areas of Newburgh pool were classified as class ‘B’ habitats. The dominance of small substrate particles (fines and sand) was less than ideal; however, the supplementation of woody habitat at many of the sites may have provided adequate habitat to support the diverse fish populations of the Newburgh pool.

### *5.4 Water Quality and Flow Conditions*

The minor fluctuations in river level did not affect the survey of Newburgh pool. Rain events were

sparse throughout the field season therefore sampling was conducted during low flows. Secchi depths indicated sufficient visibility for sampling. There were no water quality measurements that exceeded their respective criteria or provided any major insight into the assessment results for Newburgh pool.

### *5.5 Conclusions and Assessments of Condition*

The analysis of Newburgh pool estimates that 13% (+/- 14%) of the pool was in failing condition. The precision of this estimate overlaps the threshold (25%) established to determine if a pool met its aquatic life use designation (Appendix A, Figure 10). Normally the pool would require additional sampling, however, ORSANCO biologists decided to accept the Newburgh pool as meeting its aquatic life use designation, focusing more on the estimate of 13% than on the range of precision. Biologists decided that limited resources are better spent assessing new areas of the Ohio River. This decision was supported by the members of the ORSANCO Biological Water Quality Subcommittee.

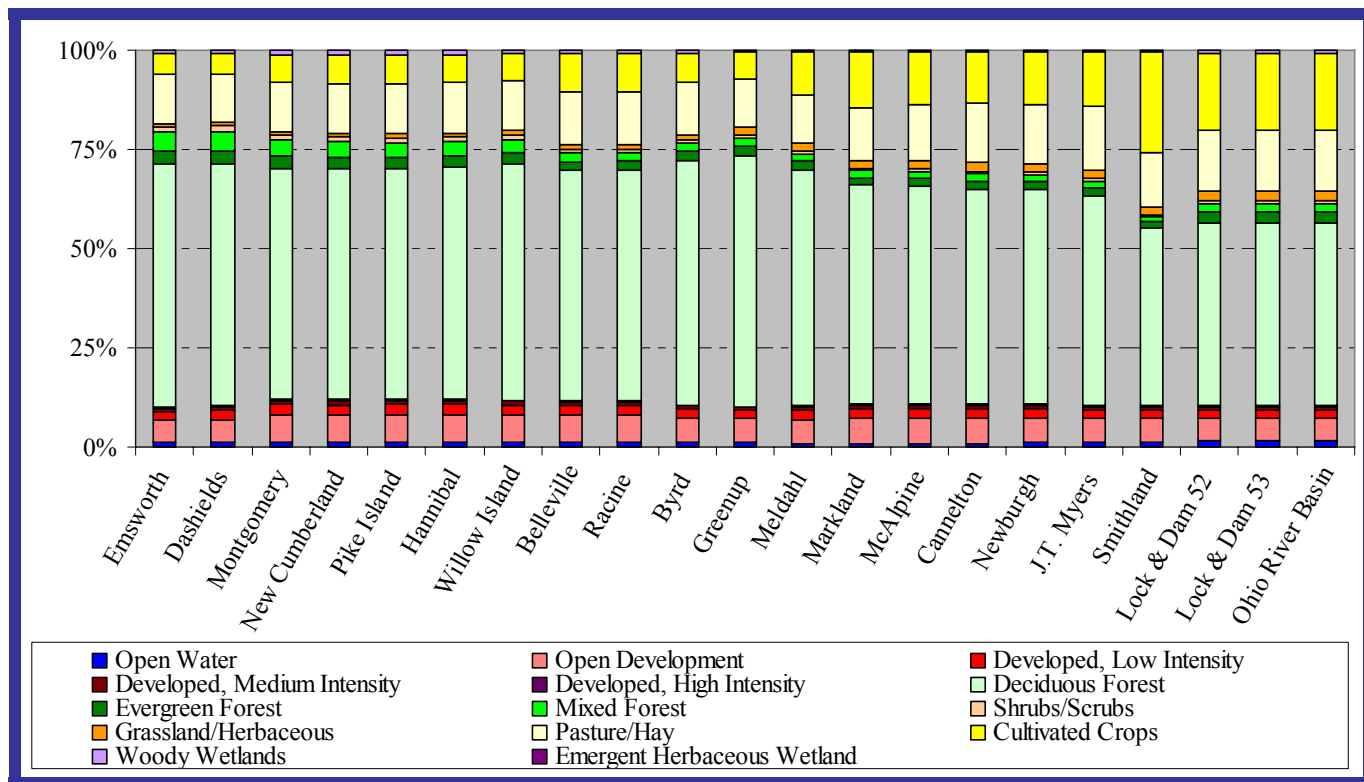
## **6.0 Interpool Comparisons**

### *6.1 Purpose*

As of 2007, 12 of 20 pools have been surveyed and assessed. This section was developed to compare Newburgh pool to other previously surveyed pools in the Ohio River.

### *6.2 Land Use*

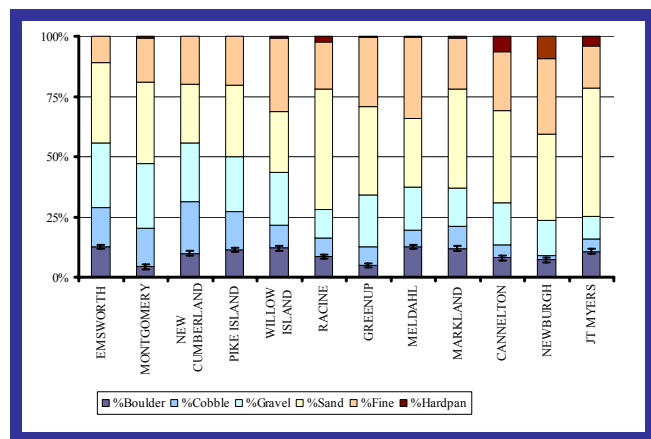
Newburgh pool lies in the downstream third of the Ohio River and the primary land use within the catchment is deciduous forest (Figure 12). However, the area immediately surrounding the pool is heavily influenced by agriculture.



**Figure 12.** Land use within the catchment area of each pool of the Ohio River.

### 6.3 Substrate Composition

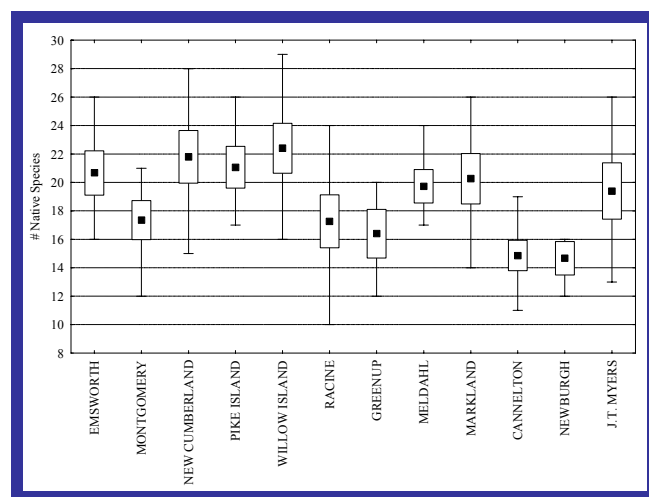
The substrate composition in this pool was dominated by sand and fines. The relatively high proportion of agricultural land use, which was quite similar to other pools near this portion of the river, can probably account for the large percentages of smaller substrates (Figure 13).



**Figure 13.** Substrate composition for each pool surveyed as of 2007.

### 6.4 Species Richness

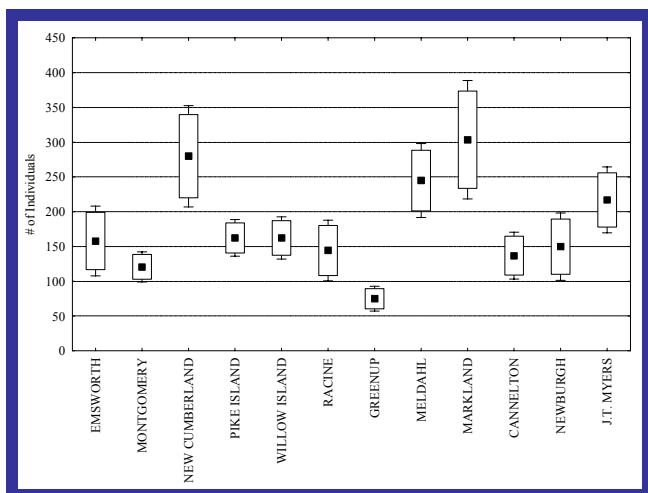
Newburgh pool had the lowest average number of native species per site (14.7) of all surveyed pools (Figure 14).



**Figure 14.** The average number of native species collected at each site within each pool surveyed as of 2007 (■=Average, □= 90% Confidence Interval, I=Non-Outlier Range).

### 6.5 Number of Individuals

An average of 149.8 individuals (excluding gizzard shad and emerald shiners) was collected at each site in Newburgh pool and ranked 8<sup>th</sup> in comparison (Figure 15).



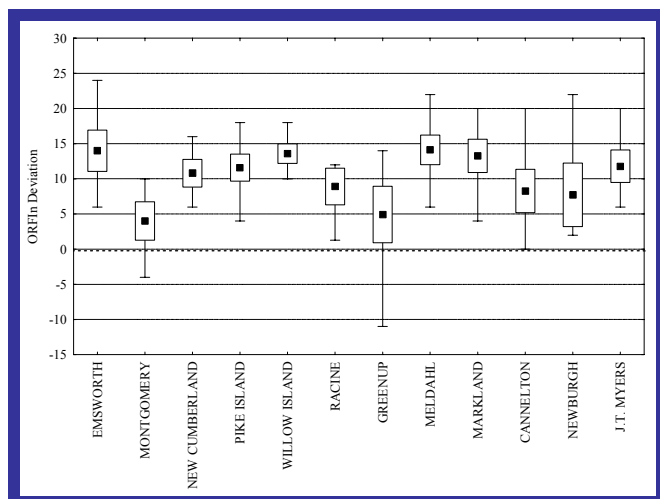
**Figure 15.** The average number of individuals (excluding gizzard shad & emerald shiner) collected at each site within each pool surveyed as of 2007 (■=Average, □=90% Confidence Interval, I=Non-Outlier Range).

### 6.6 Noteworthy Fish Observations

Four species were collected in Newburgh that were unique to the pool including: paddlefish, spotted gar, bighead carp, and silver carp. The latter two are invasive species. Several other species were collected that were only found in the downstream portions of the Ohio River such as: goldeye, threadfin shad, and shortnose gar (See Table 4).

### 6.7 ORFIn Deviation

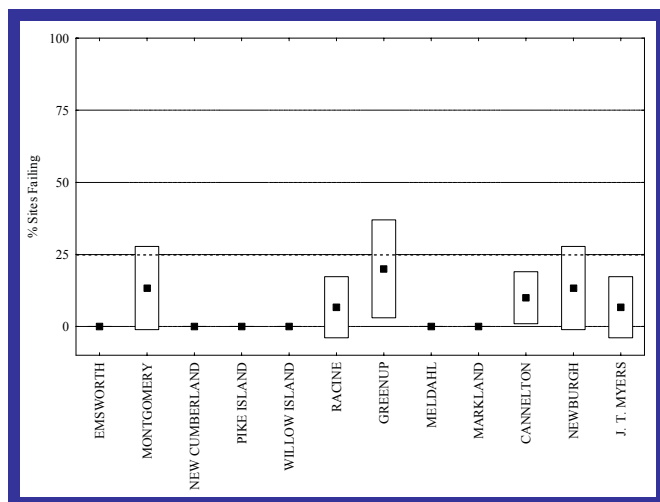
The ORFIn deviation is a measure of how well the pool performed in regard to expected ORFIn values. Positive values indicate that scores were greater than expected. Newburgh pool had an average deviation of 7.7 and was among the lowest of other pools surveyed as of 2007 (Figure 16). In comparison to other pools, the fish community was in satisfactory condition.



**Figure 16.** The average ORFIn deviation of each site within pools surveyed as of 2007 (■=Average, □=90% Confidence Interval, I=Non-Outlier Range).

### 6.8 Assessment of Condition

In Newburgh pool, 87% of the sites were in passing condition and the pool was assessed as marginally passing. The nearest surveyed pools to Newburgh were Cannelton (immediately upstream) and J. T. Myers (immediately downstream). Both pools were assessed as passing with 90% and 93% of the sites in passing condition respectively (Figure 17).



**Figure 17.** The percentage of sites (including +/- precision) failing in each pool surveyed as of 2007 (■=Average, □=90% Confidence Interval).



**Table 4.** A compiled species list containing the number of individuals collected per pool.

#	Species	Emsworth 07	Montgomery 06	New Cumberland 05	Pike Island 07	Willow Island 06	Racine 05	Greenup 06	Meldahl 07	Markland 05	Cannelton (30) 06-07	Newburgh 07	Myers 05
1	Silver Lamprey							1					
2	Paddlefish											<b>1</b>	
3	Spotted Gar											<b>1</b>	
4	Longnose Gar	13	10	11	43	46	24	23	22	15	48	<b>20</b>	
5	Shortnose Gar											<b>9</b>	2
6	Goldeye											<b>12</b>	
7	Mooneye	20	6	22	37		1		48	12	8	<b>10</b>	4
8	Skipjack Herring	8		3	6		1		64	145	174	<b>70</b>	249
9	Gizzard Shad	167	266	1202	7326	216	8048	267	2408	1743	3527	<b>600</b>	444
10	Threadfin Shad										1	<b>9</b>	112
11	Central Stoneroller			4		1				1			
12	Goldfish			1									
13	Grass Carp			1								<b>1</b>	
14	Spotfin Shiner		1	21	14	24	63	2	32	2	63	<b>8</b>	12
15	Common Carp	63	44	25	15	22	9	9	8	20	5	<b>4</b>	10
16	Gravel Chub								1				
17	Miss. Silvery Minnow												1
18	Silver Carp											<b>2</b>	
19	Bighead Carp											<b>2</b>	
20	Striped Shiner						2						
21	Silver Chub	26	12	20	11	57	44	33	90	171	130	<b>126</b>	206
22	River Chub			1	1								
23	Golden Shiner	1		1									
24	Emerald Shiner	82	8	342	197	728	795	50	637	303	1331	<b>166</b>	801
25	River Shiner	1							54	8	276	<b>3</b>	91
26	Spottail Shiner			6	2								
27	Mimic Shiner	35	13	76	162	306	402	61	7	5	195	<b>6</b>	43
28	Bluntnose Minnow			2	2	120	3	1	1		2		
29	Fathead Minnow						6						
30	Bullhead Minnow					4	5		23	2			8
31	Creek Chub			1					3				
32	Ictiobinae Sp			20									
33	Carpiodes Sp				14		2		1		2		
34	River Carpsucker	18	13	46	36	18	50	49	87	47	122	<b>179</b>	86
35	Quillback	17	30	80	27	66	16	17	31	137	21	<b>34</b>	57
36	Highfin Carpsucker		37	3	10	1	7	4		2	1	<b>12</b>	3
37	Northern Hog Sucker	3	3	132	4	15				14	1	<b>1</b>	
38	Smallmouth Buffalo	97	217	283	94	60	96	49	123	150	147	<b>72</b>	314
39	Bigmouth Buffalo						1					<b>3</b>	7

**Table 4.** A compiled species list containing the number of individuals collected per pool.

#	Species	Emsworth 07	Montgomery 06	New Cumberland 05	Pike Island 07	Willow Island 06	Racine 05	Greenup 06	Meldahl 07	Markland 05	Cannelton (30) 06-07	Newburgh 07	Myers 05
40	Black Buffalo	1			5	2		1		2	1	<b>7</b>	3
41	Spotted Sucker					1	1	5	1		1		
42	Moxostoma Sp			58									
43	Silver Redhorse	221	157	63	78	51	11	12	25	19	3		
44	Smallmouth Redhorse	61	110	110	28	168	5	30	62	31	12	<b>3</b>	11
45	River Redhorse	39	3	5	27	2		6	1	1		<b>1</b>	
46	Black Redhorse	18		11		4				1	1		
47	Golden Redhorse	7	227	90	66	277	11	39	120	105	4	<b>14</b>	
48	Brown Bullhead							1					
49	Blue Catfish												1
50	Channel Catfish	32	34	123	40	61	70	58	89	247	48	<b>11</b>	330
51	Flathead Catfish	14	11	15	35	21	32	32	49	38	63	<b>11</b>	43
52	Muskellunge	1											
53	Trout-Perch						3						
54	Banded Killifish					1							
55	Brook Silverside						1			1	1	<b>1</b>	1
56	Morone Sp	27	6	568	419	17	561	2	152	250	625	<b>403</b>	253
57	White Perch	5		4		3				5			
58	White Bass	9	36	6	2	58	3	64	18	22	66	<b>4</b>	17
59	Striped Bass					1					6		12
60	Hybrid Striper		4	17		1	46			40	6		11
61	Rock Bass	16	8	5	1	3							1
62	Lepomis Hybrid		1			9							
63	Lepomis Sp					16	1				1		1
64	Green Sunfish	12	2	4	2	4	6	4	3	10	2	<b>4</b>	10
65	Pumpkinseed		2			18							
66	Warmouth					1			1	1			1
67	Orangespotted Sunfish			1		2	1		1	1			2
68	Bluegill	379	216	53	46	232	58	112	207	245	103	<b>11</b>	31
69	Longear Sunfish					23	3	14	35	53	39	<b>3</b>	11
70	Redear Sunfish		4		1	1	1	1		2	16		1
71	Bluegill X Green Sunfish				1						1		
72	Longear X Green Sunfish												1
73	Smallmouth Bass	339	185	262	208	61	6	7	4	28	7	<b>1</b>	4
74	Spotted Bass	125	15	79	74	62	22	43	90	123	53	<b>49</b>	104
75	Largemouth Bass	4	8	8	16	16	22	65	16	56	37	<b>2</b>	70
76	White Crappie	5						4		1	1	<b>1</b>	
77	Black Crappie	3	6	2	2		3			2	3		
78	Greenside Darter	5	2	11	5					1			
79	Rainbow Darter		4	1		2				8			12

**Table 4.** A compiled species list containing the number of individuals collected per pool.

#	Species	Emsworth 07	Montgomery 06	New Cumberland 05	Pike Island 07	Willow Island 06	Racine 05	Greenup 06	Meldahl 07	Markland 05	Cannelton (30) 06-07	Newburgh 07	Myers 05
80	Fantail Darter	3	1						1				
81	Johnny Darter	1				2							
82	Banded Darter		1	4						1			1
83	Yellow Perch		4	2									
84	Logperch	141	67	244	85	108	6	12	20	60	39	4	3
85	Channel Darter	16	1	9		3		20					1
86	Slenderhead Darter									5			5
87	Dusky Darter												3
88	River Darter				2	1	2	1	6	4	11		4
89	Sauger	283	243	180	244	341	173	220	1174	664	1314	747	484
90	Walleye	44	11	31	70	1	4	1	3	1		7	
91	Saugeye	2		5	4		4			17			7
92	Freshwater Drum	254	47	1468	496	120	375	121	1000	1778	435	378	612
	Total # of Taxa	43	42	53	43	51	46	38	41	51	46	44	50
	Total # of Individuals	2618	2076	5742	9958	3378	11006	1441	6718	6600	8953	3013	4501

### Literature Cited

- Emery, E.B., T.P. Simon, F.H. McCormick, P.L. Angermeier, J.E. Deshon, C.O. Yoder, R.E. Sanders, W.D. Pearson, G.D. Hickman, R.J. Reash, and J.A. Thomas. 2003. Development of a multimetric index for assessing the biological condition of the Ohio River. *Transactions of the American Fisheries Society*. 132:791-808.
- Gammon, J.R. 1998. *The Wabash River Ecosystem*. Indiana University Press, Bloomington, IN.
- Omerik, J.M. 1987. Ecoregions of the conterminous United States. *Annals of the Association of American Geographers*. 77:179-190.
- ORSANCO (Ohio River Valley Water Sanitation Commission). 1994. *Ohio River Fact Book*. ORSANCO, Cincinnati, OH.
- ORSANCO (Ohio River Valley Water Sanitation Commission). 2003. *Pollution Control Standards for Discharges to the Ohio River*. ORSANCO, Cincinnati, OH.
- Reash, R.J. 1999. Considerations for characterizing Midwestern large river habitats. Pages 463-473, *In* T.P. Simon. 1999. *Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities*. CRC Press, Boca Raton, FL.
- Sanders, R.E. 1992. Day versus night electrofishing catches from near-shore waters of the Ohio and Muskingum rivers. *Ohio Journal of Science* 92:51-59.

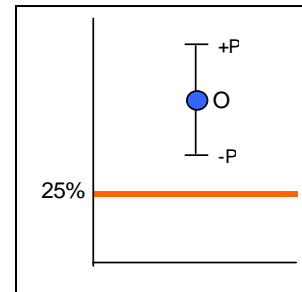


## Appendix A: Assessment Unit Criteria Details

- Each individual navigational pool will serve as a separate and distinct Assessment Unit (AU).
- All AUs will be sampled and assessed on a 5-year rotating basis. This is consistent with state schedules, and it allows ORSANCO (after one full rotation) in each 305(b) report, to incorporate 5 years worth of data and report on 100% of the resource. USEPA accepts 305(b) reports which use the most recent 5 years of data.
- AUs that yield >25% failure will be considered for listing as non-supporting.
  - Recognizing that even the least impacted (LI) sites in the Ohio River exhibit variability in condition, the 25<sup>th</sup> percentile of LI sites is used as the biocriteria within each habitat class.
    - Even among a random draw of LI sites, up to 25% of sites could be expected to fail, or fall below the criterion.
  - AUs with more than 25% failure rate could be listed as impaired if the BWQSC feels an “adequate assessment”, as defined below, is made.
- Characteristics of “Adequate Assessments”
  - Each AU is assessed with a minimum of 15 sites, regardless of pool length.
  - 1 of 3 situations occurs after sampling 15 sites (illustrated in figure below):

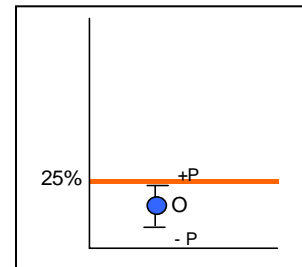
### Situation ‘A’

- If an observation ‘O’ of > 25% of the sites failing is made and O minus (-) the estimated precision (P) is >25%, the assessment is accepted as valid, the AU is listed as ‘Assessed’ and failing to meet the established aquatic life use. The entire AU will be properly listed on the 303(d) list.
  - If  $O - P > 25\%$  then AU fails.



$$\text{Precision } (P) = Z_{1-\alpha} * 100 * \text{Sqrt}[p(1-p)/n]$$

$Z_{1-\alpha}$  is related to the desired level of confidence  
1.645 is used for 90% confidence  
(use 1.96 for 95% confidence)

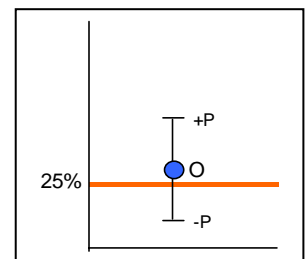


### Situation ‘B’

- If an observation ‘O’ of < 25% of the sites failing is made and  $O + P$  (precision) is <25%, the assessment is accepted as valid, the AU is listed as ‘Assessed’ and as meeting the established aquatic life use.
  - If  $O + P < 25\%$  then AU passes.

### Situation ‘C’

- If after sampling 15 sites,  $O \pm P$  includes (overlaps) the criterion (25%), 1 of 2 scenarios will occur:
  - C1:** if resources allow, an “Optimal Assessment” as defined below, will be conducted.
    - Additional probability sites will be sampled the next year to increase the sample size and improve precision (reducing the error bars).



- This process is repeated until one of the following occurs:
    - either Situation A or Situation B (above) is achieved.
    - precision of +/- 12 is achieved.
    - maximum of 45 samples is reached.
  - At that point the AU will be considered 'Assessed', the results will be considered valid and accepted, and condition will be reported.
- **C2:** in cases where resources are limited, the BWQSC will consider other available and relevant information when deciding to accept the assessment as valid or to require more sampling.
  - Additional information to be considered in these cases include (but are not limited to):
    - additional available statistics from the current assessment
    - additional available biological & water chemistry data
    - prior performance
    - presence of known impacts
  - In these cases, ORSANCO biologists will provide a narrative justification explaining how information other than the assessment in question was used to make the assessment
  - If O + P includes 25% and multiple lines of evidence indicate that the AU is in acceptable condition, then the AU may be listed as attaining.
  - If O – P includes 25% and multiple lines of evidence indicate that the AU is in unacceptable condition, then the AU may be listed as impaired.
  - If O +/- P includes 25% and multiple lines of evidence are inconclusive, then the AU will be listed as “unassessed” and additional samples would be needed.
- Listing on the 303(d) list as
  - 4a if the determined case already has an approved TMDL in place
  - 4b if the impairment is expected to be removed by other programs (SF, RCRA, NPDES, 319, harbor dredging)
  - 4c if the impairment is caused by something other than a pollutant
    - Habitat, natural, hydrologic, etc.
  - 5a if there is an impaired biological condition due to unknown stressor/cause.
    - Follow-up work would be needed.
      - e.g., examining WQ/Habitat/Bio interactions as a data exercise or through additional field work.
  - 5b if it is determined impairment is based on fish tissue contamination, in which case no TMDL is required.
  - 5c if a pollutant is positively identified, triggering the need for the development of a TMDL for that pollutant.

It is most likely that if any of the AUs fail, it will be listed as Category 5a.

- If follow-up work determines that a pollutant is the cause, it will be listed as Category 5c.
- If follow-up work shows impairment due to something other than a pollutant, it will be listed as Category 4c.

It will be possible to list an AU under any one of the categories shown above, although listing in any category other than 5a will require additional work, data integration, and the utmost certainty beforehand because of the resource implications of potentially triggering the need to develop a TMDL.

**Appendix B.** Fish survey data from the Newburgh pool.

Site #	River Mile	Bank	Date	Common Name	Latin Name	Count
1	721.2	LDB	31-Jul-07	longnose gar	<i>Lepisosteus osseus</i>	3
1	721.2	LDB	31-Jul-07	shortnose gar	<i>Lepisosteus platostomus</i>	2
1	721.2	LDB	31-Jul-07	skipjack herring	<i>Alosa chrysochloris</i>	30
1	721.2	LDB	31-Jul-07	gizzard shad	<i>Dorosoma cepedianum</i>	43
1	721.2	LDB	31-Jul-07	threadfin shad	<i>Dorosoma petenense</i>	2
1	721.2	LDB	31-Jul-07	grass carp	<i>Ctenopharyngodon idella</i>	1
1	721.2	LDB	31-Jul-07	silver chub	<i>Macrhybopsis storeriana</i>	1
1	721.2	LDB	31-Jul-07	river carpsucker	<i>Carpionodes carpio</i>	4
1	721.2	LDB	31-Jul-07	quillback	<i>Carpionodes cyprinus</i>	5
1	721.2	LDB	31-Jul-07	smallmouth buffalo	<i>Ictiobus bubalus</i>	5
1	721.2	LDB	31-Jul-07	bigmouth buffalo	<i>Ictiobus cyprinellus</i>	1
1	721.2	LDB	31-Jul-07	smallmouth redhorse	<i>Moxostoma breviceps</i>	1
1	721.2	LDB	31-Jul-07	golden redhorse	<i>Moxostoma erythrurum</i>	2
1	721.2	LDB	31-Jul-07	channel catfish	<i>Ictalurus punctatus</i>	2
1	721.2	LDB	31-Jul-07	morone sp	<i>Morone sp</i>	83
1	721.2	LDB	31-Jul-07	white bass	<i>Morone chrysops</i>	2
1	721.2	LDB	31-Jul-07	bluegill	<i>Lepomis macrochirus</i>	4
1	721.2	LDB	31-Jul-07	largemouth bass	<i>Micropterus salmoides</i>	2
1	721.2	LDB	31-Jul-07	white crappie	<i>Pomoxis annularis</i>	1
1	721.2	LDB	31-Jul-07	logperch	<i>Percina caprodes</i>	3
1	721.2	LDB	31-Jul-07	sauger	<i>Sander canadensis</i>	144
1	721.2	LDB	31-Jul-07	freshwater drum	<i>Aplodinotus grunniens</i>	24
2	724.8	LDB	31-Jul-07	longnose gar	<i>Lepisosteus osseus</i>	1
2	724.8	LDB	31-Jul-07	skipjack herring	<i>Alosa chrysochloris</i>	7
2	724.8	LDB	31-Jul-07	gizzard shad	<i>Dorosoma cepedianum</i>	41
2	724.8	LDB	31-Jul-07	quillback	<i>Carpionodes cyprinus</i>	2
2	724.8	LDB	31-Jul-07	northern hog sucker	<i>Hypentelium nigricans</i>	1
2	724.8	LDB	31-Jul-07	smallmouth buffalo	<i>Ictiobus bubalus</i>	6
2	724.8	LDB	31-Jul-07	smallmouth redhorse	<i>Moxostoma breviceps</i>	2
2	724.8	LDB	31-Jul-07	river redhorse	<i>Moxostoma carinatum</i>	1
2	724.8	LDB	31-Jul-07	golden redhorse	<i>Moxostoma erythrurum</i>	10
2	724.8	LDB	31-Jul-07	morone sp	<i>Morone sp</i>	55
2	724.8	LDB	31-Jul-07	longear sunfish	<i>Lepomis megalotis</i>	3
2	724.8	LDB	31-Jul-07	spotted bass	<i>Micropterus punctulatus</i>	1
2	724.8	LDB	31-Jul-07	logperch	<i>Percina caprodes</i>	1
2	724.8	LDB	31-Jul-07	sauger	<i>Sander canadensis</i>	135
2	724.8	LDB	31-Jul-07	freshwater drum	<i>Aplodinotus grunniens</i>	16
3	736.7	RDB	30-Jul-07	skipjack herring	<i>Alosa chrysochloris</i>	2
3	736.7	RDB	30-Jul-07	gizzard shad	<i>Dorosoma cepedianum</i>	12
3	736.7	RDB	30-Jul-07	threadfin shad	<i>Dorosoma petenense</i>	6
3	736.7	RDB	30-Jul-07	spotfin shiner	<i>Cyprinella spiloptera</i>	4
3	736.7	RDB	30-Jul-07	emerald shiner	<i>Notropis atherinoides</i>	64
3	736.7	RDB	30-Jul-07	river shiner	<i>Notropis blennioides</i>	1
3	736.7	RDB	30-Jul-07	mimic shiner	<i>Notropis volucellus</i>	4
3	736.7	RDB	30-Jul-07	smallmouth buffalo	<i>Ictiobus bubalus</i>	2
3	736.7	RDB	30-Jul-07	channel catfish	<i>Ictalurus punctatus</i>	2

Site #	River Mile	Bank	Date	Common Name	Latin Name	Count
3	736.7	RDB	30-Jul-07	flathead catfish	<i>Pylodictis olivaris</i>	4
3	736.7	RDB	30-Jul-07	morone sp	<i>Morone sp</i>	24
3	736.7	RDB	30-Jul-07	spotted bass	<i>Micropterus punctulatus</i>	2
3	736.7	RDB	30-Jul-07	sauger	<i>Sander canadensis</i>	16
3	736.7	RDB	30-Jul-07	freshwater drum	<i>Aplodinotus grunniens</i>	5
4	740.4	LDB	01-Aug-07	longnose gar	<i>Lepisosteus osseus</i>	2
4	740.4	LDB	01-Aug-07	shortnose gar	<i>Lepisosteus platostomus</i>	1
4	740.4	LDB	01-Aug-07	mooneye	<i>Hiodon tergisus</i>	2
4	740.4	LDB	01-Aug-07	skipjack herring	<i>Alosa chrysochloris</i>	16
4	740.4	LDB	01-Aug-07	gizzard shad	<i>Dorosoma cepedianum</i>	8
4	740.4	LDB	01-Aug-07	spotfin shiner	<i>Cyprinella spiloptera</i>	1
4	740.4	LDB	01-Aug-07	emerald shiner	<i>Notropis atherinoides</i>	12
4	740.4	LDB	01-Aug-07	river carpsucker	<i>Carpodes carpio</i>	2
4	740.4	LDB	01-Aug-07	quillback	<i>Carpodes cyprinus</i>	8
4	740.4	LDB	01-Aug-07	golden redhorse	<i>Moxostoma erythrurum</i>	2
4	740.4	LDB	01-Aug-07	flathead catfish	<i>Pylodictis olivaris</i>	2
4	740.4	LDB	01-Aug-07	morone sp	<i>Morone sp</i>	37
4	740.4	LDB	01-Aug-07	bluegill	<i>Lepomis macrochirus</i>	3
4	740.4	LDB	01-Aug-07	spotted bass	<i>Micropterus punctulatus</i>	3
4	740.4	LDB	01-Aug-07	sauger	<i>Sander canadensis</i>	27
4	740.4	LDB	01-Aug-07	freshwater drum	<i>Aplodinotus grunniens</i>	10
5	742.4	LDB	01-Aug-07	spotted gar	<i>Lepisosteus oculatus</i>	1
5	742.4	LDB	01-Aug-07	skipjack herring	<i>Alosa chrysochloris</i>	10
5	742.4	LDB	01-Aug-07	gizzard shad	<i>Dorosoma cepedianum</i>	2
5	742.4	LDB	01-Aug-07	threadfin shad	<i>Dorosoma petenense</i>	1
5	742.4	LDB	01-Aug-07	spotfin shiner	<i>Cyprinella spiloptera</i>	1
5	742.4	LDB	01-Aug-07	common carp	<i>Cyprinus carpio</i>	1
5	742.4	LDB	01-Aug-07	emerald shiner	<i>Notropis atherinoides</i>	25
5	742.4	LDB	01-Aug-07	river carpsucker	<i>Carpodes carpio</i>	1
5	742.4	LDB	01-Aug-07	quillback	<i>Carpodes cyprinus</i>	1
5	742.4	LDB	01-Aug-07	morone sp	<i>Morone sp</i>	3
5	742.4	LDB	01-Aug-07	spotted bass	<i>Micropterus punctulatus</i>	6
5	742.4	LDB	01-Aug-07	sauger	<i>Sander canadensis</i>	5
5	742.4	LDB	01-Aug-07	freshwater drum	<i>Aplodinotus grunniens</i>	2
6	747.3	LDB	01-Aug-07	longnose gar	<i>Lepisosteus osseus</i>	1
6	747.3	LDB	01-Aug-07	shortnose gar	<i>Lepisosteus platostomus</i>	1
6	747.3	LDB	01-Aug-07	skipjack herring	<i>Alosa chrysochloris</i>	2
6	747.3	LDB	01-Aug-07	gizzard shad	<i>Dorosoma cepedianum</i>	170
6	747.3	LDB	01-Aug-07	silver chub	<i>Macrhybopsis storeriana</i>	1
6	747.3	LDB	01-Aug-07	emerald shiner	<i>Notropis atherinoides</i>	3
6	747.3	LDB	01-Aug-07	river carpsucker	<i>Carpodes carpio</i>	2
6	747.3	LDB	01-Aug-07	quillback	<i>Carpodes cyprinus</i>	5
6	747.3	LDB	01-Aug-07	flathead catfish	<i>Pylodictis olivaris</i>	1
6	747.3	LDB	01-Aug-07	morone sp	<i>Morone sp</i>	4
6	747.3	LDB	01-Aug-07	green sunfish	<i>Lepomis cyanellus</i>	4
6	747.3	LDB	01-Aug-07	bluegill	<i>Lepomis macrochirus</i>	1
6	747.3	LDB	01-Aug-07	sauger	<i>Sander canadensis</i>	15



Site #	River Mile	Bank	Date	Common Name	Latin Name	Count
6	747.3	LDB	01-Aug-07	freshwater drum	<i>Aplodinotus grunniens</i>	2
7	748.8	LDB	07-Aug-07	paddlefish	<i>Polyodon spathula</i>	1
7	748.8	LDB	07-Aug-07	longnose gar	<i>Lepisosteus osseus</i>	6
7	748.8	LDB	07-Aug-07	shortnose gar	<i>Lepisosteus platostomus</i>	2
7	748.8	LDB	07-Aug-07	mooneye	<i>Hiodon tergisus</i>	1
7	748.8	LDB	07-Aug-07	gizzard shad	<i>Dorosoma cepedianum</i>	6
7	748.8	LDB	07-Aug-07	common carp	<i>Cyprinus carpio</i>	2
7	748.8	LDB	07-Aug-07	silver chub	<i>Macrhybopsis storeriana</i>	18
7	748.8	LDB	07-Aug-07	emerald shiner	<i>Notropis atherinoides</i>	7
7	748.8	LDB	07-Aug-07	mimic shiner	<i>Notropis volucellus</i>	1
7	748.8	LDB	07-Aug-07	river carpsucker	<i>Carpionodes carpio</i>	13
7	748.8	LDB	07-Aug-07	quillback	<i>Carpionodes cyprinus</i>	4
7	748.8	LDB	07-Aug-07	highfin carpsucker	<i>Carpionodes velifer</i>	4
7	748.8	LDB	07-Aug-07	smallmouth buffalo	<i>Ictiobus bubalus</i>	10
7	748.8	LDB	07-Aug-07	black buffalo	<i>Ictiobus niger</i>	2
7	748.8	LDB	07-Aug-07	channel catfish	<i>Ictalurus punctatus</i>	1
7	748.8	LDB	07-Aug-07	flathead catfish	<i>Pylodictis olivaris</i>	1
7	748.8	LDB	07-Aug-07	morone sp	<i>Morone sp</i>	23
7	748.8	LDB	07-Aug-07	spotted bass	<i>Micropterus punctulatus</i>	2
7	748.8	LDB	07-Aug-07	sauger	<i>Sander canadensis</i>	31
7	748.8	LDB	07-Aug-07	walleye	<i>Sander vitreus</i>	1
7	748.8	LDB	07-Aug-07	freshwater drum	<i>Aplodinotus grunniens</i>	23
8	749.3	RDB	07-Aug-07	longnose gar	<i>Lepisosteus osseus</i>	3
8	749.3	RDB	07-Aug-07	shortnose gar	<i>Lepisosteus platostomus</i>	1
8	749.3	RDB	07-Aug-07	gizzard shad	<i>Dorosoma cepedianum</i>	5
8	749.3	RDB	07-Aug-07	common carp	<i>Cyprinus carpio</i>	1
8	749.3	RDB	07-Aug-07	silver chub	<i>Macrhybopsis storeriana</i>	14
8	749.3	RDB	07-Aug-07	emerald shiner	<i>Notropis atherinoides</i>	6
8	749.3	RDB	07-Aug-07	river shiner	<i>Notropis blennioides</i>	2
8	749.3	RDB	07-Aug-07	mimic shiner	<i>Notropis volucellus</i>	1
8	749.3	RDB	07-Aug-07	river carpsucker	<i>Carpionodes carpio</i>	45
8	749.3	RDB	07-Aug-07	highfin carpsucker	<i>Carpionodes velifer</i>	7
8	749.3	RDB	07-Aug-07	smallmouth buffalo	<i>Ictiobus bubalus</i>	5
8	749.3	RDB	07-Aug-07	bigmouth buffalo	<i>Ictiobus cyprinellus</i>	1
8	749.3	RDB	07-Aug-07	black buffalo	<i>Ictiobus niger</i>	2
8	749.3	RDB	07-Aug-07	flathead catfish	<i>Pylodictis olivaris</i>	1
8	749.3	RDB	07-Aug-07	morone sp	<i>Morone sp</i>	24
8	749.3	RDB	07-Aug-07	sauger	<i>Sander canadensis</i>	37
8	749.3	RDB	07-Aug-07	freshwater drum	<i>Aplodinotus grunniens</i>	17
9	752.0	LDB	08-Aug-07	longnose gar	<i>Lepisosteus osseus</i>	2
9	752.0	LDB	08-Aug-07	shortnose gar	<i>Lepisosteus platostomus</i>	1
9	752.0	LDB	08-Aug-07	goldeye	<i>Hiodon alosoides</i>	1
9	752.0	LDB	08-Aug-07	mooneye	<i>Hiodon tergisus</i>	1
9	752.0	LDB	08-Aug-07	skipjack herring	<i>Alosa chrysochloris</i>	2
9	752.0	LDB	08-Aug-07	gizzard shad	<i>Dorosoma cepedianum</i>	104
9	752.0	LDB	08-Aug-07	spotfin shiner	<i>Cyprinella spiloptera</i>	1
9	752.0	LDB	08-Aug-07	silver carp	<i>Hypophthalmichthys molitrix</i>	1

Site #	River Mile	Bank	Date	Common Name	Latin Name	Count
9	752.0	LDB	08-Aug-07	silver chub	<i>Macrhybopsis storeriana</i>	2
9	752.0	LDB	08-Aug-07	emerald shiner	<i>Notropis atherinoides</i>	14
9	752.0	LDB	08-Aug-07	river carpsucker	<i>Carpiodes carpio</i>	10
9	752.0	LDB	08-Aug-07	smallmouth buffalo	<i>Ictiobus bubalus</i>	1
9	752.0	LDB	08-Aug-07	morone sp	<i>Morone sp</i>	16
9	752.0	LDB	08-Aug-07	bluegill	<i>Lepomis macrochirus</i>	1
9	752.0	LDB	08-Aug-07	spotted bass	<i>Micropterus punctulatus</i>	6
9	752.0	LDB	08-Aug-07	sauger	<i>Sander canadensis</i>	69
9	752.0	LDB	08-Aug-07	freshwater drum	<i>Aplodinotus grunniens</i>	4
10	754.3	RDB	08-Aug-07	mooneye	<i>Hiodon tergisus</i>	1
10	754.3	RDB	08-Aug-07	skipjack herring	<i>Alosa chrysochloris</i>	1
10	754.3	RDB	08-Aug-07	gizzard shad	<i>Dorosoma cepedianum</i>	29
10	754.3	RDB	08-Aug-07	emerald shiner	<i>Notropis atherinoides</i>	2
10	754.3	RDB	08-Aug-07	river carpsucker	<i>Carpiodes carpio</i>	7
10	754.3	RDB	08-Aug-07	quillback	<i>Carpiodes cyprinus</i>	3
10	754.3	RDB	08-Aug-07	black buffalo	<i>Ictiobus niger</i>	2
10	754.3	RDB	08-Aug-07	morone sp	<i>Morone sp</i>	20
10	754.3	RDB	08-Aug-07	bluegill	<i>Lepomis macrochirus</i>	2
10	754.3	RDB	08-Aug-07	spotted bass	<i>Micropterus punctulatus</i>	6
10	754.3	RDB	08-Aug-07	sauger	<i>Sander canadensis</i>	30
10	754.3	RDB	08-Aug-07	walleye	<i>Sander vitreus</i>	2
10	754.3	RDB	08-Aug-07	freshwater drum	<i>Aplodinotus grunniens</i>	23
11	754.8	LDB	08-Aug-07	longnose gar	<i>Lepisosteus osseus</i>	1
11	754.8	LDB	08-Aug-07	goldeye	<i>Hiodon alosoides</i>	4
11	754.8	LDB	08-Aug-07	gizzard shad	<i>Dorosoma cepedianum</i>	14
11	754.8	LDB	08-Aug-07	silver carp	<i>Hypophthalmichthys molitrix</i>	1
11	754.8	LDB	08-Aug-07	bighead carp	<i>Hypophthalmichthys nobilis</i>	2
11	754.8	LDB	08-Aug-07	silver chub	<i>Macrhybopsis storeriana</i>	4
11	754.8	LDB	08-Aug-07	emerald shiner	<i>Notropis atherinoides</i>	7
11	754.8	LDB	08-Aug-07	river carpsucker	<i>Carpiodes carpio</i>	7
11	754.8	LDB	08-Aug-07	smallmouth buffalo	<i>Ictiobus bubalus</i>	5
11	754.8	LDB	08-Aug-07	brook silverside	<i>Labidesthes sicculus</i>	1
11	754.8	LDB	08-Aug-07	morone sp	<i>Morone sp</i>	25
11	754.8	LDB	08-Aug-07	spotted bass	<i>Micropterus punctulatus</i>	3
11	754.8	LDB	08-Aug-07	sauger	<i>Sander canadensis</i>	55
11	754.8	LDB	08-Aug-07	walleye	<i>Sander vitreus</i>	4
11	754.8	LDB	08-Aug-07	freshwater drum	<i>Aplodinotus grunniens</i>	19
12	759.7	LDB	07-Aug-07	longnose gar	<i>Lepisosteus osseus</i>	1
12	759.7	LDB	07-Aug-07	shortnose gar	<i>Lepisosteus platostomus</i>	1
12	759.7	LDB	07-Aug-07	goldeye	<i>Hiodon alosoides</i>	5
12	759.7	LDB	07-Aug-07	gizzard shad	<i>Dorosoma cepedianum</i>	39
12	759.7	LDB	07-Aug-07	silver chub	<i>Macrhybopsis storeriana</i>	29
12	759.7	LDB	07-Aug-07	emerald shiner	<i>Notropis atherinoides</i>	5
12	759.7	LDB	07-Aug-07	smallmouth buffalo	<i>Ictiobus bubalus</i>	1
12	759.7	LDB	07-Aug-07	channel catfish	<i>Ictalurus punctatus</i>	1
12	759.7	LDB	07-Aug-07	flathead catfish	<i>Pylodictis olivaris</i>	1
12	759.7	LDB	07-Aug-07	morone sp	<i>Morone sp</i>	17

Site #	River Mile	Bank	Date	Common Name	Latin Name	Count
12	759.7	LDB	07-Aug-07	spotted bass	<i>Micropterus punctulatus</i>	5
12	759.7	LDB	07-Aug-07	sauger	<i>Sander canadensis</i>	59
12	759.7	LDB	07-Aug-07	freshwater drum	<i>Aplodinotus grunniens</i>	50
13	762.5	LDB	07-Aug-07	gizzard shad	<i>Dorosoma cepedianum</i>	53
13	762.5	LDB	07-Aug-07	spotfin shiner	<i>Cyprinella spiloptera</i>	1
13	762.5	LDB	07-Aug-07	silver chub	<i>Macrhybopsis storeriana</i>	3
13	762.5	LDB	07-Aug-07	emerald shiner	<i>Notropis atherinoides</i>	9
13	762.5	LDB	07-Aug-07	quillback	<i>Carpionodes cyprinus</i>	3
13	762.5	LDB	07-Aug-07	smallmouth buffalo	<i>Ictiobus bubalus</i>	1
13	762.5	LDB	07-Aug-07	bigmouth buffalo	<i>Ictiobus cyprinellus</i>	1
13	762.5	LDB	07-Aug-07	black buffalo	<i>Ictiobus niger</i>	1
13	762.5	LDB	07-Aug-07	morone sp	<i>Morone sp</i>	7
13	762.5	LDB	07-Aug-07	spotted bass	<i>Micropterus punctulatus</i>	11
13	762.5	LDB	07-Aug-07	sauger	<i>Sander canadensis</i>	42
13	762.5	LDB	07-Aug-07	freshwater drum	<i>Aplodinotus grunniens</i>	16
14	768.9	RDB	06-Aug-07	gizzard shad	<i>Dorosoma cepedianum</i>	50
14	768.9	RDB	06-Aug-07	silver chub	<i>Macrhybopsis storeriana</i>	9
14	768.9	RDB	06-Aug-07	emerald shiner	<i>Notropis atherinoides</i>	7
14	768.9	RDB	06-Aug-07	river carpsucker	<i>Carpionodes carpio</i>	71
14	768.9	RDB	06-Aug-07	quillback	<i>Carpionodes cyprinus</i>	2
14	768.9	RDB	06-Aug-07	smallmouth buffalo	<i>Ictiobus bubalus</i>	5
14	768.9	RDB	06-Aug-07	channel catfish	<i>Ictalurus punctatus</i>	4
14	768.9	RDB	06-Aug-07	morone sp	<i>Morone sp</i>	30
14	768.9	RDB	06-Aug-07	smallmouth bass	<i>Micropterus dolomieu</i>	1
14	768.9	RDB	06-Aug-07	spotted bass	<i>Micropterus punctulatus</i>	4
14	768.9	RDB	06-Aug-07	sauger	<i>Sander canadensis</i>	37
14	768.9	RDB	06-Aug-07	freshwater drum	<i>Aplodinotus grunniens</i>	54
15	772.1	LDB	06-Aug-07	goldeye	<i>Hiodon alosoides</i>	2
15	772.1	LDB	06-Aug-07	mooneye	<i>Hiodon tergisus</i>	5
15	772.1	LDB	06-Aug-07	gizzard shad	<i>Dorosoma cepedianum</i>	24
15	772.1	LDB	06-Aug-07	silver chub	<i>Macrhybopsis storeriana</i>	45
15	772.1	LDB	06-Aug-07	emerald shiner	<i>Notropis atherinoides</i>	5
15	772.1	LDB	06-Aug-07	river carpsucker	<i>Carpionodes carpio</i>	17
15	772.1	LDB	06-Aug-07	quillback	<i>Carpionodes cyprinus</i>	1
15	772.1	LDB	06-Aug-07	highfin carpsucker	<i>Carpionodes velifer</i>	1
15	772.1	LDB	06-Aug-07	smallmouth buffalo	<i>Ictiobus bubalus</i>	31
15	772.1	LDB	06-Aug-07	channel catfish	<i>Ictalurus punctatus</i>	1
15	772.1	LDB	06-Aug-07	flathead catfish	<i>Pylodictis olivaris</i>	1
15	772.1	LDB	06-Aug-07	morone sp	<i>Morone sp</i>	35
15	772.1	LDB	06-Aug-07	white bass	<i>Morone chrysops</i>	2
15	772.1	LDB	06-Aug-07	sauger	<i>Sander canadensis</i>	45
15	772.1	LDB	06-Aug-07	freshwater drum	<i>Aplodinotus grunniens</i>	113

**Appendix C.** Habitat survey data from the Newburgh pool.

Site #	River Mile	Bank	% Boulder	% Cobble	% Gravel	% Sand	% Fine	% Hardpan	% Other	Depth	% Submerged Vegetation	% Woody Cover	% Overhanging Vegetation	Land Use	Human Influence	Bank Profile	Bank Erosion
1	721.2	LDB	0.0	5.5	29.4	60.6	4.6	0.0	0.0	5.6	0	1.2	0	NF	none	flat	highly
2	724.8	LDB	0.0	0.6	40.4	41.7	17.3	0.0	0.0	3.0	0	0.0	0	NF, A	none	sloped	intact
3	736.7	RDB	0.0	4.3	17.4	21.7	13.0	43.5	0.0	19.2	0	8.0	0	NF, A	none	cliff	moderately
4	740.4	LDB	0.0	0.7	33.3	47.4	14.1	4.4	0.0	4.2	0	2.0	0	NF, A	none	sloped	moderately
5	742.5	LDB	0.0	0.0	15.9	43.9	32.6	7.6	0.0	5.6	0	3.3	0	NF, A	none	sloped	slightly
6	747.3	LDB	2.4	4.7	5.5	44.1	40.9	0.8	1.6	9.5	0	2.2	0	NF, A	ramp	sloped	moderately
7	748.8	LDB	0.0	0.0	21.3	52.0	26.0	0.8	0.0	7.9	0	1.2	0	NF, A	none	sloped	slightly
8	749.3	RDB	0.0	0.0	16.2	45.6	34.6	3.7	0.0	6.5	0	1.2	0	NF, A	none	steep	moderately
9	752.0	LDB	0.0	0.0	6.7	49.3	44.0	0.0	0.0	5.9	0	8.0	0	NF, I	moorings	sloped	slightly
10	754.3	RDB	0.0	0.7	26.3	39.4	24.1	9.5	0.0	7.1	0	7.5	0	NF	none	steep	moderately
11	754.8	LDB	6.5	6.5	11.3	25.8	41.9	8.1	0.0	17.8	0	18.6	0	NF, I, R, A	boats, docks	steep	intact
12	759.7	LDB	0.0	0.0	0.0	11.2	73.0	15.7	0.0	8.3	0	4.7	0	NF, A	none	steep	moderately
13	762.5	LDB	0.0	0.0	3.0	49.3	47.8	0.0	0.0	9.8	0	6.4	0	NF	none	steep	slightly
14	768.9	RDB	0.0	5.2	6.7	41.8	44.0	2.2	0.0	4.8	0	10.7	0	NF, A	none	steep	highly
15	772.1	LDB	0.0	0.0	0.0	0.0	47.6	52.4	0.0	8.4	0	3.6	0	NF, A	none	steep	highly

I = Industry, NF = Natural Forest, R = Residential lawns, A = Agriculture (Listed in order of prevalence)



**Appendix D.** Water quality parameters measured prior to fish sampling in Newburgh pool.

Site #	River Mile	Bank	pH	Temp (C)	Dissolved Oxygen (mg/L)	Conductivity	Secchi (in)
1	721.2	LDB	7.6	28.24	6.72	489	54
2	724.8	LDB	7.7	28.45	6.62	486	114
3	736.7	RDB	7.6	28.82	6.97	482	156
4	740.4	LDB	7.5	29.22	7.50	485	108
5	742.4	LDB	7.8	28.72	6.83	484	96
6	747.3	LDB	7.6	28.76	6.85	482	102
7	748.8	LDB	8.1	30.71	8.09	505	42
8	749.3	RDB	8.7	31.15	9.85	496	102
9	752.0	LDB	7.9	30.39	7.15	526	66
10	754.3	RDB	7.8	30.83	6.28	518	102
11	754.8	LDB	8.0	31.49	7.51	5	66
12	759.7	LDB	7.9	30.37	8.34	506	72
13	762.5	LDB	8.1	30.34	8.35	506	114
14	768.9	RDB	8.6	31.39	9.88	479	42
15	772.1	LDB	8.3	30.78	10.19	476	52

**Appendix E.** Water quality parameters analyzed from Newburgh pool in 2007. Values in bold exceed water quality criteria for respective analyte.

Site #	River Mile	Round	Ammonia	Chloride	Hardness	Nitrate-Nitrite	Phenolics	Sulfate	TKN	TOC	Phosphorus	TSS
1	721.2	1	0.05	36	176	0.87	<5.0	92	0.433	3.00	0.040	5.8
		2	0.13	34	204	0.64	<5.0	100	0.409	3.52	0.052	7.6
		3	0.03	40	172	1.24	<5.0	148	0.563	2.61	0.051	6.2
2	724.8	1	0.07	34	168	0.80	<5.0	84	0.324	3.59	0.023	3.2
		2	0.20	34	148	0.67	<5.0	126	0.445	3.60	0.026	9.4
		3	0.03	44	164	1.20	<5.0	144	0.532	3.90	0.042	5.2
3	736.7	1	0.06	34	160	0.93	<5.0	84	0.375	3.67	0.023	1.2
		2	0.11	32	152	0.70	<5.0	100	0.486	3.82	0.010	4.0
		3	0.03	44	164	1.11	<5.0	148	0.586	4.58	0.034	3.6
4	740.4	1	0.04	40	176	0.77	<5.0	88	0.390	2.50	0.030	1.0
		2	0.08	34	144	0.70	<5.0	94	0.438	3.29	0.010	5.2
		3	0.03	44	160	1.06	<5.0	118	0.504	3.29	0.038	5.0
5	742.4	1	0.06	36	164	0.78	<5.0	82	0.436	3.08	0.017	2.4
		2	0.11	34	152	0.73	<5.0	126	0.390	3.16	0.010	4.0
		3	0.03	44	160	0.98	<5.0	150	0.563	5.59	0.036	3.8
6	747.3	1	0.03	36	168	0.70	<5.0	84	0.447	2.86	0.019	2.8
		2	0.08	30	160	0.65	<5.0	88	0.305	3.86	0.010	5.2
		3	0.03	46	164	1.16	<5.0	144	0.719	5.44	0.046	3.8
7	748.8	1	0.03	38	160	0.81	<5.0	84	0.374	3.13	0.014	4.2
		2	0.06	32	140	0.65	<5.0	92	0.495	3.54	0.010	4.6
		3	0.03	46	156	1.17	<5.0	148	0.584	4.76	0.028	4.0
8	749.3	1	0.06	34	164	1.19	<5.0	96	0.357	3.12	0.020	3.4
		2	0.14	30	152	0.79	<5.0	96	0.399	3.24	0.010	6.2
		3	0.03	42	166	1.30	<5.0	136	0.448	2.88	0.032	3.0
9	752.0	1	0.03	40	168	0.79	<5.0	74	0.477	3.24	0.029	10.8
		2	0.10	32	148	0.64	<5.0	94	0.252	3.69	0.016	19.0
		3	0.03	42	168	1.23	<5.0	168	0.566	4.04	0.037	12.6
10	754.3	1	0.03	36	164	0.87	<5.0	82	0.402	3.12	0.010	1.8
		2	0.10	32	152	0.87	<5.0	116	0.404	3.57	0.010	4.4
		3	0.03	40	160	1.27	<5.0	152	0.464	3.22	0.028	2.4
11	754.8	1	0.03	36	164	0.75	<5.0	76	0.152	3.25	0.020	4.0
		2	0.08	30	144	0.67	<5.0	110	0.344	3.68	0.010	6.0
		3	0.03	44	172	1.32	<5.0	140	0.526	3.66	0.048	9.4
12	759.7	1	0.03	38	168	0.65	<5.0	88	0.532	3.00	0.017	5.2
		2	0.09	32	152	0.83	<5.0	114	0.318	3.49	0.015	5.8
		3	0.03	44	176	1.35	<5.0	148	0.440	3.67	0.050	5.8
13	762.5	1	0.03	36	156	0.61	<5.0	92	0.370	3.02	0.012	2.8
		2	0.09	32	144	0.87	<5.0	80	0.351	3.04	0.063	3.8
		3	0.03	42	196	1.31	<5.0	144	0.481	3.53	0.049	5.8
14	768.9	1	0.03	38	156	0.71	<5.0	90	0.473	3.13	0.010	2.0
		2	0.13	32	148	0.77	<5.0	116	0.462	4.66	0.023	9.6
		3	0.03	42	180	1.19	<5.0	150	0.520	3.82	0.033	4.2
15	772.1	1	0.03	34	152	0.68	<5.0	88	0.447	3.69	0.023	3.8
		2	0.10	32	152	0.68	<5.0	116	0.375	3.49	0.014	8.2
		3	0.03	44	180	0.98	<5.0	148	0.524	2.22	0.038	10.0

TKN = Total Kjeldahl Nitrogen

TOC = Total Organic Carbon

TSS = Total Suspended Solids