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Division of Surface Water

INTEGRATED WETLAND ASSESSMENT PROGRAM.
Part 7: Amphibian Index of Biotic Integrity (AmphIBI) for Ohio Wetlands

Including New Sites in the Erie/Ontario Lake and Drift Plains and Western Allegheny Plateau Ecoregions and Mitigation Sites

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INCLUDING NEW SITES IN THE ERIE/ONTARIO LAKE AND DRIFT PLAINS AND WESTERN ALLEGHENY PLATEAU ECOREGIONS AND MITIGATION SITES

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ABSTRACT

The Amphibian Index of Biotic Integrity (AmphIBI) for Ohio wetlands was previously developed using the amphibian communities of wetlands as indicators of overall wetland condition (Micacchion 2002). In that study sixty-seven wetlands representing different wetland types from the Eastern Cornbelt Plains and Erie/Ontario Lake and Drift Plains ecoregions were monitored during the years 1996-2000. This report includes those sites as well as additional monitoring information from wetlands in the Erie/Ontario Lake and Drift Plains ecoregion and wetlands in a new ecoregion, the Western Allegheny Plateau monitored in 2001 and 2002 respectively. Existing and new amphibian community attributes were tested as metrics that might provide the most reliable information of the condition of the wetlands. In the end, the same five metrics originally selected are used and the AmphIBI continues to correlate significantly with the original disturbance gradient and provides a tool for determining wetland condition. A second wetland disturbance scale, the Landscape Disturbance Index (LDI), that measures and scores land use percentages within a one kilometer radius of the wetlands is also compared to wetland condition based on AmphIBI scores and the results discussed. As in the previous study, the AmphIBI works well for forested and shrub sites but there is little ability to discriminate the condition of emergent sites based on their AmphIBI scores. Emergent sites generally score low across the spectrum for several reasons including the presence of predatory fish, improper within and around wetland habitat features for amphibians adapted to a forested landscape, and because these wetlands are often dominated by emergent vegetation due to disturbances. AmphIBI scores from ten constructed wetlands, nine of which were developed as compensatory mitigation, are presented and discussed. A large percentage of the wetlands destroyed and for which compensatory mitigation wetlands are developed are natural forested and shrub sites. AmphIBI scores for the constructed wetlands monitored do not compare favorably to scores of the natural sites they are attempting to replace. Tiered Aquatic Life Uses (TALUs) for wetlands are proposed with AmphIBI scores serving as the numeric criteria for assigning the varying use designations.

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INTRODUCTION

Amphibians have long been recognized as sensitive indicator species of environmental conditions (Wyman 1990, Wake 1991, Griffiths and Beebe 1992). While not all of the causes are clearly identifiable, it is thought that this environmental sensitivity has lead to recent worldwide declines of amphibians. Potential causes include habitat loss or degradation, acid deposition, climate warming, increases in UV radiation, spread of toxic substances, and introduction of predators (Sparling et al. 2002). This sensitivity to the state of the environment make amphibians an excellent taxa group to provide information on environmental conditions including those in wetlands.

Amphibians are not solely dependent on within wetland features to determine the suitability of wetlands to their life needs. Most species spend the bulk of their life in the upland habitats adjacent to the wetlands they use for breeding. For terrestrial home ranges, the distance away from the wetland varies by species. Some species such as wood frogs (*Rana sylvatica*), leopard frogs (*Rana pipiens*), red spotted newts (*Notophthalmus viridescens*) and others can migrate far distances and have larger home ranges (Walker 1946, Harding 2000, Pfingsten and Downs 1989, Petranka 1998). However, most wetland breeding species stay in close proximity to the wetlands and have small home ranges during their terrestrial life stages. Semlitsch (1998) estimates that 95% of the terrestrial habitat needs of populations of pond breeding salamander species are meet within 164.3 meters of the breeding wetland's boundaries.

Therefore, the suitability of a wetland to amphibian species is also dependent on the land use around the wetland, and for most species, the land use in the immediate vicinity. Although for some species the composition of large areas of landscape surrounding wetlands is important in determining the fitness of those wetlands for their breeding and other habitat needs.

Porej et al. (2004) used information about amphibian species occurrence data collected at our Ohio reference wetlands in the Eastern Corn Belt Plains (ECBP) (till plains) and Erie/Ontario Lake and Drift Plains (EOLP) (glaciated Allegheny Plateau) ecoregions (Omernik 1989) (Woods et al. 1998) as well as remote sensing information about their surrounding landscapes to develop predictive models. By analyzing the information about the landscapes adjacent to wetlands linked to any species' presence a great deal can be learned about the individual habitat needs of that species. The models are species specific and highly reliable and point out the varying needs of the species studied.

Porej et al. (2004) found that the presence of spotted salamanders (*Ambystoma maculatum*) and salamanders of the Jefferson's complex (*A. jeffersonianum*) at individual wetlands was highly correlated with the amount of forest cover within 200 meters. Whereas, for wood frogs the amount of forest within 1 kilometer was the most important factor in the presence of this species at wetlands. While the amount of forested habitat within 1 kilometer was an important factor in the presence of red-spotted newts, the most important predictor for newts was the distance to the nearest five wetlands. Tiger salamanders (*A. tigrinum*) presence at wetlands showed no correlation to the amount of forest in the landscape but was negatively linked to the total length or roads within1 kilometer. All of this information confirms that while wetland condition is an important predictor of the composition of the amphibian community broader landscape factors must also be considered.

In earlier reports (Micacchion et al. 2000, Micacchion 2002) the use of attributes of wetland amphibian communities to develop initial metrics and an overall index of wetland condition were discussed. The index, known as the Amphibian Index of Biotic Integrity (AmphIBI), is based on monitoring data from 67 wetlands in the ECBP and EOLP ecoregions gathered in the years 1996-2000. This report adds to that information by including monitoring results from an additional 35 wetlands in the EOLP and Western Allegheny Plateau (WAP) ecoregions, as well as resampling two sites in the ECBP ecoregion, collected during the years 2001 and 2002. It also covers monitoring data from ten constructed wetlands monitored in 2001, nine of which were developed as compensation for wetland losses under Ohio's Clean Water Act Section 401 program.

The natural sites were monitored to determine if the existing index would work across a larger range of sites and to determine if there are ecoregional differences in the amphibian communities of wetlands in Ohio that need to be accounted for when choosing metrics, assigning index scores or scoring break points. The constructed sites were monitored to determine the composition of their biological communities, their levels of biological integrity, and whether they are replacing the functions lost when natural wetlands are eliminated through the regulatory process.

The additional natural wetlands sampled in the EOLP and WAP ecoregions spanned the range of human disturbance levels. The wetlands in the EOLP ecoregion were comparable in types and landscape positions to the wetlands monitored there in past parts of the study. However, the WAP ecoregion which accounts for approximately one third of the state's land mass has wetlands with much different landscape positions then those found in other parts of the state. This can be owed to the much older age of geologic formations given that this area was not glaciated during the recent ice ages.

In general, isolated depressional systems do not occur in this ecoregion. Instead almost every wetland has a stream connection of some type. This is largely attributable to the relatively significant differences in topography within the ecoregion, with almost all wetlands being present in the only relatively flat areas present, the flood plains of various order streams. The exception is the few completely ground water fed systems that occur on slopes in the occasional areas of expressions. All other wetlands have a stream as a major contributor to their annual water budget. In my experience, almost nowhere in this ecoregion are there wetlands whose sole hydrologic contribution is surface water from an isolated watershed.

A large number of these stream-fed, flood plain WAP ecoregion wetlands have developed as a result of impoundment. Beaver dams account for a large percentage of the impoundments in the flood plains. While the beaver dams are sometimes on the main stems of larger streams, they are most often built on smaller headwater tributaries in the flood plains, at or near their confluence, with the larger streams.

Impoundments that are the result of human activities are also a frequent element in the development of wetlands in the WAP ecoregion. Historically, many of the railroads and road systems of the area have been built through portions of flood plains, often paralleling some of the major drainages. Embankments have been constructed to keep the railroads and roadways above the level of all but the most severe flooding events. These embankments often impound water because of the way they trap flood waters behind them or by essentially reducing the size the working flood plain causing more permanent hydrology within depressions in the flood plain. In many places the impounded waters have over time resulted in the development of new wetlands.

Often beavers utilize the artificial dikes, developed when roads and railroads were constructed, to make their impoundments. They accomplish this by plugging up areas of constriction or drainage ways through the dikes and backing the water up. The dikes then serve as sides of their impoundments. In some river valleys this has resulted in wetland complexes that cover large acreages.

Coal mining has traditionally been a driving force in the economy of the WAP ecoregion. The sediment runoff and redeposition into the flood plain and stream channels from upland coal strip mining has also been a contributing factor in the development of many wetlands in this ecoregion. It also means that in many watersheds acid mine drainage is a persistent pollution source of surface water bodies. Some streams in this ecoregion have been so heavily impacted that they are essentially biologically dead.

The unique factors shaping wetlands in the WAP ecoregion have significant influences on the amphibians that inhabit them and use them for breeding. First, 18 of the 20 wetlands we monitored there had populations of predatory fish. The two sites that did not have them were depressions in the flood plain relatively far removed from the main channel. In one instance there is an abandoned railroad grade that lies between the wetland and the stream and serves as a dike. The grade keeps flood waters on the stream side and does not allow them to spread into that part of the flood plain where the wetland depression is located. In the second case, the wetland is located near the upland edge of the flood plain and does not receive flood waters unless there is a severe flooding event. In most years, fish have no way to enter this wetland. Since it has seasonal hydrology, any fish present as a result of a major flood event are eliminated when the pool dries up later that year.

Where there are predatory fish in wetlands it appears that the amphibians are often able to coexist with them. This contradicts what is widely reported in the literature for the majority of amphibian species and our results from other parts of Ohio.

There are probably a couple of reasons for this. For many wetlands the stream inputs only occur during flooding events. This means that often within a few days of the events the waters reside and the wetlands are again isolated from the stream. Our monitoring results indicate that relatively few predatory fish are left in the pools after the water resides. This is probably an adaption to flood plain conditions by the fish. And when these individuals sense the flood waters residing they return to the stream channel. Those few who do not respond or get stranded face the almost certain demise brought about when the wetland pools dry up. For these types of wetlands, while predatory fish were present, their numbers were extremely low with only a few individuals encountered throughout the monitoring season.

Even though populations of predatory fish are present the amphibians seem to be able to coexist and breed in these habitats. Red-spotted newts produce toxic secretions that make them unpalatable to most predators (Kats et al. 1998) (Petranka 1998). Still it is not unusual to find marbled salamanders (*Ambystoma opacum*), spotted salamanders, Jefferson salamanders or wood frogs breeding in pools with predatory fish populations in this ecoregion. In our experience, this never occurs in the ECBP or EOLP ecoregions. It is my belief that these WAP ecoregion amphibian populations have historically utilized habitats where predatory fish exist and have adapted their behaviors according. This is coupled with the generally low numbers of predatory fish present in flood-induced seasonal pools. These factors result in amphibian populations being able to maintain or increase their numbers through breeding activities despite the presence of predatory fish in many WAP ecoregion wetlands.

METHODS

Amphibian Community Assessment

Required Supplies:

-Flagging tape (hot pink)
-Triangular ring frame dip net (#30 mesh size)
-Field forceps
-White collection and sorting pans
-Funnel traps (window screen mesh size)
-Sample containers (4oz. wide-mouth glass jars, 1 liter wide-mouth plastic bottles)
-Heavy duty plastic bags to carry empty plastic bottles - 10 bottles/bag/by site
-Duffle bag to carry equipment and bottles in field
-2" Masking tape for labeling jars and bottles
-Fine point permanent marker (Sharpy)
-Plastic 1 liter squeeze bottles with 95% ethanol
-Preservatives (10% formalin, 95% ethanol)

-*Salamanders of Ohio* (Pfingsten and Downs 1989)
-*The Frogs and Toads of Ohio* (Walker 1946)
-*A Key to the Anuran Tadpoles of the United States and Canada* (Altig et al., in prep.)
-*Salamanders of the United States and Canada* (Petranka 1998)

Quantitative Collection Protocol

Funnel traps are used in sampling both the macroinvertebrate and amphibians present in wetlands. The following methods discussion pertains to the collection of both amphibians and macroinvertebrates since the same sampling protocols are used simultaneously to monitor the two taxa groups. Each time a wetland was sampled we collected a quantitative sample using funnel traps and a qualitative sample collected by using a dip net and by hand picking natural substrates.

Ohio EPA began evaluating wetland macroinvertebrate and amphibian sampling methods in 1996. A variety of sampling methods including artificial substrate samplers, several types of funnel traps, and qualitative sampling with dip nets were evaluated (see Fennessy 1998a). The use of funnel traps as a method of sampling has been used extensively for amphibians and more recently as a protocol for macroinvertebrate collections in wetlands. A number of different kinds of funnel traps have been described ranging from modified two liter pop bottles to custom-made designs of PVC or clear acrylic plastics to using different types of metal meshes.

In addition to the sampling method, the time of year to sample, the intensity, frequency, and duration of sampling were evaluated. At first it was thought that different methods would need to be used for each taxa group. However, the use of window screen mesh funnel traps proved to be affective in collection of both amphibians as well as wetland macroinvertebrates. Since 1997, field collection techniques have become standardized and the same protocols are used at each wetland sampled.

For this project, funnel traps are constructed of aluminum window screen cylinders with fiberglass window screen funnels at each end. The funnel traps are similar in design to commercially available minnow traps. However, the use of window screen, with its smaller mesh, makes the traps better able to collect a wide range of sizes of larval amphibians and macroinvertebrates. Aluminum screening is used for the cylinders to provide maximum structure and fiberglass screening is used for the funnels to allow flexibility to ease funnel inversion and eversion.

The aluminum screen cylinders are 18" long and 8" in diameter and held together with wire office staples. The bases of the fiberglass screen funnels are 9" in diameter and attached with wire staples to both ends of the cylinder such that the funnel directs inward. The funnels have a circular opening in the middle that is 1.75" in diameter which serves as the means of entry into the trap. We have also developed a smaller version of the trap that is 5 inches in diameter for use in wetlands with naturally shallower water depths and in other wetlands as they are drying up. When these are used the data is adjusted to account for the smaller surface area of the traps' funnel ends and the corresponding expected decrease in trapping productivity.

In the typical application, 10 funnel traps are placed evenly around the perimeter of the wetland. This is done by first pacing around the wetland perimeter to provide a measure of the total wetland perimeter (with practice pacing can be a highly reliable measuring technique). Time can be saved if the perimeter of the wetland can be determined in advance using aerial photos, topographic maps, plans or other information. The perimeter total is then divided by 10 and a trap is placed each time that amount is paced off while traversing the perimeter for the second time.

Alternatively, for large wetlands or where the placement around the entire perimeter is not feasible (slopes too steep, water too deep, etc), transects along one or several sides of the wetland are used. Also, in some years larger wetlands were monitored with more than 10 traps (12-20). Care should be taken to assure that all habitat types within the wetland are represented proportionally within the transect.

Each funnel trap location is marked using flagging tape both at the standing water/saturated soil interface and in vegetation above or near the trap. Since flagging is applied before the growing season it is important that an attempt be made to place it where it will not be obscured by new vegetation growth during the later passes. Flagging is numbered sequentially using a permanent marker and traps are set at the same locations throughout the sampling season. Numbering the flagging serves as an aid to navigation both during deployment and retrieval, especially in heavily vegetated sites, and as further confirmation that all traps are accounted for and placed in the same location each sampling pass. If vegetation is extremely dense a hand held GPS unit can be used to record and navigate to trap locations.

Each wetland was sampled three times between March and early July spaced approximately six weeks apart. The late winter/early spring (March-early April) sample allows monitoring of adult ambystomatid salamanders, early breeding frog species and macroinvertebrates such as fairy shrimp, caddis fly larvae, some microcrustaceans and other early season taxa which are often present for a limited time in some wetlands.

Adult salamanders enter wetlands to breed following the first few warm, rainy nights of late winter to early spring. The actual timing of their arrival is highly weather dependent and varies greatly by year and location. The timing of amphibian breeding runs can also vary greatly from south to north within the state, with southern populations in some years breeding up to several weeks before northern populations. Ideally, one should closely monitor the weather and begin monitoring when it seems appropriate or when adults are first observed at the pools. However, this is not practicable when monitoring a large number of sites. In those instances average dates of the beginning of amphibian breeding for that region can be determined and this should be the target for scheduling the start of that year's monitoring efforts with adjustments made in accordance with amphibian breeding behaviors that year.

A middle spring sample (late April-mid May) is conducted in order to collect some adult frog species entering the wetland to breed, to sample early-breeding amphibian larvae and to sample for macroinvertebrates. A late spring/early summer (early June-early July) sampling is performed to collect relatively well developed amphibian larvae and macroinvertebrates.

The traps are placed on the substrates of the wetland and the trap is almost completely submersed. Traps are placed to allow some exposure of air into the upper part of the cylinder. This protocol works to reduce trap mortality by allowing, those organisms that need it, access to fresh air. Placement to allow organisms access to atmospheric oxygen becomes more important as the season progresses, water temperatures rise and oxygen levels in the water decrease. Traps can be placed in shallower water as long as the funnel openings remain immersed during the sampling period. In all cases, the traps are left in the wetland for twenty-four hours in order to ensure unbiased sampling for species with diurnal and nocturnal activity patterns. Limiting trapping time to twenty-four hours also works to minimize the potential for mortality due to individuals being in the traps for extended periods.

No bait is used in traps. These are activity traps and designed to collect any amphibians or macroinvertebrates that swim, crawl or float into the funnel openings. Due to the shape of the funnel ends, once an individual organism is inside a trap, it is difficult to impossible for it to make its way back out.

Since the traps are modeled after commercially available minnow traps they also are effective in capturing fish. So in addition to amphibians and macroinvertebrates, information on the fish taxa trapped is also recorded. The taxa of fish present are often valuable in explaining trends in the amphibian and macroinvertebrate communities and may themselves be indicators of wetland condition or type.

Upon retrieval, the traps are emptied by everting the funnel and shaking the contents into a white collection and sorting pan. Organisms that can be readily identified in the field (especially adult amphibians and larger and easily identified fish) are counted and recorded in the field notebook and released. The remaining organisms are transferred to wide-mouth one liter plastic bottles by washing them out of the collection and sorting tray into the bottles using a plastic squeeze bottle filled with 95% ethanol. The collection pan is then thoroughly rinsed with water from the wetland to remove any trace of alcohol that might adversely affect amphibians to be released from the next trap collection.

Before leaving the field, if needed, generally at the field vehicle, bottles are supplemented with additional 95% ethanol in proportion to the number of individuals collected. The contents of each trap are kept in separately marked bottles for individual analysis in the laboratory. If large numbers of amphibians and/or fish are kept for identification in the lab, those samples are topped off with 10% formalin in the field to maximize the preservation of identification features.

Laboratory analysis of the funnel trap macroinvertebrate and fish samples follows the standardized Ohio EPA procedures (Ohio EPA 1989). Salamanders and their larvae are identified using keys in (Pfingsten and Downs 1989) and (Petranka 1998). Frogs, toads and tadpoles are identified using keys in (Walker 1946) and (Altig et al., in prep.).

Qualitative Collection Protocol

Qualitative collections of macroinvertebrates and amphibians are made concurrently with funnel trapping at each wetland during the three sampling periods. It should be pointed out that these qualitative protocols are targeted at sampling the macroinvertebrate community. While amphibians are often collected in this process, and on a few occasions species have been obtained that were not collected by the funnel traps, use of this method does not seem necessary to adequately sample the amphibian community and develop an index.

Qualitative sampling involves the collection of macroinvertebrates and amphibians from all available natural wetland habitat features using triangular ring frame dip nets, collection and sorting trays and also by manual picking of substrates and woody debris with field forceps. Dip net sweeps are made in all habitat types where possible. The collection and sorting tray is often used as a repository for dip net contents to aid in examination and can itself be dipped into the water to yield a sample . Woody debris and other substrate materials are manually collected, searched and picked through with the aid of the forceps or by hand. The goal is to compile a comprehensive species/taxa inventory of macroinvertebrates and amphibians at the site. At least one individual of each taxa encountered will be collected or recorded. There is no attempt to quantify absolute organism densities although observed predominant populations will be noted.

Generally, one field crew member will collect the qualitative sample while another crew member deploys or collects the funnel traps (qualitative sampling may occur on either the day of trap deployment or retrieval). A minimum of thirty minutes will be spent collecting the qualitative sample. Sampling will continue until the field crew determines that further sampling effort is not likely to produce new taxa. Samples are deposited in 4 ounce wide-mouth glass bottles marked as qualitative samples and preserved with 95% ethanol. The qualitative field collection and laboratory analysis of these samples for macroinvertebrates and fish will follow the standardized Ohio EPA procedures (Ohio EPA 1989). Salamanders and their larvae will be identified using keys in (Pfingsten and Downs 1989) and (Petranka 1998). Frogs and tadpoles will be identified using keys in (Walker 1946) and (Altig et al., in prep.).

Laboratory Methods

Upon submission to the laboratory, all funnel trap and qualitative samples are assigned a unique lab number for tracking purposes. The contents of each funnel trap are processed individually so that each site has ten quantitative samples to process for each of the three collection dates. Samples preserved in 10% formalin are washed with water under a hood and transferred to 70% ethyl alcohol before the contents are identified.

All organisms within each funnel trap sample are identified and counted. All individuals from each trap are stored in the same 4oz. wide-mouth glass jar. Jars are labeled by site, date and trap number placed on shelves and stored at Ohio EPA's Groveport Field Facility. The numbers of each taxa in each trap are entered into our database along with the duration of the trapping effort so that relative abundance, number of individuals per hour of trapping, and other attributes can be calculated.

Statistical Analyses

Minitab v. 12.0 was used to perform all statistical tests. Regression analysis, analysis of variance, Tukey's multiple comparison test, correlation coefficients, and t tests were used to explore and evaluate the biological attributes measured for development of an amphibian index of biotic integrity.

SITE SELECTION

This report includes the results collected from wetlands reported on in earlier reports (Micacchion et. al 2000, Micacchion 2002) as well as an addition 35 wetland and two sites from the ECBP ecoregion that were resampled in 2001. The 35 new wetlands are made up of 15 from the EOLP ecoregion and 20 from the WAP ecoregion. Natural wetlands were selected from five hydrogeomorphic classes and all three major vegetation types: forested, shrub and emergent.

Additionally, data from 10 constructed wetland sites were collected, evaluated and compared to natural wetland systems. All but one of these constructed sites was built as mitigation to compensate for permitted wetland losses. In all, 111 wetlands are included in this report.

Various means were used to locate natural wetlands. Several field biologists from around the state were consulted about wetlands they knew in the state or their area. Additionally, we meet with numerous staff from land protection/management organizations to gather information about wetlands on their land holdings and nearby areas. We also conducted exhaustive reviews of maps, aerial photos and GIS databases as well as driving roads in the study areas to locate wetlands that might meet our study goals.

The Ohio Rapid Assessment Method for Wetlands Version 5.0 (ORAM 5.0) (Mack 2001) was used to determine the degree of disturbance experienced by natural wetlands in our data set. As in the past natural wetlands spanning the range of disturbance levels, from least impacted to severely disturbed, were sampled. Forested and shrub wetlands that had experienced more than moderate levels of disturbance were difficult to locate especially in the WAP ecoregion. All wetlands located that had experienced severe disturbance were dominated by emergent vegetation. In many cases, the absence of woody vegetation was a result of the disturbances the wetlands had received.

ORAM 5.0 questions are designed to measure a wetland's biological and functional integrity and provide a rating of the overall condition. ORAM 5.0 is comprised of six metrics that are measured and scored and then summed to provide a composite score for the wetland. The six metrics evaluated are: wetland area: upland buffers and surrounding land use, hydrology (sources and intactness); habitat alteration and development; special wetlands (pre-identified high quality and rare wetland systems receive extra points and extremely low quality sites lose points); and plant communities, interspersion, and microtopography. This rating can be performed relatively rapidly, usually in less than an hour, if the rater is familiar with the wetland being scored.

In Ohio, ORAM 5.0 is used to score and place wetlands into antidegradation categories for regulatory reviews. There are a possible 100 points and breaks for the antidegradation categories are as follows: Category 1 (low quality, low functional levels, low biological integrity) - 0 to 29.5; Category 2 (moderate quality, moderate functional levels, moderate biological integrity); 35 to 59.5; and Category 3 (superior quality, superior functional levels, superior biological integrity) - 65 to100. Scores in the range 30 to 34.5 and 60 to 64.5 represent the "gray zones" between categories. When a wetland receives a score within the "gray zones" the higher category is assigned unless more detailed information is provided that makes clear the appropriate category assignment. A typical use of the biological indices we have developed would be to provide the information to confirm wetland category assignments.

The Landscape Development Intensity Index (LDI) (Brown and Vivas 2004), was also used as an alternative, quantitative human disturbance scale. The LDI is calculated by multiplying land use percentages with a weighting factor derived from the amount of supplemental "emergy" needed to maintain that use, where "emergy" has a unit of solar emergy joule (sej) or $sej/ha*yr^{-1}$ (Brown and Vivas 2004) (Odum 1996). The equation for calculating the LDI is,

$$LDI_{Total} = \sum \%LU_i * LDI_i$$

where, LDI_{Total} = the LDI score, $\%LU_i$ = percent of total area in that land use *I*, and LDI_i = landscape development intensity coefficient for land use *I*. More intensive land uses receive higher LDI coefficients with a range of 1 (natural system) to 9.42(urban).

The %LU*i* was calculated with landscape composition data from the National Land Cover Database (NLCD) using ArcView v. 3.2 (ESRI 1999) to obtain land composition percentages within a 1 km radius circle of each wetland sampled. Brown and Vivas (2004) report emergy coefficients for 27 land use classes using a Florida land use classification system. This number of land uses is many more classes than are used in the NLCD classification. Emergy coefficients were assigned to the NLCD classes in our study area as follows: forest, wetland forest, emergent wetland = 1.00; water = 1.00; pasture = 3.41; row crop = 7.00; suburban 7.55; rock, transitional = 8.32, urban = 9.42.

The LDI has been calculated for a 1 kilometer radius watershed around each wetland monitored. This disturbance metric is compared to individual metrics and the overall Amphibian Index of Biotic Integrity as a second human disturbance gradient.

RESULTS AND DISCUSSION

Numerous attributes of the amphibian communities of the wetlands sampled were considered as possible metrics in the development of the Amphibian Index of Biotic Integrity (AmphIBI) (Micacchion 2002). As discussed many of the attributes of other taxa groups that have resulted in meaningful metrics did not work for wetland amphibian communities. Total taxa richness of other indicator groups has been shown to be a common metric that has a positive relationship to the intactness of a resource. However, for our data set the overall taxa richness of a wetland's amphibian community has no correlation to the amount of disturbance that wetland has received or its level of functional integrity. More important then taxa richness are the types of species and relative abundances that comprise the amphibian community. That the total number of amphibian species that inhabit or breed in Ohio wetlands is small (about 20 species) limits the number of attributes of the community that might yield useful metrics. This greatly reduces the potential to use the types of family, genus, trophic level and various other grouping metrics commonly used in other IBIs for a wetland amphibian index.

With most indices of biotic integrity for other taxa groups there are at least one or two metrics that deal with exotic species and their presence as indicators of disturbance and insults to biological integrity. Ohio has no exotic amphibian species. Given the detrimental affects of exotic species on ecosystems, the fact that Ohio amphibians may be the one of the few taxa groups where no exotics exist is undoubtably a positive. However, the lack of exotics further limits the possible attributes that might result in metrics.

Additional attributes that might serve as meaningful metrics were examined during data analysis. None were identified that showed promise to serve as new metrics. In the end the same five attributes of the amphibian community used in Micacchion (2002) were selected as the metrics that comprise the AmphIBI. The metrics are: 1.) the Amphibian Quality Assessment Index (AQAI); 2.) number of species of pond-breeding salamanders; 3.) relative abundance of sensitive taxa; 4.) relative abundance of tolerant taxa; and 5.) presence of spotted salamanders and/or wood frogs.

Amphibian Quality Assessment Index

As reported earlier (Micacchion et al. 2000, Micacchion 2002) an amphibian index known as the Amphibian Quality Assessment Index (AQAI) has been developed for wetlands. This is modeled after indices that have been developed utilizing plants to give information on the overall condition of a resource (Andreas and Lichvar 1995, Wilhelm and Ladd 1988, Swink and Wilhelm 1979) and commonly referred to as floristic quality assessment indices. In a similar manner we have used the varying sensitivities to disturbance and other habitat requirements to place wetland breeding amphibian species within a range of coefficients of conservatism © of C) from 1 to 10. Since no non-native amphibians have been documented as reproducing in the wild in Ohio nor have we encountered any during our monitoring no species are assigned a C of C of 0. Lower C of Cs are assigned to those species that are adapted to a greater degree of disturbance and a broader range of habitat requirements (niche). Those species assigned higher C of Cs are considered to be sensitive to disturbance and have narrower niches. The C of Cs were assigned after reviewing numerous texts, especially those that include Ohio data, about the autecology of each species and based on the experience of the researchers involved in this project both through the years of this study and throughout their careers. The species encountered in wetlands, their C of Cs and supporting rationale are contained in Table 1. Species have been added since the last report as a result of their occurrence at wetlands we have monitored in the past several field seasons.

As calculated for this study, the AQAI is a weighted index that not only takes into account the sensitivity to disturbance of the individual species at a wetland but also includes the number of individuals of each species collected. In doing so the AQAI results in a score that provides information on the overall condition of the amphibian community present and allows for comparisons among wetlands. Ideally the AQAI should represent composite monitoring from a twenty-four hour period for each of the three sampling runs. Our sites have all been monitored for approximately that time period but may vary by up to a few hours. These variations are a result of the logistics of monitoring several sites within the same two day time frame. To compensate for this the AQAI can be adjusted by using the number of individuals per trap hour rather than just the number of individuals collected. Comparisons of the AQAI results using both methods were so small as to be insignificant. Therefore, the results from the number of individuals collected is used for the calculations in this study.

The index is developed by first summing

Table 1. Wetland Amphibian Coefficients of Conservation and Rationale

species	CofC	rationale
Ambystoma jeffersonianum complex (includes *ambystomatid hybrids)*	5	Jefferson salamanders and associated hybrids require relatively intact wooded habitat adjacent to breeding pools with low to moderate levels of disturbance
Ambystoma opacum	9	Marbled salamanders require intact mature woods surrounding vernal pools that fill in the late fall/early winter
Ambystoma maculatum	8	Spotted salamanders have only been collected in least disturbed wetlands or moderately disturbed wetlands where disturbance has been recent
Ambystoma texanum	4	Smallmouth salamanders are the most ubiquitous of the ambystomatid salamanders and will tolerate wetlands with relatively short hydro-periods
Ambystoma tigrinum	6	Tiger salamanders have been found in a range of wetlands with pools that are deep and long lasting with nearby uplands that are reasonably intact
Ambystoma laterale	10	Blue spotted salamanders, listed as state "endangered" due to their extremely limited range, are only found at a few sites in extreme NW Ohio
Hyla versicolor and *Hyla chrysoscelis*	5	Tree frogs require some areas of shrubs or trees adjacent to breeding pools and are less tolerant of other disturbances than most anurans
Bufo spp. (*Bufo americanus* and *Bufo fowerli* tadpoles are indistinguishable)	1	American and Fowler's toads require little except enough water to allow for their short reproductive cycle and will tolerate disturbances other amphibians cannot
Hemidactylium scutatum	10	Four-toed salamanders are listed as state "special interest" and have a high fidelity to undisturbed forested vernal pool sites with woody debris and sphagnum moss
Notophthalmus viridescens	9	Red spotted newts are extremely intolerant of disturbance and are found only in well buffered intact wetlands for (much more abundant in the WAP ecoregion than other ecoregions of Ohio)
Rana catesbeiana	2	Bullfrogs which are widely spread, are most common in marshes, but can be found in forested and shrub sites and are tolerant of most disturbances
Rana clamitans melanota	3(2)	Green frogs are found in a wide range of wetlands and are tolerant of most disturbances (consideration is being given to lowering this species' tolerance coefficient)
Rana palustris	7	Pickerel frogs prefer clear, cool streams and areas of groundwater expression and have only been collected at a few of our least impacted sites
Rana pipiens pipiens	2	Leopard frogs breed in a range of sites, the main requirement is enough water for their breeding cycle and some suitable adjacent habitat
Rana sylvatica	7	Wood frogs are dependent on forested wetlands and adjacent areas and require pools within a landscape of minimal disturbance
Pseudacris crucifer	2	Spring peepers breed in a range of sites, main requirement is enough water for breeding cycle and some suitable adjacent habitat
Pseudacris triseriata & *Pseudacris brachyphona*	3	Western and mountain chorus frogs are slightly less tolerant of disturbance than the closely related *P. crucifer*

the number of individuals from all species trapped at a wetland to develop a total. Next the numbers of individuals of each species is multiplied by its corresponding C of C to yield a subtotal for each species. The subtotals for each species are then added together to yield a second total. The second total is then divided by the first total to derive the AQAI for that wetland. This index represents the average C of C of individual amphibians trapped at that wetland throughout the sampling season (information from all three passes is totaled). The equation for the AQAI is shown below. Calculation of the AQAI for a hypothetical forested vernal pool wetland is shown in Table 2.

The WAP Ecoregion, Eastern Red-Spotted Newts and Marbled Salamanders

The most significant difference in the composition of the amphibian communities in the Western Allegheny Plateau wetlands when compared to the rest of the state is the distribution and abundance of eastern red-spotted newts (Notophthalmus viridescens viridescens). In the rest of the state this amphibian species is extremely rare resulting in the assignment of a C of C of 9 to this species. In the WAP ecoregion wetlands sampled this species was present at 19 of the 21 sites. Whereas at 82 sites sampled in the ECBP and EOLP ecoregions newts only occurred at 10 sites.

The dependence of newts on areas of contiguous forest habitat is well documented (Petranka 1998, Harding 1997). This is especially important for this species because there is a juvenile stage called a red eft that spends up to several years in terrestrial habitats before it matures and returns to the pools. Pfingsten and Downs (1989) report that red-spotted newts are far more numerous in the unglaciated southern and eastern portions of Ohio. Porej et al. (2004) also found that red-spotted newts were negatively associated with the average distance to the nearest five wetlands.

Given the red-spotted newt's life history and the far ranging behavior of this species, it is understandable that the WAP with its largely forested landscape interconnecting individual wetlands would have a higher number of sites that meet the newt's life strategy requirements. Marbled salamanders were far more common at wetlands in the WAP ecoregion then at sites we have monitored in other ecoregions of the state. This observation is not surprising since the large majority of this species' range is withing the WAP ecoregion, especially the southern part (Pfingsten and Downs 1989, Conant and Collins 1998, Petranka 1998).

Marbled salamanders also rely heavily on a forested landscape as appropriate habitat, especially bottomland hardwood forests, and as with the red-spotted newt are more likely to be found where higher percentages of forested landscape exist (Pfingsten and Downs 1998, Petranka 1998). We collected larvae of this species at 7 of the 21 wetlands we monitored in the WAP. Larvae were already present during the first sampling pass and were collected throughout the sampling season. Those larvae collected during the third pass were well developed and near to completely metamorphosed.

The presence of red-spotted newts at most emergent sites monitored in the WAP ecoregion elevated their AmphIBI scores when compared to emergent sites from the ECBP and EOLP ecoregions. One way to address this inflation of the WAP sites AmphIBI scores due the relative abundance of red-spotted newts and marbled salamanders might be to differ the C of Cs of these two species by ecoregions. However, for forest and shrub wetlands the overall AmphIBI scores correlated well with disturbance levels as measured by ORAM 5.0. (Figure 6). Therefore, the previously assigned C of Cs for these two species were left unchanged.

Amphibian Quality Assessment Index (AQAI)

Graphics for this metric are in Figure 1. Plotting AQAI scores versus ORAM 5.0 shows that for most cases as disturbance increases (lower ORAM 5.0 scores) the AQAI scores decrease. Below ORAM 5.0 scores of

Table 2. Calculation of AQAI for a hypothetical forested vernal pool.

Species	Number of Individuals	Coefficient of Conservatism	Subtotals
Ambystoma maculatum	50	8	400
Ambystoma jeffersonianum	30	5	150
Ambystoma texanum	20	4	80
Notophthalmus viridescens	25	9	225
Pseudacris crucifer	30	2	60
Hyla versicolor	20	5	100
Rana pipiens pipiens	30	2	60
Rana clamitans melanota	2	3	6
Totals	**187**	–	**1081**

$$\text{AQAI} = \frac{\text{SUM (individual species numbers X species' C of C)}}{\text{total number of amphibians}}$$

AQAI = **5.79** (1081/187)

approximately 50 the AQAI scores decrease significantly. It appears this level of human disturbance presents a threshold above which the amphibian community is very negatively impacted.

When the AQAI is compared to ORAM 5.0 score tertiles (ORAM 5.0 scoring breaks based on thirds; 0-33; 33.5 -67; and 67.5-100) good separation is demonstrated and the means of the second and third tertiles are significantly different than the mean of the first tertile at p=<0.001. In the third graph it can be seen that as human disturbance increases, as reflected in higher LDI scores, a general trend of lowering of AQAI scores is observed.

Relative Abundance of Sensitive Species

Graphics for this metric are in Figure 2. This metric demonstrates important differences among the wetlands monitored. Sensitive species are those species that been assigned a C of C of 6 or higher. For disturbed sites relative abundances of sensitive species are very low. All are below 10% with the majority scoring much lower. The relationship is somewhat curvilinear and only when wetlands that are reasonably intact are sampled (generally around ORAM 5.0 scores of the mid-50s) do relative abundances of sensitive species exceed 10%.

When the sites are grouped based on ORAM 5.0 tertiles. The first tertile is dominated by communities with extremely low relative abundances of sensitive species. The third tertile is dominated by amphibian communities where the relative abundance of sensitive species is above 50%. The means of the three tertiles are significantly different than each other at p=<0.001 and this metric provides good separation between groups. Additionally, the differences between sites in the first tertile (severely disturbed sites) and those in the third tertile (minimally disturbed sites) is very marked. This ability to distinguish between the two extremes makes this attribute of the amphibian community a strong metric (Karr and Chu 1999). There is a very general trend represented in the plot of LDI scores versus this metric that as disturbance increases the relative abundances of sensitive species decrease.

Relative Abundance of Tolerant Species

The graphics for this metric are in Figure 3. Tolerant species are species that have been assigned a C of C of 3 or less. Plotting the relative abundance of tolerant species of sites against their ORAM 5.0 scores shows some interesting relationships. First, the sites on the disturbed end of the scale (ORAM scores <45) all have amphibian communities that have relative abundances of tolerant species greater than 60% with most having a much higher percentage. Secondly, once an ORAM score in the high 60s is reached (a level of high functional intactness), those sites have less than 45% of their of the amphibian communities dominated by tolerant species. Also, the majority of the minimally disturbed sites have relative abundances of tolerant species that is much lower than 45%.

Looking at the range of scores based on ORAM tertiles (thirds) shows good separation between groups. The means of the three tertiles are all significantly differently than each other. Additionally, there is strong separation between the relative abundances of tolerant species at the site in the first tertile (severely disturbed sites) and those in the third tertile (minimally disturbed sites).

Plotting the relative abundance of tolerant species found at sites against the LDI (1km) does not result in a strong relationship. Likely this result indicates that the factors affecting this attribute are working at a smaller scale than 1km.

Number of Species of Pond-breeding Salamanders

The graphics for this metric are in Figure 4. The number of pond-breeding salamander species present is an attribute that works well to separate sites based on their condition (Micacchion 2002). We have found a range of from zero to five species at wetlands we have sampled. Analysis of the data from the additional wetlands monitored in 2001 and 2002 still show that more than two species of salamanders are only found at sites that are relatively intact. We do not find three or more species at sites until they score in the mid-50s (reasonably intact) and most of the sites with three or more species have much higher ORAM 5.0 scores.

Plotting this metric versus ORAM 5.0 tertiles provides good separation especially between the first and third tertiles. Plotting this metric against the LDI does not provide a strong relationship. It appears that some of the important factors affecting this metric are working at a smaller scale then one kilometer.

Presence of Spotted Salamanders and/or Wood Frogs

Graphics for this metric are in Figure 5. As reported in Micacchion (2002) for shrub and forested wetlands spotted salamanders and wood frogs are good indicators of relatively undisturbed conditions. Porej et al. (2004) also found that both of these species are positively associated with the amount of forest within 200m of breeding wetlands and that there is also a positive relationship between the amount of forest within 1km and the presence of wood frogs. The elimination of large contiguous forested areas in much of the ECBP ecoregion appears to be the major limiting factor to the presence of wood frogs within their historic range (Walker 1946, Davis and Menze 2000).

When the relative abundances of spotted salamanders and/or wood frogs is plotted against ORAM 5.0 scores several results are apparent. Neither species occurs at sites that are severely degraded and there are only a few occurrences at sites that are moderately disturbed. A large majority of the sites that do have either or both species present are considered to be "reference condition", that is, sites where there are no easily detectable signs of human disturbance. Plotting this metric versus ORAM 5.0 tertiles provides some interesting results. Neither species shows up in sites within the first tertile (severely degraded sites). While these species do show up in sites in the second tertile the greatest relative abundances are in sites from the third tertile. Plotting this metric against the LDI does not provide a strong relationship.

Because of the high levels of intactness of wetlands where one or both of these species occur this attribute serves as an excellent metric. Different than the other metrics that comprise the AmphIBI this metric has only two possible scores. Wetlands without the presence of either of these two species score zero whereas wetlands that are habitat for one or both species score ten.

Amphibian Index of Biotic Integrity (AmphIBI)

The scoring breakpoints for the metrics that make up the AmphIBI are summarized in Table 3. The scoring protocol for the presence of spotted salamanders and/or wood frogs metric is discussed in that metric's section. The breakpoints for the other four metrics were established by mathematically quadrasecting the data values for the metrics. If the breakpoints corresponded to what appeared to be the ecological breakpoints those values were used. This worked for two of the four metrics, for the other two, breakpoints were drawn where there appeared to be ecological differences in the data values.

Graphics for the AmphIBI are in Figures 6, 7 and 8. Plotting the AmphIBI scores against the ORAM 5.0 disturbance gradient scores for the forested and shrub wetlands shows a strong correlation (Figure 6). Plotting the scores based on ORAM 5.0 tertiles provides good separation between groups. Plotting ORAM scores against the LDI shows somewhat of a threshold affect. Once LDI scores of sites reach approximately 5 the corresponding AmphIBI scores drop markedly, with the exception for a few outliers on both extremes.

When AmphIBI scores are plotted against the ORAM 5.0 metrics that measure disturbance directly (buffer widths, surrounding land use and hydrology, substrate and habitat intactness) (39 possible points) a stronger relationship than comparing the AmphIBI scores to the composite ORAM 5.0 scores is demonstrated (Figure 7, first graph).

The study sites along with information on their ecoregions, vegetation and HGM classes, metric, AmphIBI and ORAM 5.0 scores appear in Table 4.

Wetland Tiered Aquatic Life Uses (TALUs)

Mack (2004) proposed Tiered Aquatic Life Uses (TALUs) for wetlands based on their VIBI scores, ecoregion, landscape position and plant community. Based on how the AmphIBI scores plot against the disturbance gradients I am proposing preliminary TALUs for wetlands. Wetlands with AmphIBI scores less than 10 would comprise the Limited Wetland Habitat (LWLH) aquatic life use. Restorable Wetland Habitat (RWLH) would be assigned to sites that score between 10 and 19. Wetland Habitat (WLH) would be assigned to those sites that score between 20 and 39. Superior Wetland Habitat (SWLH) would be assigned to those sites that score 40 or above.

Wetland Vegetation Classes

As reported in Micacchion (2002) only amphibian communities of shrub and forested wetlands showed responses that correlated with disturbance levels. Conversely the emergent communities only scored in the lower levels of AmphIBI scores (26 of 27 sites with AmphIBI scores <20). Additional attributes of the amphibian communities of emergent wetlands have been examined and plotted against the disturbance scales. However, responses are flat and offer no promise as additional metrics that might allow for separation of emergent sites using an amphibian index. These results indicate

Table 3. Scoring breakpoints for assigning metric scores for AmphIBI.

Metric	Score 0	Score 3	Score 7	Score 10
AQAI	<3.00	3.00 - 4.49	4.50 - 5.49	≥ 5.5
Rel. Abundance Sensitive Spp.	0%	.01 - 9.99%	10 - 49.99%	≥ 50%
Rel. Abundance Tolerant Spp.	>80%	50.01 - 79.99%	25.01 - 50%	≤ 25%
# of Pond-Breeding Salamander Spp.	0 -1	2	3	> 3
Spotted Salamanders and/or Wood Frogs	absent	-	-	present

that amphibian communities of emergent wetlands do not vary significantly enough with different levels of disturbance to use them for predictors of condition for this class of wetlands.

With this expanded data set the same result is supported (Figure 7, second graph). As can be seen for the forested and shrub wetlands there are changes in ORAM scores throughout the range of disturbance. However, only four emergents sites score higher than 20 on the AmphIBI. This includes the one ECBP ecoregion site from the original 27 sites plus three additional sites from the WAP ecoregion.

The ECBP site as discussed in Micacchion (2000) has a breeding population of tiger salamanders (*Ambystoma tigrinum*) © of C of 6) and few other amphibians in its community. This breeding tiger salamander population results in the site's AmphIBI score being much higher than its vegetation community type or disturbance level would predict. The other three sites that have AmphIBI scores greater then 20 are from the WAP. As presented in the AQAI results section, it is the presence of red-spotted newts in WAP emergent sites that inflates the AmphIBI scores of those wetlands.

So with the exception of these four sites, all of the emergent sites in this study score less than 20 on the AmphIBI. This small range of possible scores seen for emergent wetlands limits the ability to differentiate among them based on their AmphIBI scores. There are several possible explanations why the amphibian communities of emergent sites generally represent a lower quality.

First, most of Ohio's sensitive amphibian species are adapted to living within wetlands that have seasonal hydrology and are in landscapes that are largely forested. Brooks (2004) has noted this same reliance in New England wood frog and spotted salamander populations. These amphibians are dependent on the adjacent forested terrestrial habitat for most of their adult lives and this habitat is more likely to be found adjacent to forested wetlands.

The more permanent hydrology of most emergent sites favors generalists like the bullfrog (*Rana catesbeiana*) and green frog (*Rana clamitans melanota*) which require at least two seasons for their larvae to metamorphose (Walker 1946) and can coexist with predatory fish and other predators. Also, these two species along with other tolerant amphibian species such as leopard frogs (Rana pipiens pipiens), spring peepers (Pseudacris crucifer), western chorus frogs (Pseudacris triseriata), mountain chorus frogs (Pseudacris brachyphona) and toads (Bufo spp.) are adapted to living in a wide range of conditions including those habitats that are highly degraded.

Further, many emergent wetlands are dominated by an emergent community because they have experienced severe disturbances in the recent past. Ohio was 95% forested prior to European settlement (Lafferty 1979) therefore historically you would expect no more than 5% of the landscape to have been populated by emergent vegetation communities including wetlands, most typically in large marsh or wet prairie expanses. There is a high likelihood that an emergent site is dominated by that type of vegetation today because of disturbance that has set it back on the successional trajectory.

As well as often being within surrounding land uses that are incompatible to amphibian habitat needs emergent wetlands also generally lack the within wetland habitat features favored by sensitive amphibian species. As discussed, prime among these is an environment that is free of predatory fish.

Additionally, many pond-breeding amphibian species are adapted to specific habitat features. These include substrates covered with layers of leaf litter in different stages of decomposition, the presence of ample woody debris provided by live woody vegetation, typically provided by buttonbush, (*Cephalanthus occidentalis*) or other similarly structured wetland shrub species and dead fallen twigs, branches and trunks (Egan and Paton 2004). Also a shade cover provided either by a canopy of shrubs or trees is preferred to supply the important cooler, moister microclimates required by most amphibian species. All of these features are lacking in the majority of emergent systems. Their absence often limits the potential of emergent wetlands to host sensitive amphibian species such as most of the pond-breeding salamander species, wood frogs and pickerel frogs.

For these reasons, the AmphIBI should only be applied to shrub and forested sites with temporary to semi-permanent hydroperiods, known as vernal pools. For calculation of metrics and overall AmphIBI scores the shrub and forest sites have been combined.

Hydrogeomorphic Classes

Wetlands from 5 hydrogeomorphic (HGM) classes (Brinson 1993) were sampled for their amphibian communities. This included wetlands in the depressional, riverine, impoundment, slope and coastal landscape positions. The wetland study sites, separated out by their HGM classes, are plotted showing their AmphIbI versus their ORAM 5.0 scores (Figure 7, bottom graph). Wetlands that comprised the set of forested and shrub sites used to develop the AmphIBI were from the depressional, riverine, impoundment and slope HGM classes but were highly dominated by those in the depressional class. The two impoundments were originally riverine sites that had been impounded, in one case by beavers and in the other by a railroad grade. The slope site was a difficult wetland to assign to a single HGM class and had elements of depressional, riverine and slope features. The riverine sites were depressions within various elevations of stream flood plains.

Wetland Size

When the AmphIBI scores for the woody sites are broken out by ORAM 5.0 size classes there is no significant difference between the means of the groups (Figure 8, first graph). Sites in the smallest size class (<0.1 acre, <0.04 ha.) had a mean AmphIBI score of 35.50 which was highest among the groups. The lowest mean AmphIBI score was 26.50 for wetlands in the group with the largest size class represented (25 to <50 acres, 10.1 to 20.2 ha.). Much has been written about the value of small wetlands in providing amphibian habitat (Semlitsch and Bodie 1998, Snodgrass et al. 2000). The results of this study further document the ability of small wetlands to provide excellent habitat for amphibians.

When the AmphIBI scores of emergent and mitigation sites as well as woody wetlands in the study are divided out by size class further observations can be made (Figure 8, second graph). Again the smallest size class (<0.1 acre, <0.04 ha.) yielded the highest mean AmphIBI score of 29.67. Conversely the group with the largest wetlands (>50 acres, >20.2 ha.) had the lowest mean AmphIBI score of 3.64.

Mitigation Sites

Ten constructed wetlands were monitored for amphibians using the same protocols utilized in development of the AmphIBI at natural wetlands. The wetlands sampled had been constructed for from three to ten years and ranged in size from 0.37 to 25.7 acres. Seven of the ten constructed wetlands have permanent hydrology and five of the wetlands have populations of predatory fish. Nine of the ten constructed wetlands had AmphIBI scores of zero. The other constructed site had an AmphIBI score of 3, the three points were scored on the Relative Abundance of Sensitive Species metric. The wetland was built near existing forested areas at a metro park and has a breeding population of tiger salamanders (*Ambystoma tigrinum*) © of C of 6). Tiger salamanders are known to breed at a natural shrub wetland located nearby in a mature forested area of the park.

All the constructed wetlands sampled were dominated by emergent vegetation with at least some areas of open water. Nine of the ten sites have extensive areas of relatively deep unvegetated open water. None have any percentage of shrub or tree canopy cover. While some of these wetlands were constructed to mitigate for losses of forested and shrub wetlands their AmphIBI scores equate with the most disturbed forested sites that we have sampled.

The results seen in these ten sites are also reflected in a larger set of Ohio mitigation wetlands that have been surveyed (Porej 2004) and point out that amphibian biodiverstiy of forested and shrub wetlands is not being replaced in the wetlands that are being constructed for mitigation. In many parts of the state, particularly, large areas of the ECBP ecoregion this loss of natural wetlands and their surrounding habitats have resulted in extreme isolation of amphibian populations and reductions of the historic ranges of some species. If we hope to maintain the biodiversity of amphibian communities in Ohio efforts to protect the habitat of remaining populations, including the wetlands used for breeding, must be undertaken. In addition, we must began to develop constructed wetlands that meet amphibians' within wetland and surrounding habitat needs.

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LITERATURE CITED

Altig, Ronald, Roy W. McDiarmid, Kimberly A Nichols and Paul A. Ustach. Tadpoles of the United States and Canada: A Tutorial and Key (In preparation).

http://www.pwrc.usgs.gov/tadpole/division_5.htm.

Andreas, Barbara K. And R. W. Lichvar. 1995. A Floristic Quality Assessment System for Northern Ohio. Wetlands Research Program Technical Report WRP-DE-8. U.S. Army Corps of Engineers, Waterways Experiment Station. Vicksburg, MS.

Baker, Kim and Mick Micacchion. 1999. Ohio Wetland Restoration and Mitigation Blueprint. Ohio Environmental Protection Agency and Ohio Department of Natural Resources. Final product to the U.S. Environmental Protection Agency, Region V, Grant CD985853-01.

Brinson, Mark M. 1993. A hydrogeomorphic classification for wetlands. Wetlands Research Technical Report WRP-DE-4. U.S. Army Corps of Engineers, Waterways Experiment Station. Vicksburg, MS.

Brooks, Robert T. 2004. Weather-related Effects on Woodland Vernal Pool Hydrology and Hydroperiod. Wetlands 24: 104-114.

Brown, M. T. and M. B. Vivas. 2004. A landscape development intensity index. Environmental Monitoring and Assessment xxx:1-21.

Conant, Roger and Joseph T. Collins. 1998. A field guide to the reptiles and amphibians, eastern and central North America. Third edition. Houghton Mifflin Company. New York, NY. 616p.

Davis, Jeffrey G. and Scott A. Menze. 2000. Ohio Frog and Toad Atlas. Ohio Biological Survey Miscellaneous Contributions Number 6. iv + 20p. + mini poster + form.

Egan, Robert S. and Peter W. C. Paton. 2004. Within-pond parameters affecting oviposition by wood frogs and spotted salamanders. Wetlands 24: 1-13.

ESRI. 1999. ArcView GIS v. 3.2. Environmental System Research Institute, Redlands, CA.

Gibbs, James P. 1998. Distribution of woodland amphibians along a forest fragmentation gradient. Landscape Ecology 13:263-268.

Gordon, Robert B. 1966. Natural vegetation of Ohio at the time of the earliest land surveys. Ohio Biological Survey, Columbus, Ohio.

Griffiths, R.A. and T.J.C. Beebee. 1992. Decline and Fall of Amphibians. New Scientist 27:25-29.

Harding, James H. 1997. Amphibians and Reptiles of the Great Lakes Region. The University of Michigan Press, Ann Arbor, MI.

Hecnar, Stephen J. and Robert T. M'Closkey. 1997. The Effects of Predatory Fish on Amphibian Species Richness and Distribution. Biological Conservation 79:123-131.

Karr, James R., and Ellen W. Chu. 1999. Restoring life in running waters: better biological monitoring. Island Press, Washington, D.C.

Kats, L.B., J.W. Petranka, and A. Sih. 1988. Antipredator defenses and the persistence of amphibian larvae with fishes. Ecology 69:1865-1870.

Lafferty, M.D. (Ed.). 1979. Ohio's Natural Heritage. The Ohio Academy of Science, Columbus, OH.

Mack, John J. 2004. Integrated Wetland Assessment Program. Part 4: Vegetation Index of Biotic Integrity (VIBI) and Tiered Aquatic Life Uses (TALUs) for Ohio Wetlands. Ohio EPA Technical Report Wet/2004-4. Ohio Environmental Protection Agency, Wetland Ecology Group, Division of Surface Water, Columbus, OH.

Mack, John. J. 2001. Ohio Rapid Assessment Method for Wetlands v.5.0, User's Manual and Scoring Forms. Ohio EPA Technical Report WET/2001-1. Ohio Environmental Protection Agency, Division of Surface Water, 401/Wetland Ecology Unit, Columbus, OH.

Micacchion, Mick. 2002. Amphibian Index of Biotic Integrity (AmphIBI) for Wetlands. Final report to U.S. EPA Grant No. CD985875-01, Testing Biological Metrics and Development of Wetland Assessment Techniques Using Reference Sites: Volume 3. Ohio Environmental Protection Agency, Division of Surface Water, Wetland Ecology Unit, Columbus, OH.

Micacchion, Mick, Michael A. Gray and John J. Mack. 2000. Amphibian and Macroinvertebrate Attributes for Ohio Wetlands. Final Report to U.S. EPA Grant. No. CD98276, Interim Report to U.S. EPA Grant No. CD985875, Volume 2. Ohio Environmental Protection Agency, Division of Surface Water, Ecological Assessment Section and Wetland Ecology Unit, Columbus, OH.

Odum, H. T. 1996. Environmental Accounting: emergy and environmental decision making. John Wiley & Sons, New York. 370p.

Ohio EPA. 1988a. Biological Criteria for the Protection of Aquatic Life: Volume I. The role of biological data in water quality assessment. Ohio Environmental Protection Agency, Ecological Assessment Section, Division of Water Quality Planning and Assessment, Columbus, Ohio.

Ohio EPA. 1988b. Biological Criteria for the Protection of Aquatic Life: Volume II. Users Manual for biological field assessment of Ohio surface waters. Ohio Environmental Protection Agency, Ecological Assessment Section, Division of Water Quality Planning and Assessment, Columbus, Ohio.

Ohio EPA. 1989a. September 30, 1989 Addendum to Biological Criteria for the Protection of Aquatic Life: Volume II, 1988. Ohio Environmental Protection Agency, Ecological Assessment Section, Division of Water Quality Planning and Assessment, Columbus, Ohio.

Ohio EPA. 1989b. Biological Criteria for the Protection of Aquatic Life: Volume III. Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities. Ohio Environmental Protection Agency, Ecological Assessment Section, Division of Water Quality Planning and Assessment, Columbus, Ohio.

Omernik, J. M. 1987. Ecoregions of the conterminous United States. Annals of the Association of American Geographers 77:118-125.

Petranka, James W. 1998. Salamanders of the United States and Canada. The Smithsonian Institution Press. Washington, D.C. and London.

Pfingsten, Ralph A. and Floyd L. Downs. 1989. Salamanders of Ohio. Bulletin of the Ohio Biological Survey. Volume 7, No. 2. Columbus, OH.

Porej, Deni. 2003. An Inventory of Ohio Compensatory Wetland Mitigation. Report to U.S. EPA Grant No. CD97576201-0. Ohio Environmental Protection Agency, Division of Surface Water, Wetland Ecology Unit, Columbus, OH.

Porej, Deni. 2004. Faunal Aspects of Wetland Creation and Restoration. Dissertation. The Ohio State University. 120p.

Porej, Deni, Mick Micacchion and Thomas E. Hetherington. 2004. Core Terrestrial Habitat for Conservation of Local Populations of Salamanders and Wood Frogs in Agricultural Landscapes. Biological Conservation 120:399-

409.

Semlitsch, Raymond D. 1998. Biological delineation of terrestrial buffer zones for pond-breeding salamanders. Conservation Biology 12:1113-1119.

Semlitsch, Raymond D. 2000. Principles for Management of Aquatic-Breeding Amphibians. Journal of Wildlife Management 64(3):615-631.

Semlitsch, Raymond D. and J. Russell Bodie. 1998. Are Small, Isolated Wetlands Expendable? Conservation Biology 12(5): 1129-1133.

Snodgrass, Joel W., Mark J. Komoroski, A. Lawrence Bryan, and Joanna Burger. Relationships among Isolated Wetland Size, Hydroperiod, and Amphibian Species Richness: Implications for Wetland Regulations. Conservation Biology 14(2): 414-419.

Sparling, Donald W., Klaus O. Richter, Aram Calhoun and Mick Micacchion. 2002. Methods for Evaluating Wetland Condition. #12. Using Amphibians in Bioassessments of Wetlands. The United States Environmental Protection Agency, Health and Ecological Criteria Division (Office of Science and Technology) and Wetlands Division (Office of Wetlands, Oceans and Watersheds).

Swink, F. and G. Wilhelm. 1979. Plants of the Chicago Region 3rd Ed. Morton Arboretum, Lisle, Ill.

Wake, D. B. 1991. Declining Amphibian Populations. Science 253:860

Walker, Charles F. 1946. The Amphibians of Ohio, Part 1, The Frogs and Toads. Columbus: Ohio State Museum Science Bulletin Volume 1, No. 3 (1946).

Wilhelm, Gerould S., and D. Ladd. 1988. Natural area assessment in the Chicago region. Transactions 53rd North American Wildlife and Natural Resources Conference pgs. 361- 375.

Woods, Alan J., James M. Omernik, C. Scott Brockman, Timothy D. Gerber, William D. Hosteter, and Sandra H. Azevedo. 1998. Ecoregions of Indiana and Ohio (Map) and Supplementary Text.

Wright, Albert Hanzen and Anna Allen Wright. 1995. Handbook of Frogs and Toads of the United States and Canada, Third Edition. Comstock Publishing Associates, a division of Cornell University Press, Ithaca, NY and London.

Wyman, R. L. 1990. What's Happening to the Amphibians? Conservation Biology 4:350-352.

Table 4. Wetland ecoregions, vegetation classes, metrics, AmphIBI and ORAM 5.0 scores.

Wetland Name	eco code	veg class	AQAI	%sen	%tol	sal	spotwd	AmphIBI	ORAMv5.0
2-Meadows	ECBP	shrub	0	3	0	3	10	16	49
Ackerman	ECBP	shrub	0	3	0	3	0	6	24
Area K	ECBP	shrub	0	0	0	0	0	0	61.5
Bailey Peeper	WAP	forest	10	10	7	0	0	27	49.5
Baker Swamp	WAP	emergent	7	7	3	0	0	17	81
Ballfield Marsh	EOLP	emergent	0	3	0	3	10	16	83
Berger Road	ECBP	emergent	0	0	0	0	0	0	24.5
Big Bailey	WAP	emergent	7	7	3	0	0	17	64
Big Island Area C	ECBP	emergent	0	0	0	0	0	0	mitigation
Big Woods	ECBP	forest	10	10	10	3	10	43	68.5
Birkner Pond	EOLP	emergent	0	0	0	0	0	0	30
Blackfork Swamp	WAP	forest	3	7	0	3	0	13	62
Blackjack Rd Back	EOLP	shrub	0	3	0	0	10	13	66
Blackjack Rd Front	EOLP	shrub	10	10	10	0	10	40	55.5
Blanchard Oxbow	ECBP	shrub	3	0	3	3	0	9	48
Bloomville Swamp	ECBP	emergent	0	0	0	0	0	0	36
Bluebird	ECBP	emergent	0	0	0	0	0	0	mitigation
Buckeye Furnace	WAP	shrub	10	10	10	0	0	30	66.5
Calamus 1997	ECBP	emergent	3	3	0	0	0	6	77
Calamus 2001	ECBP	emergent	3	7	3	0	0	13	77
Callahan	ECBP	shrub	10	7	7	10	0	34	57.5
Cessna	ECBP	shrub	3	3	3	7	10	26	61
Collier Woods	ECBP	forest	10	10	10	3	10	43	73.5
County Rd 200	ECBP	emergent	10	10	10	3	0	33	19
Crall Woods	EOLP	forest	10	10	10	0	10	40	77.5
Daughmer	ECBP	emergent	0	0	0	0	0	0	68
Dever 1997	ECBP	emergent	7	0	10	0	0	17	19
Drew Woods	ECBP	shrub	3	3	10	0	0	16	70
Eagle Cr Beaver	EOLP	emergent	0	3	0	0	0	3	68
Eagle Cr Bog	EOLP	shrub	10	10	10	0	10	40	81
Eagle Cr Vernal	EOLP	forest	10	10	10	3	10	43	69
Eagle Creek BB	EOLP	shrub	0	0	0	0	0	0	81
Eagle Creek Marsh	EOLP	emergent	3	3	0	0	0	6	75
East Branch Sunday	WAP	emergent	7	7	3	0	0	17	52
Falling Tree	WAP	shrub	10	10	10	10	10	50	73
Flowing Well	ECBP	forest	10	10	10	7	0	37	54
Fowler Woods	EOLP	forest	10	10	10	10	10	50	79
Frieds Bog	EOLP	shrub	7	10	7	0	10	34	77
Gahanna 4th 1996	ECBP	shrub	3	3	0	10	10	26	67.5
Graham Rd	ECBP	forest	0	0	3	0	0	3	26
Grand R Terraces	EOLP	shrub	10	10	7	7	10	44	73
Greendale Beaver	WAP	emergent	7	7	3	0	0	17	53.5
Greendale BB	WAP	shrub	7	7	3	3	0	20	65
Greendale Vernal	WAP	forest	7	7	7	10	10	41	65
Guilford Marsh	EOLP	emergent	3	0	0	0	0	3	45.5
Hebron	ECBP	forest	0	0	0	0	0	0	54.5
Hempelman	ECBP	forest	0	3	3	3	0	9	47
Hewitt Fork	WAP	emergent	10	10	10	0	0	30	51

Table 4. Wetland ecoregions, vegetation classes, metrics, AmphIBI and ORAM 5.0 scores.

Wetland Name	eco code	veg class	AQAI	%sen	%tol	sal	spotwd	AmphIBI	ORAMv5.0
JMB	ECBP	emergent	0	0	0	0	0	0	mitigation
Johnson Rd	ECBP	forest	0	3	0	0	0	3	21
Keller High	ECBP	shrub	10	10	10	10	10	50	64.5
Keller Low	ECBP	emergent	3	7	0	0	0	10	34
Killdeer Plains	ECBP	forest	10	10	10	3	10	43	58.5
Kiser Lake	ECBP	emergent	0	0	0	0	0	0	70
Lake Abrams	EOLP	emergent	0	0	0	0	0	0	40
Lawrence High	ECBP	forest	10	10	7	10	10	47	73
Lawrence Low 1	ECBP	emergent	3	7	3	3	0	16	34
Lawrence Low 2	ECBP	forest	3	3	10	0	0	16	48
Leafy Oak 1997	ECBP	forest	7	7	10	0	0	24	78
Limeridge Rd	EOLP	shrub	10	10	10	0	10	40	45.5
Lodi North	EOLP	emergent	0	0	0	0	0	0	29
Mantua Bog	EOLP	emergent	0	0	0	0	0	0	94
McKinley	ECBP	shrub	0	3	0	3	10	16	37.5
Medallion #20	ECBP	emergent	0	0	0	0	0	0	mitigation
Minkers Run	WAP	emergent	10	10	7	0	0	27	47
Mishne 1997	ECBP	emergent	0	0	0	0	0	0	19.5
Mitchell Woods	EOLP	shrub	10	10	10	0	10	40	72
Morgan Swamp BB	EOLP	shrub	10	10	10	0	10	40	61
Morgan Swamp Marsh	EOLP	emergent	3	0	0	0	0	3	77
Mud Lake (Bog)	MIDP	emergent	3	0	0	0	0	3	91
New Albany HS	ECBP	emergent	0	0	0	0	0	0	mitigation
Old Woman Creek	EOLP	emergent	0	0	0	0	0	0	71
Orange Rd	ECBP	forest	0	0	0	0	0	0	45
Oyer Wood Frog	ECBP	shrub	10	10	10	7	10	47	69
Paine Crossing Beaver	WAP	emergent	10	10	7	0	0	27	54
Paine Crossing Forest	WAP	forest	10	10	10	7	10	47	72
Pallister	EOLP	forest	10	10	10	7	10	47	74
Palmer Rd	ECBP	emergent	0	0	0	0	0	0	17.5
Pawnee Rd	EOLP	forest	10	10	10	0	10	40	70
Pizzutti	ECBP	emergent	0	0	0	0	0	0	mitigation
Prairie Lane	EOLP	emergent	0	0	0	0	0	0	mitigation
Raccoon Cr 1	WAP	forest	7	7	7	3	10	34	58
Raccoon Cr 2	WAP	forest	10	10	10	0	10	40	72
Redstart	WAP	forest	10	10	10	3	0	33	75
Rickenbacker 1996	ECBP	emergent	0	3	0	0	0	3	51.5
Rickenbacker 2001	ECBP	emergent	0	0	0	0	0	0	51.5
Rock Outcrop	WAP	forest	10	10	10	10	10	50	54
Route 29	ECBP	shrub	3	7	7	3	0	20	59
Rutherford	WAP	emergent	3	0	0	0	0	3	52
Sacks	EOLP	emergent	0	0	0	0	0	0	constructed
Sawmill 1997	ECBP	forest	3	0	10	0	0	13	52
Scofield	ECBP	emergent	0	3	0	7	0	10	40
Silver Lake	ECBP	emergent	0	0	0	0	0	0	82
Singer Lake Bog	EOLP	emergent	0	0	0	0	0	0	86
Slate Run	ECBP	shrub	7	7	10	10	10	44	76
Slate Run 2	ECBP	emergent	0	3	0	0	0	3	mitigation

Table 4. Wetland ecoregions, vegetation classes, metrics, AmphIBI and ORAM 5.0 scores.

Wetland Name	eco code	veg class	AQAI	%sen	%tol	sal	spotwd	AmphIBI	ORAM v5.0
Springville Marsh	ECBP	emergent	0	0	0	0	0	0	51
Stages Pond	ECBP	emergent	0	0	0	0	0	0	42
Steels Corners	EOLP	emergent	3	0	0	0	0	3	30
Sumner Buttonbush	EOLP	shrub	10	10	10	0	10	40	60
Swamp Cottonwood	EOLP	shrub	10	10	10	7	10	47	76
The Rookery	ECBP	shrub	3	3	7	7	10	30	69
Tinkers Creek	EOLP	emergent	0	0	0	0	0	0	80.5
Tipp-Elizabeth Rd	ECBP	forest	0	0	3	3	0	6	29
Towners Woods	EOLP	shrub	10	10	10	3	10	43	65
Townline Rd	EOLP	shrub	3	7	3	3	10	26	62
Trotwood	ECBP	emergent	0	0	0	0	0	0	mitigation
US 42	EOLP	forest	0	0	0	0	0	0	31
Watercress Marsh	EOLP	emergent	3	0	0	0	0	3	61
Wilson Swamp	ECBP	shrub	0	0	0	0	0	0	77
Zaleski	WAP	forest	10	10	10	3	10	43	55

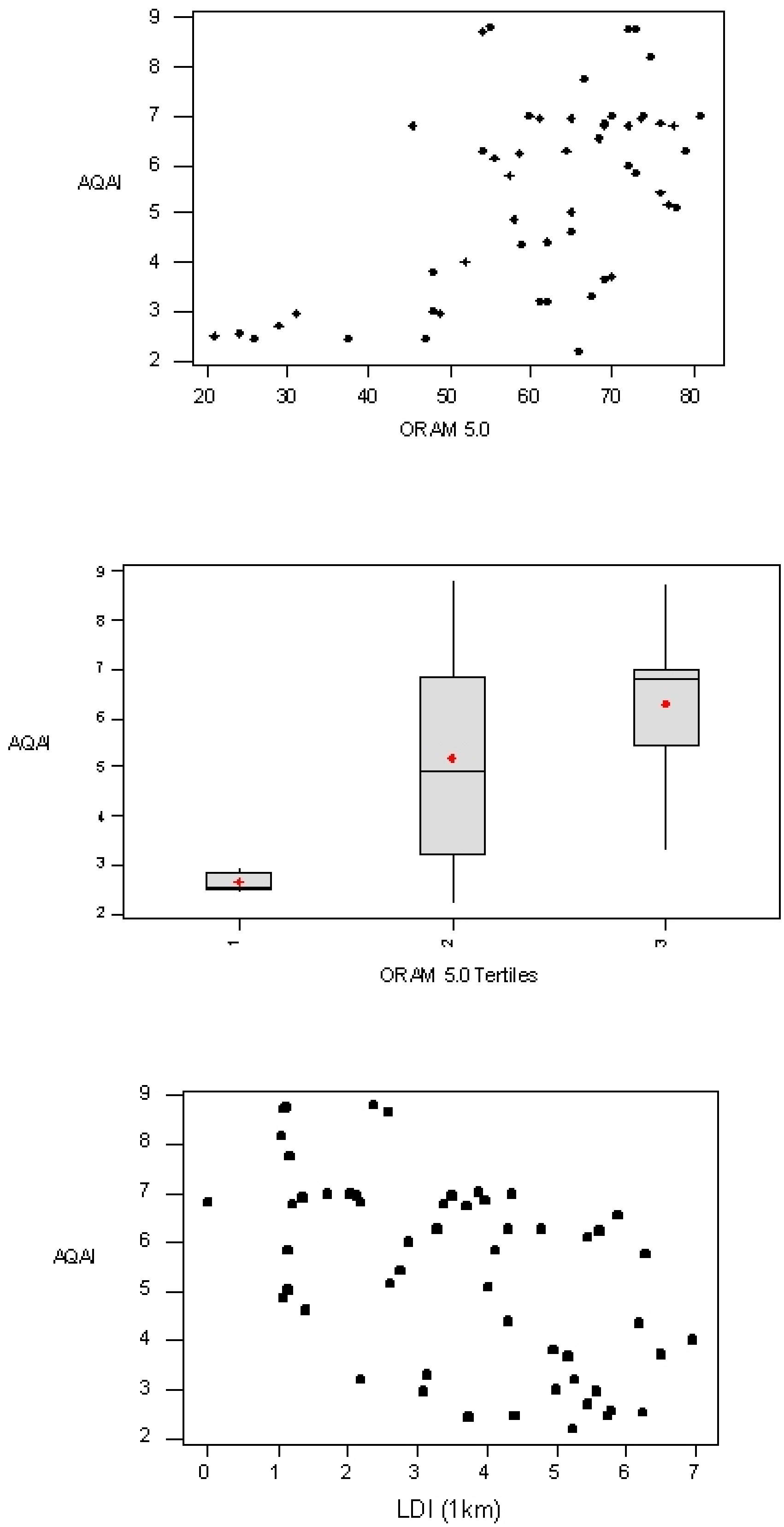


Figure 1. Summary plots of Amphibian Quality Assessment Index (AQAI) metric. Scatter plots are AQAI versus ORAM v. 5.0 score (df = 52, F = 26.21, R^2 = 33.5%, p =< 0.001) or LDI score (df = 52, F = 23.01, R^2 = 30.7%, p < 0.001). Box and whisker plots represent ORAM score tertiles (thirds).

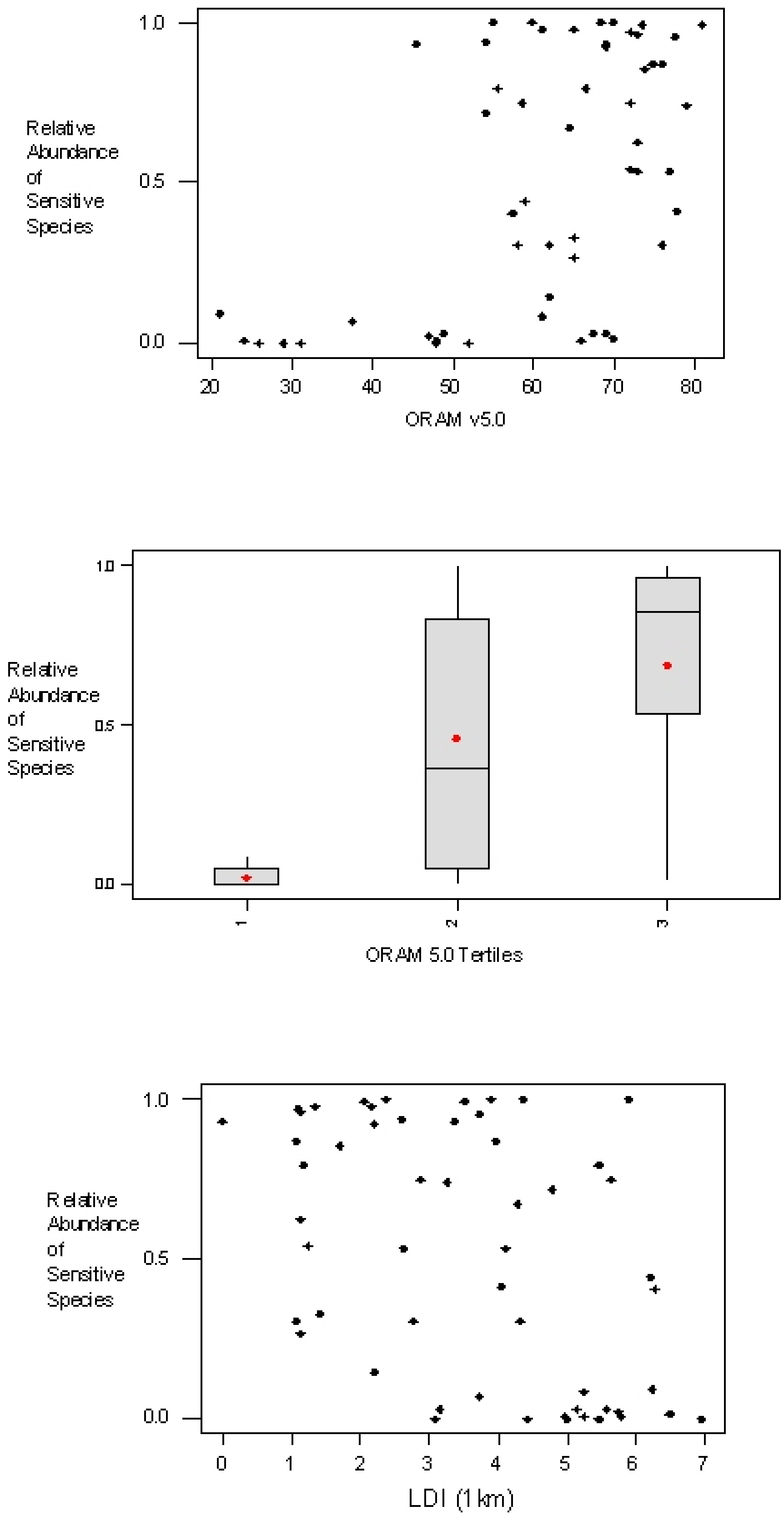
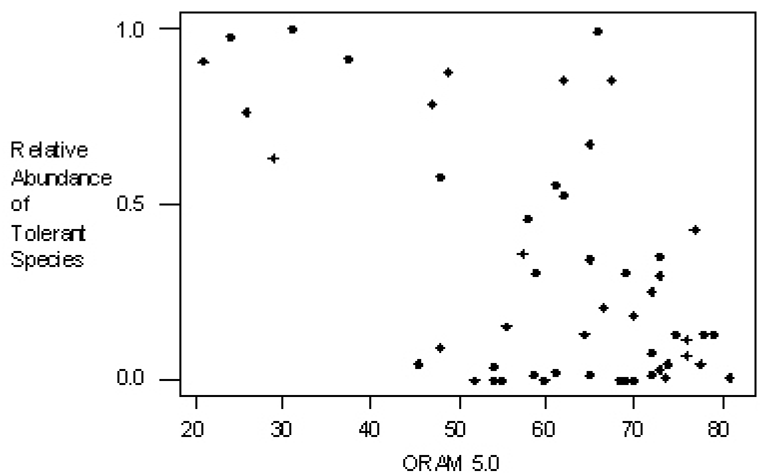
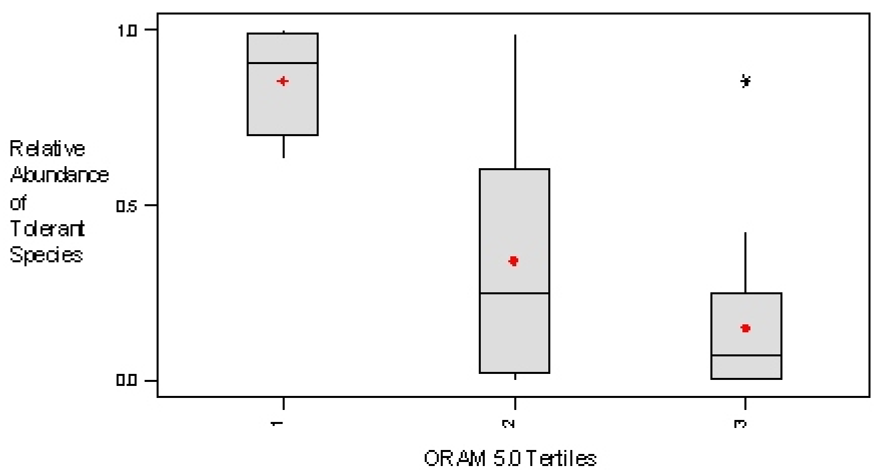


Figure 2. Summary plots of Relative Abundance of Sensitive Species (RASS) metric. Scatter plots are RASS versus ORAM v. 5.0 score (df = 52, F = 20.79, R^2 = 28.6%, p =< 0.001) or LDI score (df = 52, F = 15.56, R^2 = 23.0%, p < 0.001). Box and whisker plots represent ORAM score tertiles (thirds).





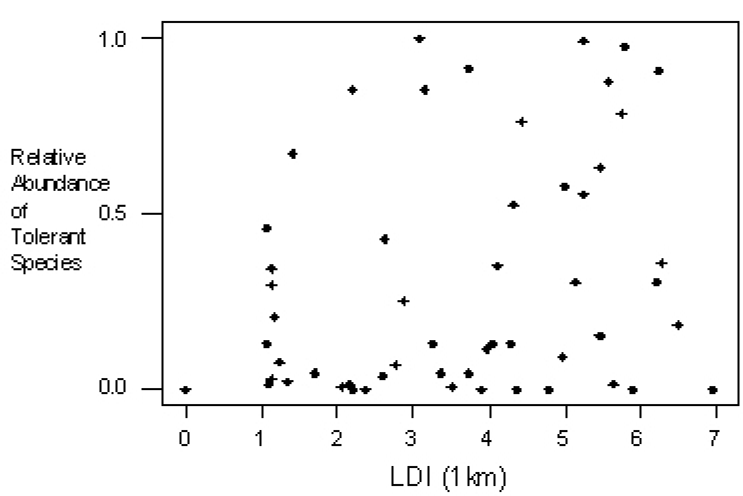


Figure 3. Summary plots of Relative Abundance of Tolerant Species (RATS) metric. Scatter plots are RATS versus ORAM v. 5.0 score (df = 52, F = 27.08, R^2 = 34.2%, p =< 0.001) or LDI score (df = 52, F = 4.09, R^2 = 7.3%, p < 0.001). Box and whisker plots represent ORAM score tertiles (thirds).

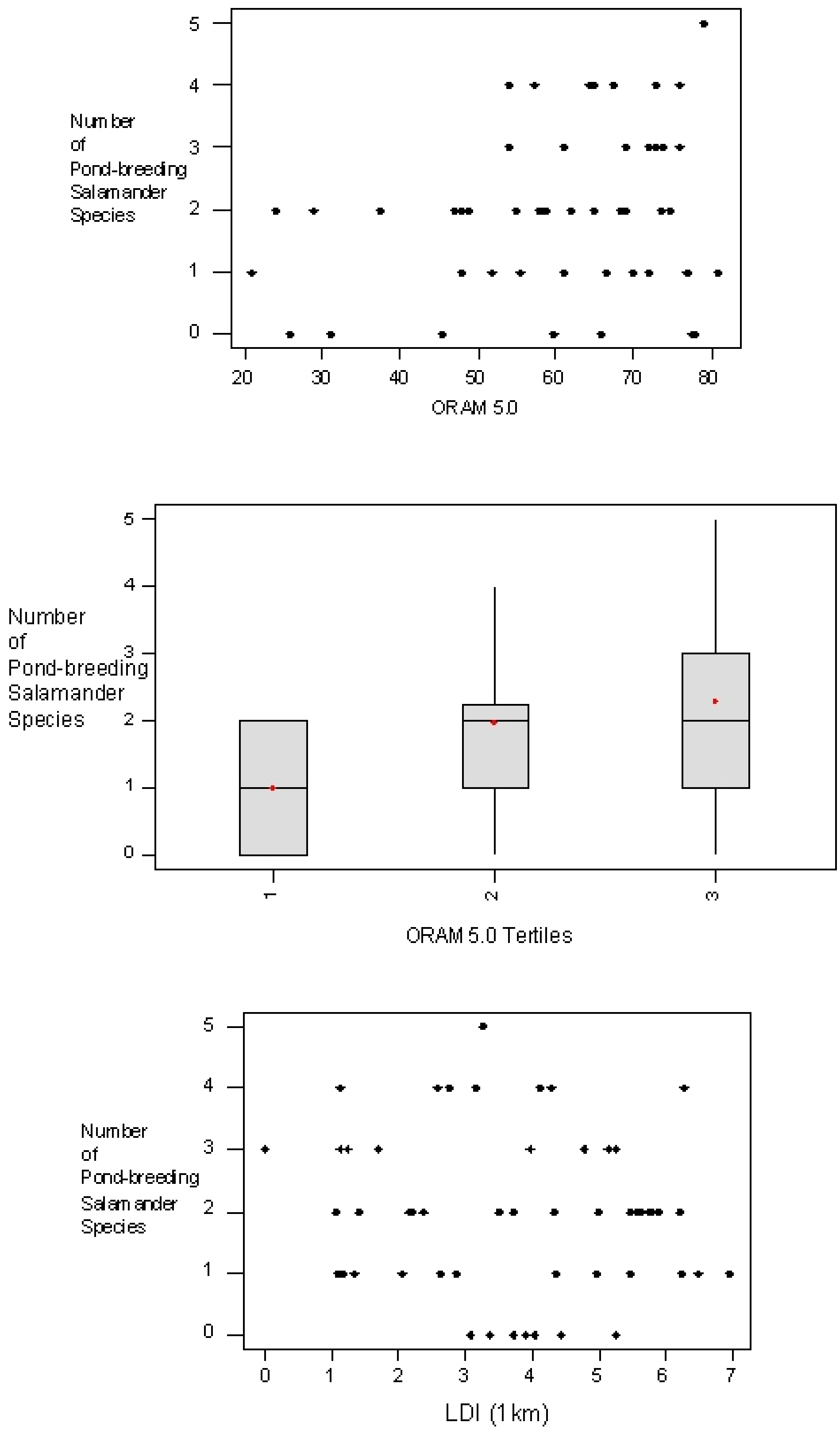


Figure 4. Summary plots of Number of Pond-breeding Salamander Species (NPBSS) metric. Scatter plots are NPBSS versus ORAM v. 5.0 score (df = 52, F = 3.93, R^2 = 7.0%, p =< 0.001) or LDI score (df = 52, F = 1.47, R^2 = 2.8%, $p < 0.001$). Box and whisker plots represent ORAM score tertiles (thirds).

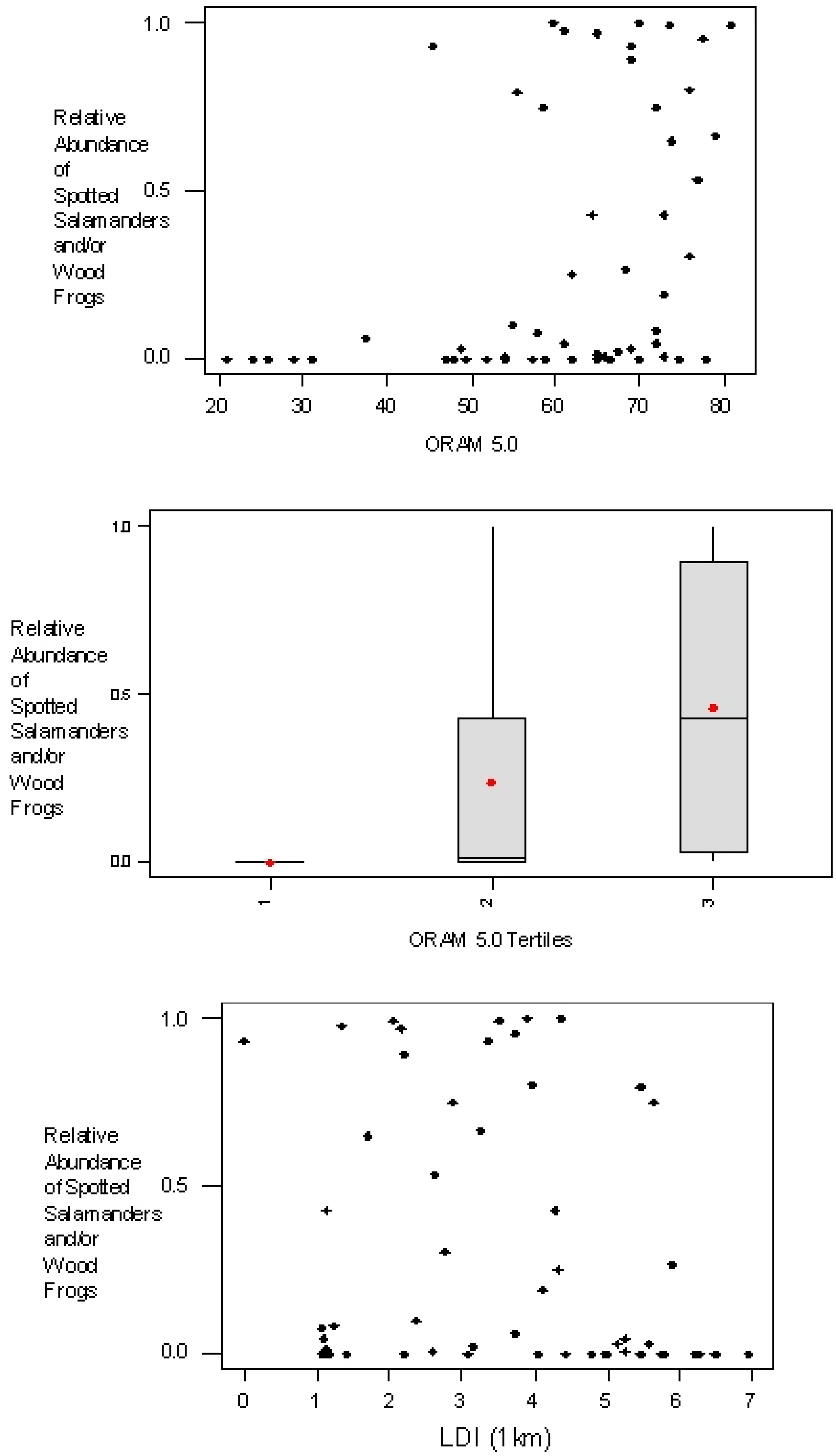


Figure 5. Summary plots of Relative Abundance of Spotted Salamanders and/or Wood Frogs (RASW) metric. Scatter plots are RASW versus ORAM v. 5.0 score (df = 52, F = 8.92, R^2 = 14.6%, p =< 0.001) or LDI score (df = 52, F = 3.00, R^2 = 5.5%, $p < 0.001$). Box and whisker plots represent ORAM score tertiles (thirds).

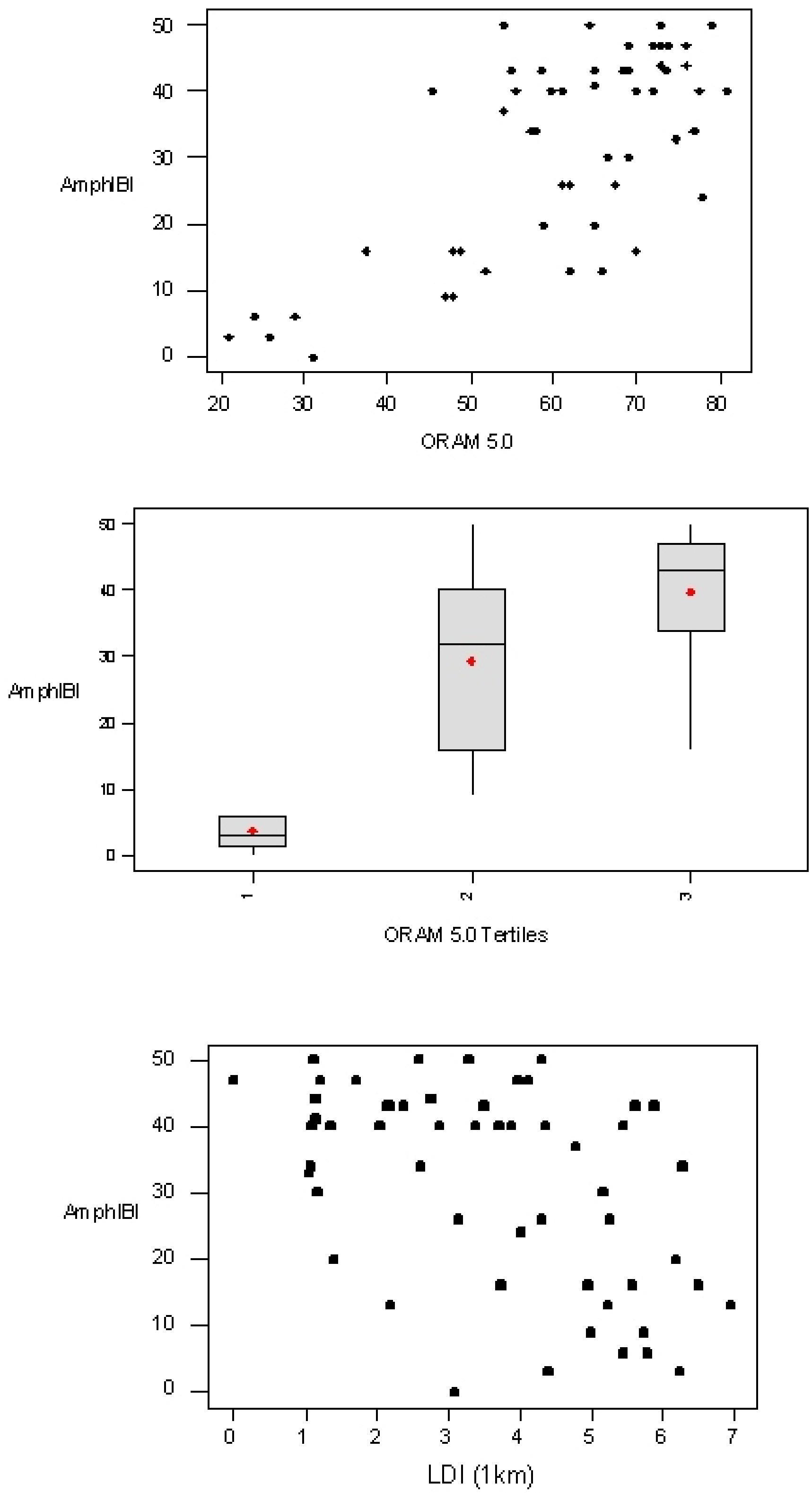
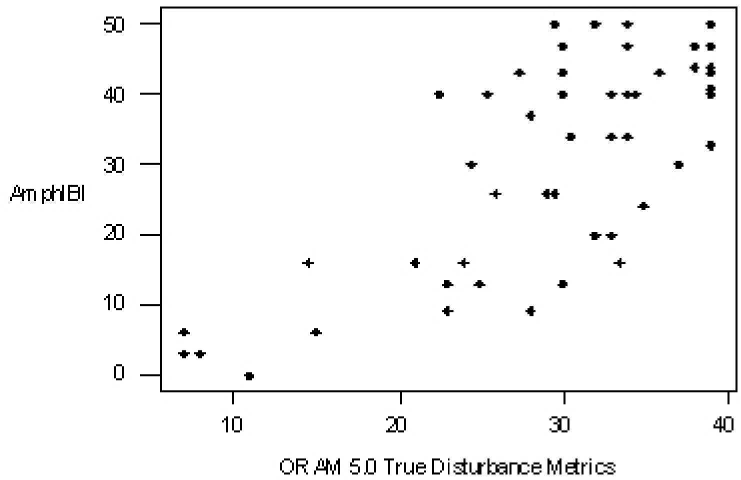
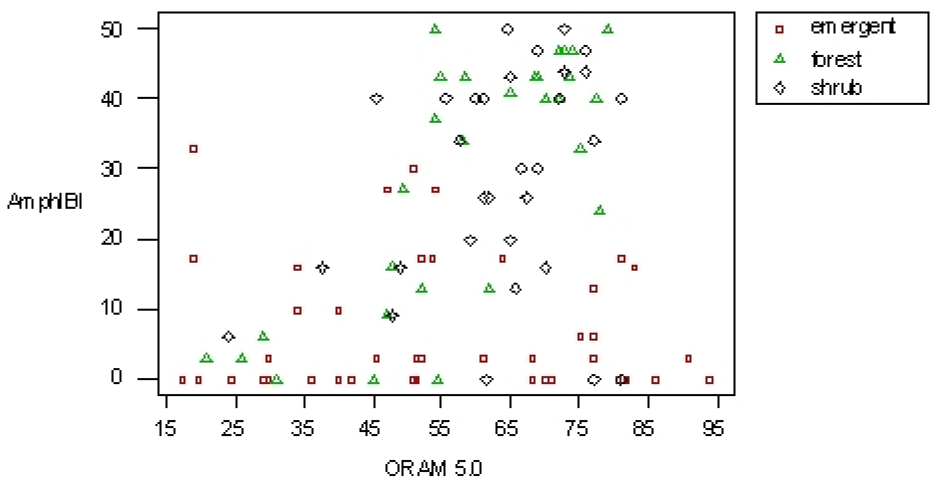


Figure 6. Summary plots of Amphibian Index of Biotic Integrity (AmphIBI). Scatter plots are AmphIBI versus ORAM v. 5.0 score (df = 52, F = 52.61, R^2 = 50.3%, p =< 0.001) or LDI score (df = 52, F = 16.83, R^2 = 24.5%, p < 0.001). Box and whisker plots represent ORAM score tertiles (thirds).





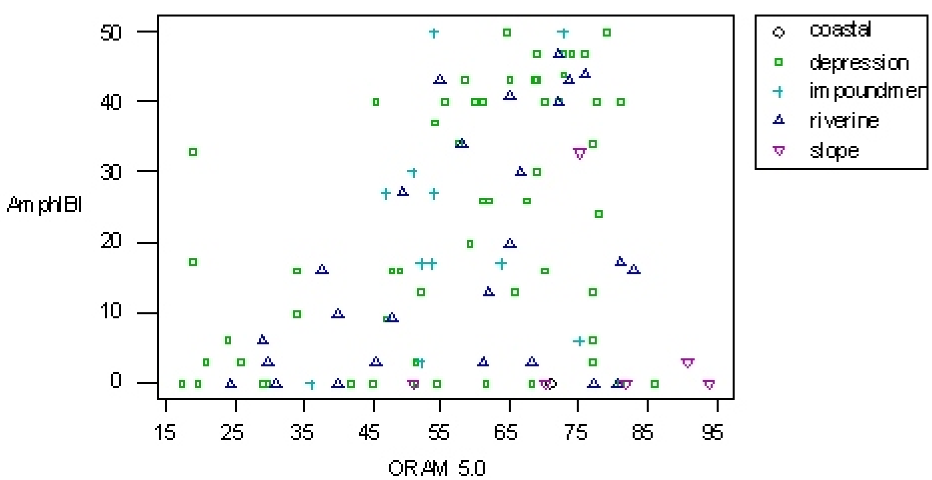
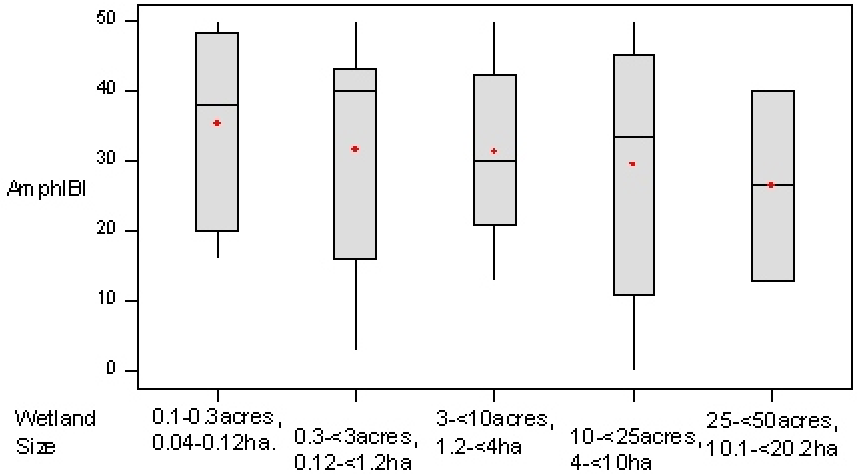


Figure 7. Summary plots of Amphibian Index of Biotic Integrity (AmphIBI). Scatter plots are AmphIBI versus ORAM v. 5.0 true disturbance metrics score (df = 52, F = 69.56, R^2 = 57.2%, p =< 0.001), AmphIBI versus ORAM v. 5.0 by vegetation class for all sites, and AmphIBI versus ORAM v. 5.0 by HGM class for all sites.



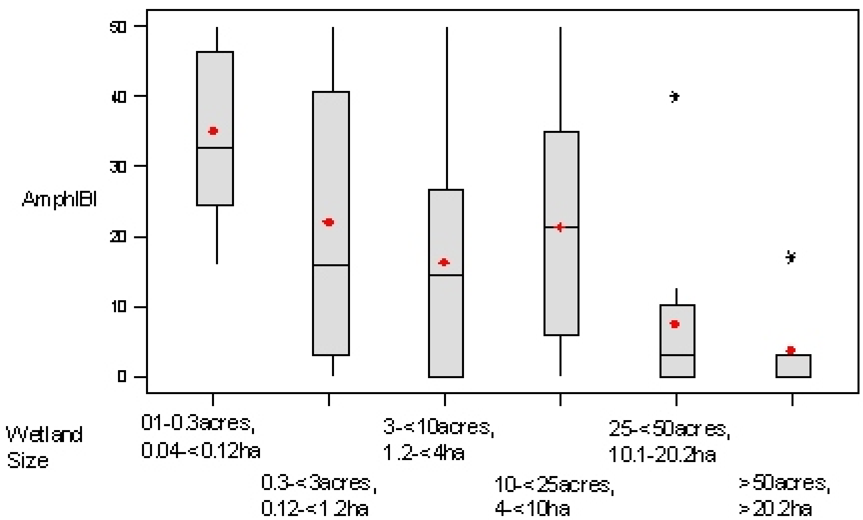


Figure 8. Summary plots of Amphibian Index of Biotic Integrity (AmphIBI). Box plots are AmphIBI versus wetland size classes for woody sites and AmphIBI versus wetland size classes for all sites. Means are indicated by solid circles. A line is drawn across the box at the median. The bottom of the box is the first quartile (25%) and the top of the box is the third quartile (75%).