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An Ecological Assessment of Wetlands Using Reference Sites
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Introduction

The principal goal of the Clean Water Act is to restore and maintain the chemical, physical and biological integrity of the nation's surface waters, including wetlands. In order to achieve this goal we must not only understand the status of wetland resources but also the effects that human activities have on their health and sustainability. This level of understanding can be obtained through the establishment and monitoring of wetland reference sites. This project was designed to begin development of a wetland biological monitoring and assessment program. We selected a total of twenty one depressional wetlands that varied considerably in their level of apparent local impact. We performed a series of rapid functional assessment techniques as well as quantitative biological assessments at each of the wetland reference sites. This included surveys of the vascular plant species, development of sampling techniques as well as characterization of the macroinvertebrate and amphibian communities, measurements of plant and biomass production. Traditional forest ecosystem metrics were also employed in the forested wetland sites, including diameter at breast height (Mueller-Domboise and Ellenberg, 1974). We used the data from the first year of the study to determine the efficacy of field methodologies and as baseline data for the expansion of sampling sites in 1997.

Several floristic metrics were used to assess the vegetation communities at each of twenty-one wetland sites in 1996 and 1997. One of these metrics, the Floristic Quality Assessment Index (FQAI; Andreas and Lichvar, 1995), has been used in an Ohio Environmental Protection Agency (Ohio EPA) pilot project at a series of riverine wetlands which showed a high correlation between

FQAI scores and the degree of site disturbance (Fennessy et al., 1998). Another previous study showed FQAI scores ranged from a value of 9 in an old field community (highly disturbed), to a value of 28 in a degraded prairie, to a high value of 50 in a high quality prairie (Wilhelm and Ladd, 1988). These results indicate a correlation between FQAI scores and the degree of site disturbance, and point to the FQAI as a potentially promising biological indicator in a wetland biological assessment program.

Ohio EPA has previously determined that the use of biological criteria to indicate the integrity of aquatic ecosystems (such as those based on macroinvertebrates and vertebrates) offers a holistic, systems approach to surface water quality assessment and management, and is appropriate for assessing the types of subtle impacts that can occur in aquatic ecosystems. For example, aquatic macroinvertebrates not only integrate a variety of environmental influences (chemical, physical, and biological), but complete their life cycles in the water body and, as such, are continuous monitors, or integrators, of environmental quality. In addition, amphibians have the potential to serve as indicators of environmental health because their geographic ranges, behaviors, and life cycles are strongly influenced by water depth, duration, and chemistry (Ohio EPA, 1987a). Ohio EPA's success in using biocriteria in streams and rivers (Ohio EPA, 1990 and Yoder, 1989) has illustrated the need to develop similar methodologies for wetlands.

There is currently very little information regarding the quality of Ohio's wetlands. To help rectify this situation Ohio EPA has developed water quality standards for wetlands. These standards necessitate the accurate assessment of wetland ecosystem functions, sensitivity to disturbance, rarity, and irreplacability. The ecological data gathered in 1996 and 1997 have furthered Ohio EPA's goal of developing a biological assessment program for wetlands.

Materials and Methods

Project 1: Site Selection, Functional Assessment, Vegetation, Chemical and Physical Measurements of Wetland Sites

Site Selection and Development of a Rapid Assessment Methodology (RAM)

A total of twenty-one wetland reference sites were selected based on the wetland hydrogeomorphic (HGM) classification (Brinson, 1993) and other considerations of the landscape (e.g. ecoregion, position in the watershed, and site accessibility). Wetlands were also selected based on their degree of disturbance; i.e., sites were chosen to span a gradient of disturbance from least-impacted to impaired. Ten of these sites were selected for preliminary study in 1996 and an additional 11 sites were selected for study in 1997. Three of the twenty-one wetland sites were sampled for two consecutive years to quantify the potential effects of temporal variability on the results of the assessment methodologies we used. Local experts from the Ohio Department of Natural Resources (ODNR) were consulted during site selection because of their knowledge about the wetlands of Ohio. ODNR experts were especially helpful in identifying particular wetlands, during each year of the study, that were likely to exist in a variety of disturbance regimes and intensities. Selecting a group of wetland sites along such an environmental gradient was a critical component of our experimental design.

Each site was initially evaluated using three rapid functional assessment methodologies, originally developed by other state agencies. These included:

1. Oregon Freshwater Wetland Assessment Methodology (Roth et al., 1993)
2. Washington State Wetlands Rating System (Hruby et al., 1993)
3. Minnesota Routine Assessment Method For Evaluating Wetland Functions (USACE, 1988)

The purpose of using these methods was to determine which type of functional assessment methodology was best suited to Ohio wetlands and to avoid "reinventing the wheel" by developing a rapid assessment from scratch (Adamus, pers.comm).

The Oregon Methodology is intended for planning and educational purposes but, "not for detailed impact analysis on individual wetlands" (Roth et al., 1993). Assessment with this method consisted of answering a series of "function and condition assessment questions" at each of the wetland sites. The wetland in question was then rated using the Oregon Methodology, based upon the answers to the survey questionnaire, as either "high", "mid", or "low" with regard to each of its nine functional qualities.

The Washington Rating System was the most rapid to perform (of the three methods) and consisted of a series of questions regarding the ecological structure and functions of the wetland in question. The Washington Methodology provides a quantitative score and was designed to be used for management decisions and as a means to apply wetland-specific protection standards in a designated area (Hruby and McMillan, 1993). The output of the Washington Methodology is a single score that ranges from 0 to 60. The wetland in question is then designated as one of four possible categories, based upon its score.

The Minnesota methodology was designed to, "differentiate between wetlands based on their sensitivity to disturbance, rarity, irreplacability, and the functions they provide" (USACE, 1988). The procedure for this methodology is similar to the Oregon methodology in that a series of function-type questions are posed. A relative "functional level" for the wetland was determined after answering the questionnaire, yielding a rating of "low", "medium", "high", or "exceptional" for each of nine functions.

During the analysis phase of the 1996 rapid assessment data, the three assessment methodologies were compared to determine their potential for use in Ohio. After using the Washington Methodology at the 1996 wetland sites, and comparing the results with the methodologies from

Oregon and Minnesota, a determination was made to modify the Washington State Wetlands Rating System to meet the particular conditions of Ohio wetlands. A work group was established to refine the Washington rapid assessment methodology specifically for Ohio and was comprised of both private and public sector contributors. The resultant Ohio Wetland Assessment Method (OWAM) is currently being tested by Ohio EPA's Division of Surface Water as an assessment tool to place wetlands in one of three possible antidegradation categories (Ohio Administrative Code Rule 3745-1-54).

Vegetation Surveys

1996 Field Season - The plant communities at the ten depressional wetland reference sites were intensively sampled during the summer and fall of 1996. Comparison of the 1996 FQAI values obtained by surveying vegetation in the summer and fall of 1996 indicated that the additional species obtained in the fall survey did not substantially change the FQAI scores of the wetlands (see results and discussion). Therefore, in 1997 we performed vegetation surveys only during the summer sampling period. The vegetation survey data was also used to assess potential indicators (or structural variables) of wetland function (Magee et al., 1993; Kentula et al., 1992). These indicators included plant species richness, percent cover of herbaceous vegetation, leaf litter depth, leaf litter cover, estimates of herbaceous plant community biomass production, diameter at breast height and dominance of tree species.

A nested quadrat sampling method was used to survey the herbaceous plant and tree species at each of the wetland sites. Thirty 0.45-meter^2 quadrats were established consecutively along transects that passed through the approximate centroid of the wetland area. The quadrats were evenly spaced, approximately 20 to 30 m apart depending on wetland size. Due to the spacing of the quadrats and the constraints of wetland size, we usually sampled along two transects that were essentially perpendicular to each other. Within each 1-meter^2 quadrat the percent cover of each plant species, litter cover, and litter depth were recorded. In the 1996 forested sites, trees within a 10-meter^2 quadrat (with the same center point as the 1-meter^2 quadrat) were identified and their

diameter at breast height was recorded. The plant data collected at each wetland was used to calculate Floristic Quality Assessment Index (FQAI):

$$I=\frac{R}{N}\sqrt{N} \quad \text{or} \quad I=\frac{R}{\sqrt{N}}$$

Where I = FQAI Score

R = Sum of Coefficients of Conservatism (C of C)

N = Number of Native Species (N-native)

In addition, the perennial:annual ratio, percent native species, plant species richness, and percentage of each plant indicator status (Reed, 1988) were also calculated at each site. Tree data were used to calculate size class distribution, relative density, relative basal area, and importance percentage on a per species basis at each of the wooded sites. Additionally, we analyzed the relationship of the (Ohio Wetland Assessment Method (formerly the Washington State Wetlands Rating System) score with the FQAI values at each of the wetland sites.

1997 Field Season - Analyses of the 1996 tree data prompted us to expand the tree survey and, in the 1997 forested sites, trees within a 100-meter^2 quadrat (with the same center point as the 1-meter^2 quadrat) were identified and their diameter at breast height was recorded. All other plant sampling methodologies practiced in 1996 were repeated in 1997 at all of the wetland sites.

Biomass Production

Total aboveground vascular plant biomass was collected at all sites that were dominated by emergent vegetation in 1996 and 1997. One of these wetlands (Calamus) was sampled in both years. Harvesting of the above-ground biomass at each of the wetlands was conducted so as to coincide with the period of peak biomass, in this study early- to mid-August. At 10 m intervals, along randomly established transects, all of the aboveground plant material in a 30 cm^2 quadrat was clipped at soil level. Where it was present, floating leaved and submersed plant material was

included with the harvested emergent vegetation. The sample from each quadrat was individually bagged and oven dried at 60° C for a minimum of 72 hours to a constant dry mass. The mean dry mass of all harvested quadrats per site was measured and converted to g/m^2. The relationship between the FQAI score of a wetland and the mean biomass production was analyzed using regression analysis.

Dissolved Oxygen Measurements

A pilot study was conducted in 1996 to test the efficacy of using two field sampling techniques for measuring diurnal dissolved oxygen and temperature in each of the reference wetlands. Dissolved oxygen concentration and water temperature were recorded continuously over a 48-hour period at four of the reference wetlands (July 31-August 2, 1996) using a single probe unit and stirrer (YSI model 56 DO) in each wetland. The probe-stirrer assembly was secured to a metal stake 12 cm beneath the surface of the water, each probe tip was equipped with a standard membrane, and calibrated per Ohio EPA Field Procedure B1.2.2 rev.2 (1993). Dissolved oxygen concentration was also recorded hourly for at least two consecutive days at eight wetland sites in early August using an automated data logger (Hydrolab Datasonde I). Two of the wetlands were dry by late July, precluding the use of the datasonde. Each datasonde unit was equipped with a dissolved oxygen probe with a low-flow membrane and calibrated prior to placement in the field per Ohio EPA Field Procedure B1.4.1, rev.2 (1993). Each datasonde unit was tied securely to a stationary object (usually a metal stake) at each of the wetland sites and, taking care to prevent burial in the substrate, the probe tip was placed 10 cm beneath the surface of the water. Malfunctions by several of the units in the field precluded the analysis of this data.

Soil Chemistry and Particle Size Characterization

Soil samples were collected at twenty wetland study sites during summer, 1997 (note that site entry at the County Road 200 wetland was denied mid-way through the study period precluding sample collection). Soil samples were randomly collected from three locations within each wetland. Two soil samples were collected between the edge of the wetland and any standing water (i.e., where inundation was intermittent) and the third soil sample was collected from a

central location that was typically still inundated at the end of summer. Prior to collecting each sample, all litter material was removed from the surface of the soil. A plastic trowel was used to excavate soil down to 10 in. beneath the soil surface. Particularly in the edge regions of the wetland, large roots and pieces of organic material, such as twigs and leaves were often intermixed with the substrate; obvious pieces of debris were removed by hand in the field. Field soil samples were stored at 4° C in sealed plastic containers prior to laboratory analysis per Ohio EPA Field Procedures.

Hydrology

A graduated staff gauge was installed at each of the sites that were sampled in 1997 in order to measure water levels. Staff gauges were placed in what was determined to be the lowest point in the wetland basin so as to measure the depth to its lowest point. Water level measurements were taken during the growing season as often as staff resources allowed, with an average of approximately every 30 days.

Spatial Analysis

A landscape level analysis was performed in the vicinity of each of the wetland sites studied in 1996 and 1997. All wetlands within a 1 km radius of each study site were identified using National Wetland Inventory (NWI) Maps (USFWS, 1995). The edge-to-edge linear distance between each study wetland and all surrounding wetlands was determined. Areal measurements of wetlands within 1 km of each of the study wetlands were made by digitizing (Summagraphics, SummaSketch) the outline of each wetland of interest on a 2X enlargement of the NWI map region and recording the scale-corrected area (AutoDesk, AutoCAD v.9.0).

Statistical Analysis

As described below, the Ohio EPA tested a method developed by the State of Washington's Department of Ecology (Hruby et al., 1993) and has begun its adaptation for use in Ohio (the Ohio Wetland Assessment Method). A serious question in the development of such assessment tool is its sensitivity, i.e. its ability to distinguish between wetlands of differing quality

and to properly evaluate (categorize) a site. Ohio EPA has also been evaluating the use of the Floristic Quality Assessment Index (FQAI) to do the same.

Several analyses were performed to determine whether the ordered differences in FQAI scores occurred such that the FQAI scores for proposed Category 1 wetlands were less than Category 2, were less than Category 3 wetlands as defined by the Ohio Wetland Assessment Method. This would provide independent support for proposed breakpoints developed for the Ohio Rapid Assessment Method. In addition, the FQAI and RAM scores were evaluated to determine whether these two assessment scores are positively correlated with each other using a regression test.

Several statistical analyses were performed. Because the category or quality of each wetland was determined *a priori* 1) qualitatively during the site selection process, and 2) quantitatively by the RAM score, the Jonckheere-Terpstra Distribution Free Test for Ordered Alternatives was used to evaluate differences in the FQAI scores for the different categories of wetlands as described by Holland and Wolfe (1997). The Jonckheere-Terpstra Test is a nonparametric method that can test whether the FQAI score for a Category 1 wetland is less than or equal to a the FQAI score for a Category 2 wetland is less than or equal to a Category 3 wetland, with at least one strict inequality. The "large sample approximation" recommended by Hollander and Wolfe (1998) was used which yields only an approximate alpha level for the test.

Because of the unequal sample sizes, a multiple comparison technique to detect which inequalities of the Jonckheere-Terpstra test are significant is not readily available. Therefore, the FQAI scores of the different categories were analyzed using the Kruskal-Wallis test and its multiple comparison counterpart (Critchlow-Fligner) as specified in Holland and Wolfe (1997).

Finally, for the six sites that were sampled more than once, the FQAI scores were analyzed using the Kruskal-Wallis test to determine whether sampling at different times during the year and in different years significantly affected the FQAI score. Minitab Version 9.2 was used to calculate

the Kruskal-Wallis test.

Project 2A: Development of Methodology For Sampling Macroinvertebrates in Wetlands

The initial step in our effort to develop a macroinvertebrate monitoring program was to select the best method for field sampling macroinvertebrates in Ohio wetlands, drawing from the existing literature and methods currently used in other regions of the U.S. Per the phase 1 portion of the project, three methods of macroinvertebrate sampling were conducted at each of ten wetland study sites in 1996: 1) Hester-Dendy (HD) artificial substrate samplers, 2) qualitative sampling using a dip net to collect as many taxa as could be found in one hour, 3) funnel traps. Funnel traps were the primary sampling method that we used for amphibians but they also proved to be effective in sampling a wide variety of macroinvertebrates.

The funnel trap resembles a minnow trap and is made of aluminum window screen. The funnel traps were constructed by stapling a 45 by 70 cm piece of screen to form a cylinder 45 cm long and 20 cm in diameter. Fiberglass window screen was cut and stapled to form a cone that covered each end of the aluminum screen cylinder. A 4 cm diameter hole was cut in the end of the fiberglass cone to allow organisms to enter the trap; bait was not used in the traps. The trap was submerged in the wetland in contact with the bottom so that organisms could swim or crawl through the cone and into the trap where they were unable to escape.

During the 1996 sampling season, we placed a single Hester-Dendy artificial substrate sampler in each wetland. The samplers remained in each wetland for six weeks. When the HD sample was collected, a qualitative sample was also collected. Field procedures followed standard Ohio EPA methods (Ohio EPA, 1987a). While HD samples are placed in streams where the water velocity is at least 0.3 feet per second, in wetlands this was not possible. We placed the HD samplers in locations where they would remain submerged for the six week colonization period. All of the wetlands were sampled with HD's during April and May. Three wetlands that held water in July

and August were sampled with HD samplers a second time.

The qualitative sample involved collecting all the different macroinvertebrate taxa that could be found from all habitat types during a one hour sampling period. A triangular ring-frame dipnet was used to sample most of the available habitat. Woody debris and aquatic macrophytes were visually inspected for macroinvertebrates that dipnet sampling could not readily collect.

Funnel traps were used approximately every month between March and August in each of the wetlands during 1996. We generally used ten traps per wetland, but this varied from 5-15 when we attempted to determine the sampling effort necessary to adequately characterize the fauna of a wetland. We measured the perimeter of the wetland and spaced the traps proportionally around the edge of the wetland. The traps were placed near the shore in water just deep enough to submerge the trap. The traps remained in the wetland for approximately 24 hours. The contents of each trap were analyzed separately and all organisms were identified and counted. The number of each taxa collected was then expressed as a number collected per 100 hours of trapping time to compare the relative abundance from one site to another. The taxonomic keys used for identification and the level of taxonomy for specific groups was per existing Ohio EPA procedures (Ohio EPA, 1987b).

In 1996 we collected 13 HD samples, 13 qualitative samples, and 399 funnel trap samples from 10 wetlands. . Based on results from our 1996 data we did not collect HD samples in 1997, but we collected a qualitative sample every time the funnel trap samplers were deployed. In 1997 we sampled 15 wetlands, with 4 of these being repeats of 1996 sites. During the 1997 field season, we collected 46 qualitative samples and 563 funnel trap samples.

Project 2B: Development And Implementation Of Amphibian Sampling Protocol In Wetlands

Funnel traps were used to sample amphibian communities in the wetlands. The same traps and procedures used for sampling macroinvertebrates with traps, as described above, were used to sample both adult and larval amphibians. The sampling period and sites are the ones used for macroinvertebrate sampling. Adult amphibians were identified, counted and released in the field. For larval forms in which field identification was not possible, specimens were preserved in 70% ethanol for laboratory identification. Voucher specimens were preserved in 10% formalin and are maintained at the Ohio Environmental Protection Agency's Ecological Assessment Unit in Columbus, Ohio. Larval and adult salamanders were identified using taxonomic keys (Pfingsten & Downs, 1989). Frogs and tadpoles were identified using taxonomic keys (Walker, 1946). The same samples that were used for macroinvertebrates were used for amphibians, so the sampling procedures and effort have already been summarized. A discussion of the sampling results and potential metric development will combine the macroinvertebrate and amphibian work.

Results and Discussion

Project 1: Site Selection, Functional Assessment, Vegetation, Chemical and Physical Measurements of Wetland Sites

Site Descriptions

A range of wetlands were selected for inclusion in this study which spanned the gradient from least-impacted to impaired. These sites were qualitatively evaluated as to their relative level of disturbance based on obvious indicators of disturbance (particularly hydrological modification), site history (e.g., from landowners), surrounding land use, the types of buffers present, and best professional judgement.

The twenty-one wetland sites selected for study in 1996 and 1997 are listed below along with a brief description of their physical and floristic attributes. Tree dominance was based upon importance percentages (see Appendix).

Ackerman Wetland - Sampled in 1997

Ackerman Wetland (39°58'43"N, 83°32'30"W) is a seasonally flooded (Cowardin et al., 1979) hardwood swamp located approximately 0.5 km north of the intersection of Houston Pike and Lundy Lane and directly east of the intersection of Lundy Lane and Arbogast Road in eastern Clark Co., Ohio (Pleasant Township), and is approximately 8.0 ha in area. The site is bounded on the west by Lundy Lane and is surrounded on the north, east and south by farmland used for row crop production. There are three linked pools, but only the southern two are under study. These pools consist of open water with little vegetation other than willow (*Salix* spp.) and cottonwood saplings (*Populus deltoides*) in the center along with numerous downed and standing dead trees. The pools are collectively fringed by a forested area which includes box elder (*Acer negundo*), honey locust (*Gleditsia triacanthos*) and cottonwood (*Populus deltoides*) trees. The vegetation around the open water is dominated by reed canary grass (*Phalaris arundinacea*) and smartweeds (*Polygonum* spp.) while the forest understory is predominately dogwoods (*Cornus* spp.) and tree

seedlings of various species. An intermittent stream enters the northernmost point of the site and a drain tile is located at the southernmost point of the site. No surface outflow was noted during field visits, however. The west and south sides of the site are underlain by Miami silt loam, with Brookston silty clay loam in the center and two pockets of Kendallville silt loam to the north and east (Petro, 1958).

Blanchard Oxbow Wetland - Sampled in 1996

Blanchard Oxbow (40°70'55"N, 83°33'15"W) is a floodplain forest, approximately 2 ha in area, located 0.04 km west of the Blanchard River in Hardin County, Ohio (Jackson Township). The steep slope of an adjacent railroad bed borders the southern edge of the forest and row crops surround the remainder of the wetland area, partially isolating the wetland from the Blanchard River. The forest is dominated by slippery elm (*Ulmus rubra*) and, to a lesser extent, white oak (*Quercus alba*). The northern half of the site is underlain by Sarnac silty clay loam and the southern half of the site contains Eel silt loam; soil in both regions exhibit qualities that indicate occasional flooding (Miller and Robbins, 1994). The entire site was flooded during spring but only the oxbow channel remained flooded through September.

Calamus Wetland - Sampled in 1996 and 1997

Calamus Wetland (39°35'2"N, 83°00'3"W) is a permanently flooded (Cowardin et al., 1979) depressional wetland approximately 6.0 ha in size and located 0.6 km south of the intersection of SR104 and SR22 in Pickaway Co., Ohio (Wayne Township). The site is a large emergent wetland with a forested perimeter (ranging from 15 to 50 m wide) that nearly encircles the entire site. In the southwestern corner of the wetland lies a small wet meadow that may be partially flooded on occasion. The southern edge of the wetland lies along a 5 m high abandoned railroad bed and the western edge is abutted by a two-lane road with relatively moderate car traffic. The remainder of the wetland is adjacent to agricultural land that is presently used for row crop production. The forested area is dominated by green ash (*Fraxinus pennsylvanica var. subintegerrima*) and silver maple (*Acer saccharinum*). Within the forested understory, vegetation

is dominated by halberd-leaved rose mallow (*Hibiscus militaris*) and smartweeds (*Polygonum* spp.). In the central ponded area southern pond lily (*Nuphar advena*) and duckweeds (*Lemna* spp.) are common. Soils have not been classified in the central ponded region of the wetland. The soils of the forested regions on the eastern and western edges are classified as Montgomery silty clay loam which are hydric, and those underlying the wet meadow area are Sleeth silt loam, possess the qualities of occasionally flooding, but are not hydric (Kerr and Christman, 1980).

Callahan Wetland - Sampled in 1997

Callahan Wetland (39°57'23"N, 83°33'34"W) is a seasonally flooded (Cowardin et al., 1979) forested/scrub shrub wetland located approximately 0.8 km north of the intersection of Callahan Road and Houston Pike in Clark Co., Ohio (Pleasant Township). It is roughly 1.2 ha in area. The site is dominated by a dense stand of buttonbush (*Cephalanthus occidentalis*) in the center with a forested perimeter that is predominately silver maple (*Acer saccharinum*), sugar maple (*Acer saccharum*) and green ash (*Fraxinus pennsylvanica var. subintegerrima*). The forest is then surrounded by agricultural fields used primarily for row crop production. The site is underlain by Miami silt loam with a small area of Brookston silty clay loam in the southeastern corner of the wetland (Petro, 1958).

Cessna Wetland - Sampled in 1996

Cessna Wetland (40°42'50"N, 83°37'59"W) is a seasonally flooded depressional area, of approximately 2 ha, without any surface water connections to streams or rivers. The wetland is located approximately 0.08 km northeast of Cessna Creek in Hardin County, Ohio (Pleasant Township). The wetland site is surrounded by row-crop agriculture and a small gravel parking area. There is a central ponded area at Cessna Wetland, densely covered by buttonbush (*Cephalanthus occidentalis*), that is encircled by a 30 to 70 m wide forested strip. The site has a mowed access road that leads to the edge of the ponded area and there is some evidence of refuse dumping. The forested region of Cessna Wetland was dominated by silver maple (*Acer saccharinum*) but had a considerable amount of slippery elm (*Ulmus rubra*), swamp white oak

(*Quercus bicolor*), and willow (*Salix* sp.). The dominant understory herbaceous species present during the summer months were false nettle (*Boehemeria cylindrica*) and moneywort (*Lysimachia nummularia*). The soils at this site have been classified as Pewamo silty clay loam (Miller and Robbins, 1994).

County Road 200 Wetland - Sampled in 1996

County Road 200 Wetland (40°33'20"N, 83°43'56"W) is a shallow-to-deep depressional wetland, of approximately 0.1 ha, located 0.16 km east of the intersection of County Road 85 and County Road 200 in Hardin County, Ohio (McDonald Township). A two-lane road (County Road 200) is adjacent to the northern edge of the wetland and services the surrounding agricultural communities. The wetland contains water for most, if not all, of the year and is surrounded by a narrow (ca. 2 m) vegetated strip. Several willows are present (*Salix spp.*) along with green ash (*Fraxinus pennsylvanica* var. *subintegerrima*) on the edge of the ponded area and the herbaceous community was dominated by reed canary grass (*Phalaris arundinacea*). Soil at this site and the adjacent farm field is classified as Pewamo silty clay loam (Miller and Robbins, 1994).

Dever Wetland - Sampled in 1997

Dever Wetland (39°59'9"N, 83°10'28"W) is a seasonally flooded (Cowardin et al., 1979) depressional wetland located approximately 120 meters north of Renner Road and 300 meters east of Alton Road in northwest Franklin Co., Ohio (Brown Township). It is approximately 1.2 ha in area. The site is an emergent wetland dominated by common cattail (*Typha latifolia*) with a few black willows (*Salix nigra*) and peachleaf willows (*Salix amygdaloides*) around the edge. The wetland lies in an agricultural field used for row crop production to the east, north and west. To the south and southeast the field is mowed instead of planted as the soils seem to be too wet for crops. The field is mowed up to the cattail stand and also to a larger depressional wetland that may be hydrologically connected to the one under study. The adjacent larger wetland is also dominated by common cattail. The study site is entirely underlain by Kokomo soil (McLoda and Parkinson, 1980).

Flowing Well Wetland - Sampled in 1997

Flowing Well Wetland (40°15'13"N, 83°56'53"W) is a semipermanently flooded (Cowardin et al., 1979) forested depressional wetland located immediately south of Flowing Well Road and approximately 0.7 km east of Rosewood-Quincy Road in Champaign Co., Ohio (Adams Township). It is approximately 3.2 ha in area. The site is bounded on the west by upland forest, on the east by agricultural fields and on the north by Flowing Well Road and then agricultural fields. There are also agricultural fields to the south of the wetland. An intermittent stream flows through the wetland from the southern end to the northern edge and then under the road. The site is dominated by green ash (*Fraxinus pennsylvanica var. subintegerrima*), cottonwood (*Populus deltoides*) and box elder (*Acer negundo*). There is also a large quantity of downed and standing dead trees. The site is underlain by Brookston silty clay loam, Celina silt loam and Crosby silt loam, (Ritchie et al.,1971).

Gahanna Woods Wetland - Sampled in 1996

Gahanna Woods Wetland (40°0'33"N, 83°50'12"W) is a hardwood swamp located 0.16 km north of Taylor Road, just west of Taylor Station Road in Franklin County, Ohio (Jefferson Township). This study site is a wet area, approximately 1 ha in area, surrounded by several other ponded areas within the Gahanna Woods State Nature Preserve. The forested region of the site was dominated by silver maple (*Acer saccharinum*) and green ash (*Fraxinus pennsylvanica* var. *subintegerrima*). An intermittent stream passes along the northeastern edge of the study site and during the late winter/early spring the ponded area overflows into the stream bed; during the summer and autumn there was a minimal flow of water through the adjacent stream. The eastern edge of the study site is underlaid by soils classified as Pewamo silty clay loam and the central ponded areas contain Carlisle muck (McLoda and Parkinson, 1980).

Hebron Hatchery Wetland - Sampled in 1997

Hebron Hatchery Wetland (39°56'16" N, 82°30'40" W) is a seasonally flooded (Cowardin et al., 1979) forested depressional wetland located on the property of the Ohio Department of Natural Resources Hebron Fish Hatchery in Licking Co., Ohio (Union Township).

The wetland is bounded on the south and west by dikes and on the north by a gravel lane and a manmade pond. Beyond this pond is a mitigation wetland and interstate 70. The eastern edge of the study area is a manmade trail through the forest, although the site is part of an extensive forested area which is all underlain by hydric Luray silty clay loam (Parkinson et al., 1992). In addition there is a large wet meadow to the east of the study area. The total area of the wetland study site is approximately 2 ha. The wetland is dominated by silver maple (*Acer saccharinum*), green ash (*Fraxinus pennsylvanica var. subintegerrima*) and standing dead trees. The center is open water that is dominated by lesser duckweed (*Lemna minor*), watermeal (*Wolffia columbiana*) and pondweed (*Potamogeton* spp).

Hempelman Wetland - Sampled in 1997

Hempelman Wetland (39°51'15"N, 82°42'14"W) is a seasonally flooded (Cowardin et al., 1979) forested depressional wetland with a small deep pool that persists only in the growing season. It is located immediately east of Carroll-Northern Road approximately 0.3 km south of the intersection with Busey Road in Fairfield Co., Ohio (Liberty Township). The study area is roughly 0.6 ha in area, although it is contiguous with a larger forested area with sections of hydric soils containing other seasonal pools. There is an intermittent stream that begins just at the southeast edge of the site flowing away from the wetland in a southeastern direction. The wetland is dominated by sugar maple (*Acer saccharum*), big shellbark hickory (*Carya laciniosa*) and pin oak (*Quercus palustris*). The site is underlain by Marengo silty clay loam throughout (Meeker et al.,1960).

Keller High Wetland - Sampled in 1997

Keller High Wetland (39°51'50"N, 82°38'0"W) is a semipermanently flooded (Cowardin et al, 1979) forested depressional wetland with scrub shrub and open water in the center. It is located approximately 0.6 km north of Giesy Road and 0.75 km east of the intersection with Rt. 256 in Fairfield Co., Ohio (Liberty Township). The total area of the study site is approximately 1 ha and is part of a larger upland forested area. The study area and surrounding forest is

surrounded by agricultural fields used for row crop and hay production during 1996 and 1997. The center of the wetland is dominated by southern pond lily (*Nuphar advena*) and buttonbush (*Cephalanthus occidentalis*). The dominant trees are silver maple (*Acer saccharinum*) and green ash (*Fraxinus pennsylvanica var. subintegerrima*). The wetland is underlain almost entirely by Bennington silt loam, with Thackery silt loam on the eastern edge and Cardington silt loam across the northern edge (Meeker et al., 1960).

Keller Low Wetland - Sampled in 1997

Keller Low Wetland (39°51'46"N, 82°37'39"W) is a seasonally flooded (Cowardin et al., 1979) emergent depressional wetland located in the center of an agricultural field used for row crop production. It is approximately 0.5 km north of Giesy Road and 1.0 km east of the intersection with Rt. 256 in Fairfield Co., Ohio (Liberty Township). This wetland lies east of the Keller High forested wetland mentioned above. The total approximate area of the study area is 2 ha. The wetland is dominated by common cattail (*Typha latifolia*), rice cutgrass (*Leersia oryzoides*) and woolgrass (*Scirpus cyperinus*). There are scattered black willows (*Salix nigra*) and silver maples (*Acer saccharinum*) around the perimeter. The site is underlain by Willette muck and is surrounded by Sleeth silt loam and Thackery silt loam, (Meeker et al., 1960).

Lawrence Woods High Wetland - Sampled in 1997

Lawrence Woods High Wetland (40°33'59"N, 83°37'25"W) is a seasonally flooded (Cowardin et al., 1979) forested depressional wetland with two pools surrounded by scrub-shrub in the understory. The site lies within a 200 ha forest which is part of a 424 ha preserve owned and managed by the ODNR Natural Areas and Preserves. The preserve is located on County Road 200 approximately 3.3 km west of Rt. 292 in Hardin Co., Ohio (Taylor Creek Township). The study area is roughly 3.2 ha in size and lies approximately 1.0 km north of County Road 200 in the forest beyond an old field. The forested wetland is dominated by American elm (*Ulmus americana*), green ash (*Fraxinus pennsylvanica var. subintegerrima*), silver maple (*Acer saccharinum*) and swamp white oak (*Quercus bicolor*). Buttonbush (*Cephalanthus occidentalis*) is dominant around the two pools. There is a small area along the southwest edge of the wetland

that is dominated by sedges (*Carex* spp). The site is underlain by Pewamo silty clay loam and is surrounded by Blount silt loam in the forested region (Miller and Robbins, 1994).

Lawrence Woods Low Wetland - Sampled in 1997

Lawrence Woods Low Wetland (40°33'27"N, 83°37'25"W) is a seasonally flooded (Cowardin et al., 1979) emergent depressional wetland located on the ODNR Natural Areas and Preserves property in Hardin Co., Ohio (Taylor Creek Township). The wetland is approximately 120 m north of County Road 200, east of the entrance to the preserve. It is roughly 0.8 ha in area and lies in a meadow that was formerly used as pasture for cattle. The site is dominated by small water plantain (*Alisma subcordatum*), fog fruit (*Phyla lanceolata*), sedges (*Carex* spp.), smartweeds (*Polygonum* spp.) and asters (*Aster* spp). There are a few black willows (*Salix nigra*) around the edges of the wetland. The site has an inlet on the northeast edge which may drain from the expanse of forest and other wetlands on the property. The wetland is underlain by Pewamo silty clay loam throughout (Miller and Robbins, 1994).

Leafy Oak Wetland - Sampled in 1996 and 1997

Leafy Oak Wetland (40°34'5"N, 83°34'46"W) is a temporarily flooded (Cowardin et al., 1979) forested depressional wetland located east of Rt. 265 approximately 1.25 km north of the intersection with County Road 200 in Hardin Co., Ohio (Hale Township). A two-lane road separates the wetland from nearby Wolf Creek, an intermittent stream. The study site is approximately 3.8 ha and lies along the western edge of a larger forested area, approximately 75 ha in area. Portions of the study site exhibit evidence of timber extraction including sawn trees and abandoned roads. To the west of the study site a 100 m wide meadow separates the forested wetland from the nearest road (Rt. 265). The wetland consists of a single pool that remained inundated through early summer, surrounded on all sides by a forest. During the later portions of the summer Leafy Oak Wetland water levels decreased to a point where two distinct pools were observed. The center of the wetland is sparsely forested and dominated by buttonbush (*Cephalanthus occidentalis*). There is an intermittent stream mapped on this site although no water was observed entering the site during field visits. The central, predominantly ponded,

region of the wetland is surrounded on all sides by forest. The forested region is dominated by American elm (*Ulmus americana*), swamp white oak (*Quercus bicolor*), and green ash (*Fraxinus pennsylvanica var. subintegerrima*). The cursed crow-foot sedge *(Carex crus-corvi)*, a state endangered species, is found at this site. The site is underlain by Pewamo silty clay loam throughout (Miller and Robbins, 1994).

McKinley Wetland - Sampled in 1996

McKinley Wetland (39°50'8"N, 82°54'45"W) is a floodplain forest, approximately 1 ha in area, located on one of many local intermittent tributaries to Big Darby Creek in Franklin Co. (Pleasant Township). The ponded area at this site may have formed as a result of impoundment by an earthen driveway located at the southern edge of the wetland. The wetland is bordered on its western edge by a two-lane paved road with relatively moderate traffic activity and on the eastern edge by a steep 15 m embankment. During storm events, water flows primarily from the northern forested region of the wetland toward the southern ponded region. The dominant floating leaved plants present during the growing season were southern pond lily (*Nuphar advena*) and duckweed (*Lemna minor*). In the northern forested area, lizard tail (*Saururus cernuus*) was dominant in the understory during mid- to late-summer. The eastern half of the site was dominated by aggregates of buttonbush (*Cephalanthus occidentalis*) and the regions along the perimeter of the wetland were dominated by willow (*Salix* sp.) and boxelder (*Acer negundo*). The soils underlying McKinley Wetland are classified as Sloan silt loam and exhibit qualities that indicate frequently flooded conditions (McLoda and Parkinson, 1980).

Mishne Wetland - Sampled in 1996

Mishne Wetland (39°54'36"N, 83°10'10"W) is an approximately 0.2 ha, seasonally flooded, depressional area dominated by emergent vegetation. This site is located 0.08 km west of Hellbranch Run in Franklin County, Ohio (Prairie Township). The wetland is entirely surrounded by agricultural land that was used for wheat production in 1996. The entire wetland was dominated by the common cattail (*Typha latifolia*) and pink knotweed (*Polygonum pensylvanicum*). Water levels were at their highest during the spring but the soil remained fairly

moist throughout August. The soils underlying Mishne Wetland are classified as Crosby silty clay loam (McLoda and Parkinson, 1980).

Rickenbacker Wetland - Sampled in 1996

Rickenbacker Wetland (30°50'8"N, 82°54'45"W) is a seasonally flooded depressional area, approximately 0.8 ha in area, located 0.16 km northwest of two intermittent tributaries of Walnut Creek in Franklin County, Ohio (Madison Township). The study area is flooded for the entire year and is adjacent to a wooded area to the south. Residential dwellings, agricultural land, and a two lane road, with relatively heavy car traffic, encompass the remainder of the wetland perimeter. Relatively few trees were present on the edge of this wetland site but several willow trees (*Salix* sp.) were growing in the center of the flooded area. Vegetation cover was dominated by duckweed (*Lemna minor*) in the deeper areas and on the perimeter by several sedge species (*Carex* spp.) and two species of rush (*Juncus* spp.). We also observed a threatened sedge (*Carex lupuliformis*) at this study site. The soils underlying the study site are classified as Montgomery silty clay loam (McLoda and Parkinson, 1980).

Route 29 Wetland - Sampled in 1997

Route 29 Wetland (40°2'56"N, 83°31'23"W) is a seasonally flooded (Cowardin et al., 1979) forested depressional wetland with a dense stand of shrubs in the center. It is located along the south side of SR 29 approximately 1.5 km southeast of the intersection with Rt. 187 in Champaign Co., Ohio (Goshen Township). The site is approximately 1.12 ha in area and is surrounded by upland forest providing an approximate 10 m buffer between the wetland and agricultural fields on three sides. The site is bounded on the northeast edge by a thin strip of meadow and Rt. 29. An intermittent stream flows south from the eastern edge of the site, but does not appear to be directly connected to the wetland pool. The vegetation is dominated by green ash (*Fraxinus pennsylvanica var. subintegerrima*), silver maple (*Acer saccharinum*) and buttonbush (*Cephalanthus occidentalis*). The site is underlain by Crosby silt loam and is surrounded by Brookston silty clay loam (Ritchie et al., 1971).

Sawmill Road Wetland - Sampled in 1996 and 1997

Sawmill Road Wetland (40°6'3"N, 83°5'9"W) is a seasonally flooded (Cowardin et al., 1979) forested depressional wetland in an urban setting. It is divided into two halves by a mowed trail. The site is located approximately 0.5 km north of Rt. 161 and 0.3 km east of Sawmill Road in Franklin Co., Ohio (Perry Township). The site is owned and managed by the ODNR and boardwalks have been installed for guided tours. This wetland is completely isolated by urban development and is diked and fenced on all sides. Three sides are surrounded by commercial development and the north side is bounded by Snouffer Road and a residential area. The wetland is virtually protected from surface runoff of the surrounding properties and roads because of the dikes. Green ash (*Fraxinus pennsylvanica var. subintegerrima*), slippery elm (*Ulmus rubra*) and pin oak (*Quercus palustris*) are the dominant trees. The site is underlain by Kokomo soil and Crosby silt loam (McLoda and Parkinson, 1980).

Project 1: Site Selection, Functional Assessment, Vegetation, Chemical and Physical Measurements of Wetland Sites

Section 1.1: Development of Rapid Functional Assessment Techniques

The regulation of wetlands under the federal and state environmental laws (Section 401 and 404 of the Clean Water Act) requires the assessment of the function and quality of wetlands in order to determine whether to permit their destruction, alteration, or degradation, and to determine the appropriate level of mitigation. This type of assessment is different from the delineation procedure used to determine whether or not a particular location is a jurisdictional wetland subject to regulation.

Wetland assessment techniques are designed to determine the ecological quality and the level of function of a given wetland. These methods are often called "rapid assessment methods" (RAM). The Ohio EPA recently adopted regulations which assign wetlands to one of three categories based on their quality or condition, and impose differing levels of regulatory review and protection based on the wetland's quality (Ohio EPA, 1998). The regulations specify three wetland categories: low (Category 1), medium (Category 2) and high quality (Category 3). These Wetland Water Quality Standards (WWQS) require applicants to use "an appropriate wetland evaluation methodology acceptable to the director" to determine the appropriate category for the wetland. In developing a rapid assessment method for use in Ohio, the decision was made to take advantage of existing methods, rather than developing a completely new technique and avoid "reinventing the wheel" (Paul Adamus, pers.comm.). For this reason, three wetland rapid assessment methods were identified that showed promise in evaluating wetland condition and functionality.

Testing Existing Methods: 1996 Field Season - Three rapid methods were tested for their suitability in assessing wetlands, and to determine their suitability in placing wetlands into antidegradation categories under the Ohio WWQS. The results of the three methods tested as

Table 1.1. OEPA 1996 assessment of 10 depressional wetlands using the Oregon Freshwater Wetland Assessment Methodology. "HIGH" indicates that the wetland possesses a particular functional quality, "MID" indicates that the wetland potentially possesses a particular functional quality, and "LOW" indicates that a wetland lacks a particular functional quality.

	Functional Quality of Wetland								
Wetland Site	Wildlife Habitat	Fish Habitat	Pollutant Removal	Hydrologic Control	Sensitivity to Impact	Enhancement Potential	Educational	Recreational	Aesthetic
Blanchard Oxbow	MID	MID	MID	MID	MID	HIGH	LOW	LOW	HIGH
Calamus	HIGH	MID	MID	MID	MID	LOW	MID	MID	HIGH
Cessna	MID	MID	MID	MID	MID	HIGH	LOW	LOW	HIGH
County Road 200	MID	MID	MID	MID	MID	HIGH	HIGH	LOW	HIGH
Gahanna Woods	HIGH	MID	MID	HIGH	HIGH	MID	MID	MID	HIGH
Leafy Oak	HIGH	MID	MID	MID	MID	MID	HIGH	LOW	HIGH
McKinley	HIGH	HIGH	MID	MID	MID	MID	MID	LOW	LOW
Mishne	MID	MID	MID	MID	LOW	MID	HIGH	LOW	HIGH
Rickenbacker	MID	HIGH	MID	MID	MID	HIGH	MID	LOW	MID
Sawmill	MID	MID	MID	MID	MID	HIGH	MID	MID	MID

Table 1.2. OEPA 1996 assessment of 10 depressional wetlands using the Minnesota Routine Assessment Method for Evaluating Wetland Functions. "EXCEPTIONAL" indicates that the wetland possesses an unusually high degree of a particular wetland quality, "HIGH" indicates that the wetland possesses a high degree of a particular wetland quality, "MED" indicates that the wetland possesses a moderate degree of a particular wetland quality, "LOW" indicates that a wetland possesses a minor degree of a particular wetland quality, and "N/A" indicates that the wetland quality does not apply to the wetland.

	Functional Level of Wetland								
Wetland Site	Wildlife Habitat	Fishery Habitat	Water Quality Protection	Flood/ Stormwater	Floral Diversity/ Integrity	Aesthetics/ Recreational/ Educational	Groundwater Interaction	Commercial Uses	Shoreline Protection
Blanchard Oxbow	MED	HIGH	LOW	MED	MED	LOW	MED	N/A	N/A
Calamus	MED	LOW	LOW	HIGH	HIGH	HIGH	MED	N/A	N/A
Cessna	MED	LOW	LOW	LOW	MED	LOW	MED	N/A	N/A
County Road 200	MED	LOW	LOW	MED	MED	LOW	MED	N/A	N/A
Gahanna Woods	HIGH	LOW	LOW	MED	MED	HIGH	MED	N/A	N/A
Leafy Oak	HIGH	LOW	LOW	MED	EXCEPTIONAL	MED	MED	N/A	N/A
McKinley	MED	HIGH	LOW	HIGH	MED	LOW	MED	N/A	N/A
Mishne	LOW	LOW	LOW	LOW	LOW	LOW	LOW	N/A	N/A
Rickenbacker	MED	HIGH	LOW	HIGH	HIGH	MED	MED	N/A	N/A
Sawmill	LOW	LOW	LOW	MED	MED	HIGH	MED	N/A	N/A

Table 1.3. a) Results of the Washington Wetlands Rating System scores (RAM) as applied to wetlands in Ohio. b) Summary of scoring system used in the Washington Rating System. The list below includes more sites than the reference wetlands included in this study (* indicates reference wetland)

a)

Site Name	Score
Mishne*	0
County Road 200*	5
River Breeze	7
Tuscawaras	11
Turnpike Commission	13
Whitlatch riverine wetlands	14
Riley Reference Site	15
Belmont Co. Ref	16
Amos mine site	17
Sawmill*	19
Triple S wetland	19
Blanchard*	21
Cedar Point coastal wetland	21
Cessna*	23
Lake Cable	23
McKinley*	24
New Albany	25
Mosquito Creek	26
Cooper Hollow Wildlife Area	29
Leafy Oak*	32
Gahanna Woods*	33
Rickenbacker*	33
Calamus*	35
Salt Fork Wildlife Area	35
Pickerington Ponds	41

b)

Scoring Category	Possible Points
Wetland Size	0 - 6
# of vegetation classes	0 - 10
Plant Diversity	0 - 12
Structural diversity	0 - 5
Plant community Interspersion	0 - 5
Habitat features	0 - 8
Connectivity to other waters	0 - 6
Buffers	0 - 5
Corridor connections	0 - 5

part of this study, including the Oregon Freshwater Wetland Assessment Methodology (Roth et al. 1993), the Minnesota Routine Assessment Method for Evaluating Wetland Functions (USACOE 1988) and the Washington State Wetland Rating System (Hruby et al. 1993), are shown on Tables 1.1 - 1.3. All reference wetlands sampled in 1996, which ranged in quality from least-impacted (e.g., Leafy Oak) to impaired (e.g., Mischne), were evaluated using each of the three methods.

A total of 9 wetland functions are evaluated using the Oregon Freshwater Wetland Assessment Methodology (Roth et al. 1993). As is common with wetland rapid assessment techniques, each function is given a rating of "high', "mid" or "low" to indicate to what degree the wetland possesses a particular function. A matrix of the results (Table 1.1) shows the results for each of the 10 reference wetland included in this study. The majority of functions evaluated using this method were assigned a "mid" rating using this method (approximately 65 percent). The fact that the wetlands, despite their differences in quality, are given very similar scores makes attempts to differentiate wetland quality based on this technique difficult. Several functions are given the same rating at nearly every site. For example, the pollutant removal function was given a "mid" rating for each site, as was the hydrologic control function in 9 of the 10 sites. Noting that the "mid" rating indicates that the wetland *potentially* possesses a particular functional quality, the evaluation of these functions is essentially inconclusive using the Oregon method.

The results of the Minnesota Routine Method are shown on Table 1.2 The scoring system for this method is similar to the Oregon Method in that each of 9 assessed functions is assigned a qualitative rating ranging from "Exceptional" to "Low". Two of the 9 functions evaluated were not applicable to the reference wetlands (Commercial Uses and Shoreline Development), leaving 7 functions evaluated. Of these, approximately 40 percent were given a score of medium ("med"). Only one function in one wetland received an "exceptional" score, in the case of floral diversity/integrity at the Leafy Oak site. This site is a very high quality forested wetland with a diverse plant community, and was the only reference site included in this study found to support a state-listed endangered species (*Carex crus-corvi*). Using this method, all of the reference

wetlands received a low rating for the water quality protection function (compared to the "mid" rating for pollutant removal function using the Oregon method).

Table 1.3 details the results of the Washington Wetlands Rating System for 25 sites in Ohio, including the 10 reference wetlands. A larger sample of wetlands were sampled in order to further test this method. Sites are arranged according to score. Scores given using the Washing System are based on wetland functions and values, sensitivity to disturbance, rarity and irreplacability (Hruby et al. 1993). The Washington RAM is unique in that a numerical score is generated for each site. This makes direct comparisons possible when evaluating wetlands relative to each other based on their characteristics or functional attributes. Scores for the Ohio reference wetlands ranged from 0 for the Mishne site to 35 for Calamus. Figure 1.1 shows a frequency distribution for scores obtained with this method. The scores roughly follow a normal distribution, identifying relatively few numbers of very degraded sites (i.e., those with scores less that 10) and very high quality sites (i.e., those greater that 30), with most sites falling in the middle range. This is the distribution one would expect for wetland quality across a population of wetlands, and provides an indication that this method has the potential to reasonably differentiate wetlands into categories for the purposes of permit decisions.

In general, characteristics that lend themselves to the use of a RAM for differentiating wetland condition (and assigning antidegradation categories under the Ohio WWQS) include results expressed as a numerical score that can be compared directly to scores at other sites, as opposed to a set of "high", "medium" and "low" ratings for a list of wetland functions. Interpretation of the latter (i.e., relative ranks for a list of functions) would be difficult in a regulatory framework. Using the matrices of scores as provided by the Oregon and Minnesota methods, it is not clear which sites are of higher quality than others. A quantitative method makes a relative ranking of sites possible and will allow a more straightforward implementation of the WWQS.

<u>Adaptation of a Rapid Assessment Method to Ohio: 1997 Field Season</u> - Late in 1996, a workgroup was formed to help in the adoption of an Ohio RAM. The Ohio Wetland Assessment

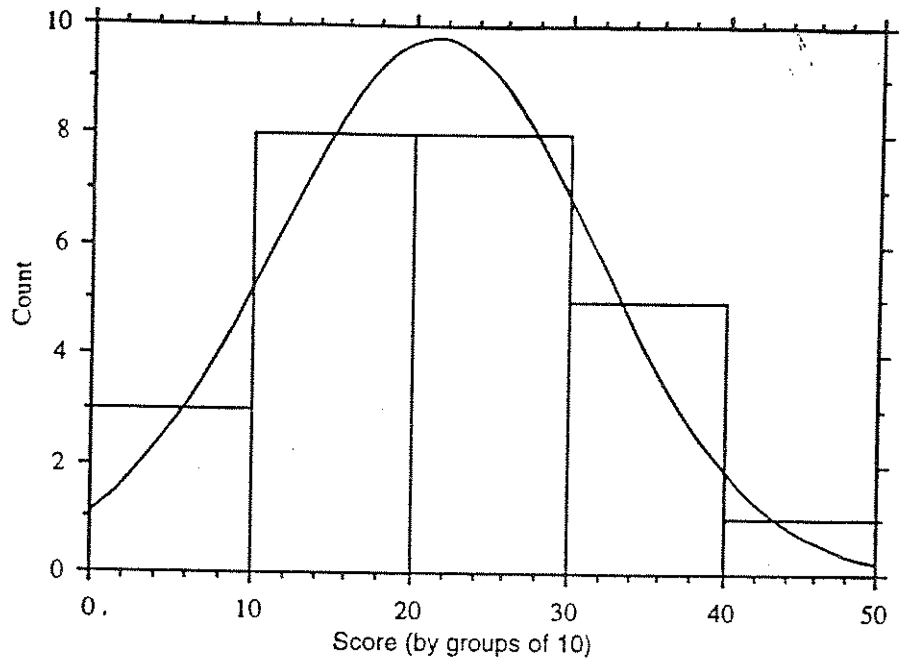


Figure 1.1. Frequency histogram for wetlands evaluated using the Washington Rating System. Count represents the number of sites which scored in each 10 point scoring category. Curve represents an idealized normal data distribution (n=25).

Workgroup was made up of 15 wetland professionals working for the federal and state government, private consultants, and members of industry and conservation groups (Table 1.4). The group agreed to meet periodically to develop the method as well as conduct and evaluate field trials.

The workgroup began by evaluating the results of the 1996 data, and making the most obvious revisions needed for use of the method in Ohio. For instance, the Washington RAM contains a provision for evaluating eel grass beds, an ecosystem type not found in Ohio. One question in the Washington method that the workgroup felt needed addressing was one that assigns point based on wetland size. Ohio's landscape (and wetlands) has been highly fragmented, making large wetlands relatively rare. The Ohio Department of Natural Resource's Ohio Wetlands Inventory (OWI) was used to determine the distribution of wetland size classes in Ohio. The OWI data is stored on a county by county basis; a total of five counties were selected to represent different areas of the state for use in this analysis (Table 1.5). The Washington RAM assigns points for wetlands up to 200 acres. The number of wetlands in Ohio of this size are extremely limited. In fact, the average size class distribution for these 5 counties showed that 93.3 percent of wetlands in Ohio are less than 5 acres in size according to the OWI. Only 0.2 percent of wetlands are greater than 100 acres and size, and this figure may be an overestimate because the OWI groups areas of open water, including ponds and reservoirs, with wetland acreage. It is unknown how many of the large sites listed on Table 1.5 are actually reservoirs (common in Ohio). This data was used to scale the points awarded for wetland size in the "Ohio Wetland Rating Field Data Form: Version 0" (all drafts of the Ohio Method can be found in the Appendix). On this scale, the highest number of points was awarded for wetlands greater than 50 acres.

Field trials held in the spring of 1997 led to the "Ohio Wetland Rating Field Data Form: Version 1" This version was used to assess the wetland reference site sampled in the 1997 field season. For comparison, results of both the Washington method (sites sampled in 1996) and the Ohio method (sites sampled in 1997) can be found on Table 1.6. Scores for the reference sites sampled in 1997 ranged from 11 to 37 using the OWAM. Upon completion of the field season,

Table 1.4. Ohio Wetland Assessment Method Workgroup members and their affiliation.

Workgroup Member	Affiliation
Sandy Doyle Ahern	EMH&T Engineering
John Baird	Ohio Department of Transportation
Kim Baker	Ohio Department of Natural Resources
Mark DeBrock	Natural Resource Conservation Service
Siobhan Fennessy	Ohio Environmental Protection Agency
John Kiertscher	Envirotech Consultants, Inc.
Roy Kroll	Winous Point Shooting Club
Ken Lammers	U.S. Fish and Wildlife Service
John Marshall	Ohio Department of Natural Resources
Jim McCormac	Ohio Department of Natural Resources
Lynn McCready	BBC&M Engineering
Mick Micacchion	Ohio Environmental Protection Agency
Ray Showman	American Electric Power
Julie Sibbing	National Audubon Society
Mark Taylor	U.S. Army Corps of Engineers

Table 1.5. Size distribution of wetlands in 5 select counties in Ohio. Distribution is reported for both total wetland numbers and total acres in each size class (Source: The Ohio Department of Natural Resources, Ohio Wetlands Inventory).

	Average for 5 Ohio Counties*			
Wetland Size Class (acres)	total # wetlands	total acres	% of total #	% of total area
less than 0.3	2776	491.5	45.2%	3.2%
greater than 0.3 and less than 1.0	1820	1058.8	29.6%	6.8%
greater than 1.0 and less than 5.0	1136	2489.1	18.5%	16.0%
greater than 5.0 and less than 10	207	1453.2	3.4%	9.4%
greater than 10 and less than 25	132	2025.6	2.1%	13.0%
greater than 25 and less than 50	37	1265.8	0.6%	8.1%
greater than 50 and less than 100	16	1157.9	0.3%	7.5%
greater than 100	14	5592.5	0.2%	36.0%
Total	**6,139**	**15,534.3**		

* Athens, Delaware, Lucas, Montgomery, Summit

Table 1.6. Washington State Rapid Assessment Method (RAM) scores and Ohio Wetland Assessment Method (OWAM) scores for 21 central Ohio depressional wetlands studied in 1996 and 1997. N/A = Not applicable.

Site Name	WA RAM	OWAM Score
Ackerman	N/A	32
Blanchard Oxbow	21	N/A
Calamus	35	35
Callahan	N/A	28
Cessna	23	N/A
County Road 200	5	N/A
Dever	N/A	11
Flowing Well	N/A	34
Gahanna Woods	33	N/A
Hebron	N/A	37
Hempelman	N/A	27
Keller High	N/A	32
Keller Low	N/A	16
Lawrence High	N/A	37
Lawrence Low	N/A	19
Leafy Oak	32	37
McKinley	24	N/A
Mishne	6	N/A
Rickenbacker	33	N/A
Route 29	N/A	25
Sawmill	19	20

further refinements were made and incorporated into the "Ohio Wetland Assessment Method Field Data Form (OWAM): Version 2". It is planned that Version 2 will be tested and revisions made if necessary, before the method is used to help implement Ohio's wetland water quality standards.

The Ohio Rapid Assessment Workgroup also assisted with a preliminary proposal for categorizing wetlands based on OWAM scores. A range of scores was defined for each category, as well as a "gray zone" between one category and the next. This will be a starting point for the implementation of Ohio's wetland water quality standards. Provisional category scores are as follows:

- 0-11 is a Category 1 wetland;
- 12-16 is a Category 1 or 2 wetland;
- 17-29 is a Category 2 wetland;
- 30-34 is a Category 2 or 3 wetland; and,
- 35+ is a Category 3 wetland.

The Ohio EPA approach specifies that for sites scoring 12-16 or 30-34, additional information is needed in order to properly categorize the wetland.

Project 1 (Continued): Site Selection, Functional Assessment, Vegetation, Chemical and Physical Measurements of Wetland Sites

Section 2.1: Chemical and Physical Measurements of the Reference Wetland

A list of the 21 reference wetland included in this study, the year(s) they were sampled, and a description of their size (ha), perimeter length (m), and hydrologic regime as described on the National Wetland Inventory maps (NWI; after Cowardin et al. 1979) are shown on Table 2.1. Three sites were sampled in both years in order to get a preliminary indication of the consistency of site assessment techniques. A fourth site, County Road 200, was scheduled to be sampled in

Table 2.1. Area and perimeter measurement of 21 central Ohio depressional wetlands sampled in 1996 and/or 1997. Hydrologic regime (after Cowardin et al., 1979) and hydrogeomorphic classification (after Brinson, 1993) were determined by National Wetland Inventory Map (USFWS, various years) and site visits, respectively. Some data were unavailable at publishing date (N/A).

Wetland Site	Year(s) Sampled	Ohio County	Wetland Perimeter (m)	Wetland Area (ha)	Perimeter:Area Ratio	Hydrologic Flooding Regime	Hydrogeomorphic Classification
Ackerman	1997	Clark	1000	2.88	347	Seasonally	Depressional
Blanchard	1996	Hardin	N/A	N/A	N/A	N/A	Riverine
Calamus	1996/1997	Pickaway	N/A	4.16	N/A	Semipermanently	Depressional
Callahan	1997	Clark	405	0.79	511	Seasonally	Depressional
Cessna	1996	Hardin	N/A	0.97	N/A	Seasonally	Depressional
County Road 200	1996	Hardin	170	0.20	850	Seasonally	Depressional
Dever	1997	Franklin	160	0.08	1960	Seasonally	Depressional
Flowing Well	1997	Champaign	250	0.32	784	Seasonally	Depressional
Gahanna Woods	1996	Franklin	N/A	0.52	N/A	Seasonally	Depressional
Hebron	1997	Licking	600	5.40	111	Seasonally	Depressional
Hempelman	1997	Fairfield	190	0.10	1884	Seasonally	Depressional
Keller High	1997	Fairfield	360	0.73	492	Semipermanently	Depressional
Keller Low	1997	Fairfield	550	2.00	275	Seasonally	Depressional
Lawrence High	1997	Hardin	720	3.45	209	Seasonally	Depressional
Lawrence Low	1997	Hardin	250	0.26	960	Seasonally	Depressional
Leafy Oak	1996/1997	Hardin	300	0.80	374	Temporarily	Depressional
McKinley	1996	Franklin	N/A	N/A	N/A	N/A	Riverine
Mishne	1996	Franklin	N/A	0.02	N/A	Seasonally	Depressional
Rickenbacker	1996	Franklin	N/A	1.23	N/A	Semipermanently	Depressional
Route 29	1997	Champaign	390	1.08	360	Seasonally	Depressional
Sawmill	1996/1997	Franklin	430	2.15	200	Seasonally	Depressional

1997 as well, but midway through the growing season site access was revoked by the landowner.

Hydrology - Figure 2.1 shows the water level data collected at each site in 1997. As can be expected, water levels tended to be highest in the spring and decline as the growing season progresses. All sites became completely dry, or very shallow during the latter part of the growing season. One site, the Ackerman wetland (Figure 2.1(a)), showed a very flashy hydroperiod, with extremes in water level of nearly a meter in response to storm events. This site was fed by an intermittent stream and was connected to adjacent agricultural lands by a drain tile. These links with other surface waters caused rapid water level changes in the wetland in response to rain events.

Results of the water chemical analysis for the wetlands sampled in 1997 are shown on Table 2.2. A range of water quality constituents were measured in order to begin to establish a baseline of data on the chemical water quality status of Ohio's wetlands. As can be expected for wetlands that are located primarily in agricultural landscapes, nutrients were present at detectable levels while metals for the most part were not. Table 2.3 shows an accuracy assessment (QA/QC) for the 1997 water samples. This analysis is based on the collection and laboratory analysis of replicate samples at various wetland reference sites throughout the growing season. A comparison was made of water chemistry measures for the replicates which shows that the overall mean project accuracy was 1.01. This indicates a high level of confidence in the data.

Results of the soil sample chemical analyses are shown on Table 2.4 and data on particle size distribution on Table 2.5. All of the reference sites were sampled in 1997 (including those sites where the biological samples were collected in 1996). There is a high degree of variability between sites. For example, percent total organic carbon ranged from 2.3 percent at the Flowing Well site to 31.4 percent at the Lawrence High site. This range of values spans the range that wetland ecosystems as a whole tend to display (Mitsch and Gosselink, 1993).

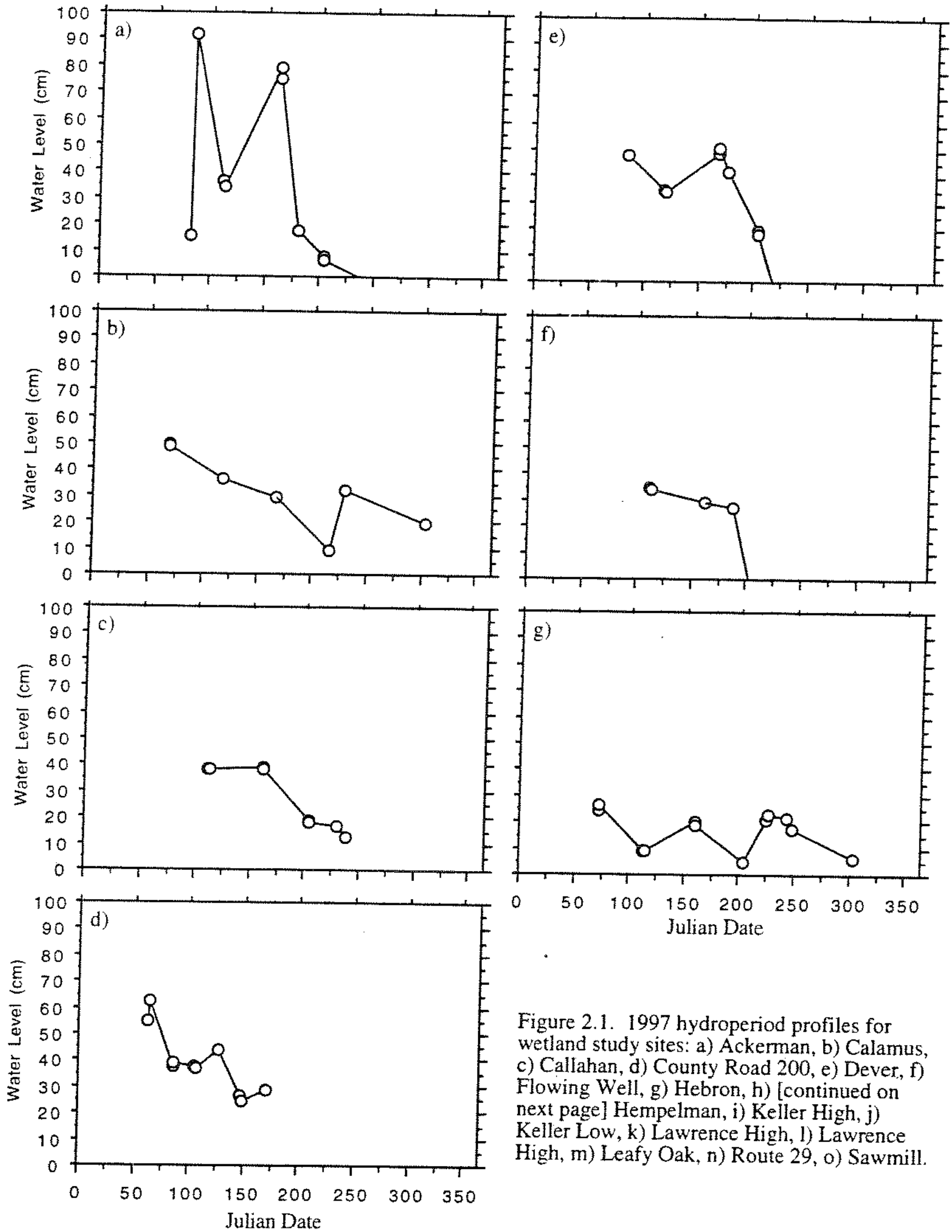
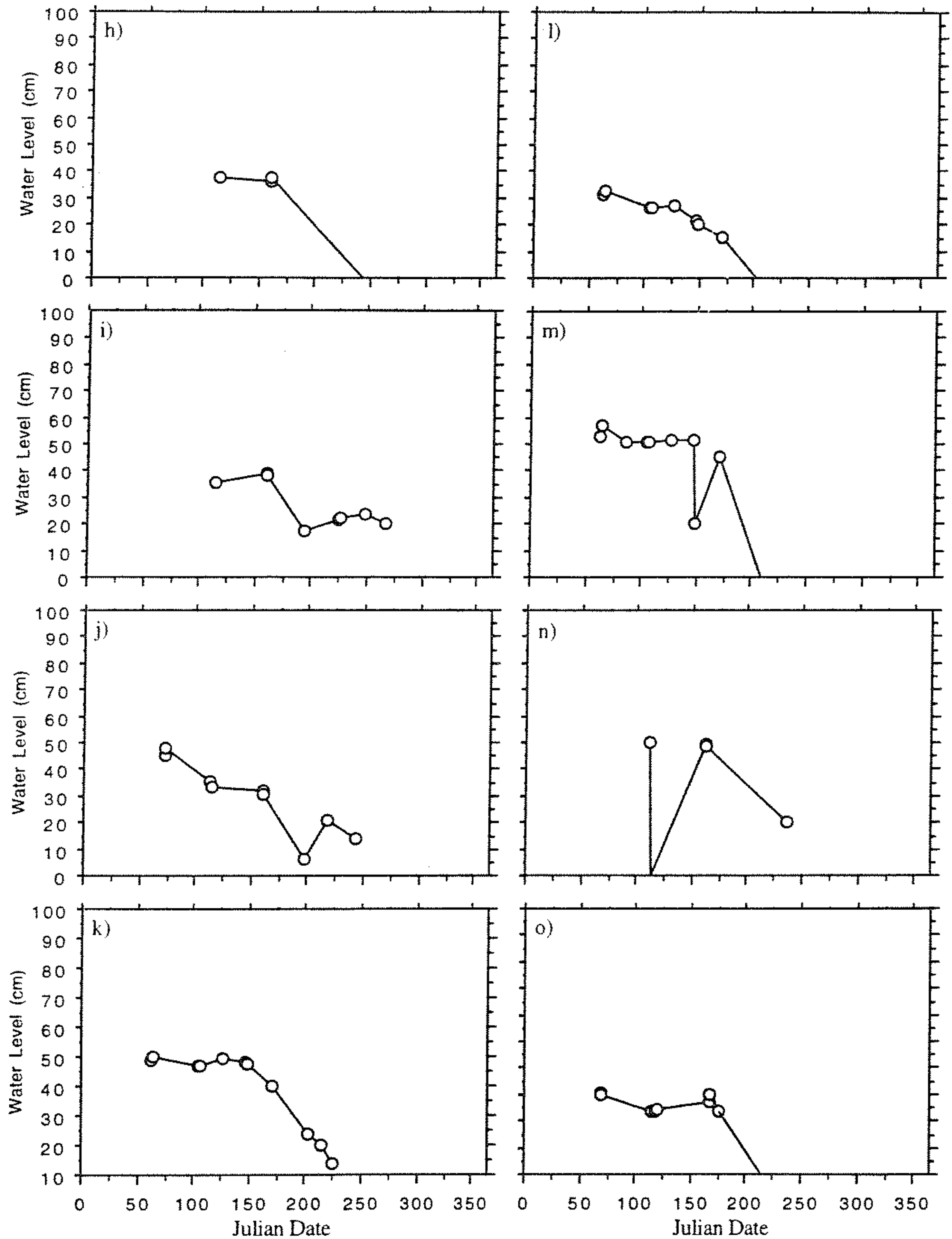


Figure 2.1. 1997 hydroperiod profiles for wetland study sites: a) Ackerman, b) Calamus, c) Callahan, d) County Road 200, e) Dever, f) Flowing Well, g) Hebron, h) [continued on next page] Hempelman, i) Keller High, j) Keller Low, k) Lawrence High, l) Lawrence High, m) Leafy Oak, n) Route 29, o) Sawmill.


h)
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350

Table 2.2. Mean values ± std. dev. for water chemistry measurements in 15 central Ohio depressional wetlands (n.t. indicates the parameter was not tested).

Wetland Site	Total Solids (mg/l)	Total Organic Carbon (mg/l)	Ammonia (mg/l)	Nitrate+ Nitrite (mg/l)	Total Phosphorus (mg/l)	Total Kjeldahl Nitrogen (mg/l)	Total Aluminum (ug/l)	Total Calcium (mg/l)	Total Iron (ug/l)	Total Magnesium (mg/l)	Total Cadmium (ug/l)	Total Copper (ug/l)	Total Lead (ug/l)	Total Selenium (ug/l)
Ackerman	212±48(5)	8±0(4)	0.10±0.09(4)	2.5±5.0(4)	0.1±0.1(4)	0.7±0.2(4)	397±576(4)	38±9(5)	472(1)	15±4(5)	0.0±0.0(5)	0.0±0.0(5)	0.0±0.0(5)	0.0(1)
Calamus	182±13(3)	12±1(3)	0.03±0.00(3)	0.0±0.0(3)	0.1±0.0(3)	1.1±0.0(3)	0±0(3)	27±6(3)	288(1)	13±1(3)	0.0±0.0(3)	0.0±0.0(3)	0.0±0.0(3)	0(1)
Callahan	217±20(3)	19±2(2)	0.06±0.05(2)	0.0±0.0(2)	0.1±0.1(2)	0.9±0.4(2)	171±122(3)	31±4(3)	715(1)	36±43(3)	0.0±0.0(3)	0.0±0.0(3)	0.0±0.0(3)	0(1)
County Road 200	278(1)	9(1)	0.30(1)	7.7(1)	0.1(1)	1.6(1)	318(1)	54(1)	1310(1)	17(1)	0.0(1)	0.0(1)	0.0(1)	0(1)
Dever	241±68(4)	13±3(4)	0.8±0.10(4)	0.0±0.0(4)	0.2±0.1(4)	1.1±0.7(4)	234±154(4)	44±15(4)	1470(1)	15±5(4)	0.0±0.0(4)	0.0±0.0(4)	0.0±0.0(4)	0(1)
Flowing Well	318±16(6)	6±1(6)	0.14±0.05(6)	0.0±0.0(6)	0.1±0.1(6)	0.5±0.1(6)	0±0(6)	67±2(6)	619±124(3)	34±22(6)	0.0±0.0(6)	0.0±0.0(6)	0.0±0.0(6)	0±0(3)
Hebron	191±38(2)	14±1(2)	0.00±0.00(2)	0.0(1)	0.5±0.1(2)	1.3±1.0(2)	745±912(2)	25±6(2)	n.t.	8±2(2)	0.0±0.0(2)	2.5±2.1(2)	2.5±2.1(2)	n.t.
Hempelman	236±9(2)	18±1(2)	0.47±0.48(2)	0.1±0.0(2)	0.3±0.2(2)	1.2±0.1(2)	0±0(2)	36±1(2)	387(1)	11±0(2)	0.0±0.0(2)	0.0±0.0(2)	0.0±0.0(2)	0(1)
Keller High	236±37(3)	15±1(2)	0.06±0.05(2)	0.0±0.0(2)	0.2±0.1(2)	1.1±0.9(2)	0±0(3)	42±13(3)	711(1)	15±5(3)	0.0±0.0(3)	1.3±0.6(3)	0.0±0.0(3)	0(1)
Keller Low	216±40(2)	12±2(2)	0.08±0.07(2)	0.0±0.0(2)	0.5±0.3(2)	0.8±0.4(2)	0±0(2)	45±8(2)	1940(1)	14±4(2)	0.0±0.0(2)	0.0±0.0(2)	0.0±0.0(2)	0(1)
Lawrence High	186±40(4)	16±4(4)	0.35±0.54(4)	0.0±0.0(4)	0.2±0.2(4)	1.2±0.6(4)	249±298(4)	32±7(4)	519±395(2)	10±3(4)	0.0±0.0(4)	1.5±1.0(4)	0.0±0.0(4)	0±0(2)
Lawrence Low	217±8(4)	18±3(4)	0.04±0.03(4)	0.0±0.0(4)	0.1±0.1(4)	1.2±0.1(4)	159±69(4)	43±3(4)	1021±148(3)	14±1(4)	0.8±0.4(4)	1.8±1.1(4)	0.0±0.0(4)	0±0(3)
Leafy Oak	229±16(2)	10±1(2)	0.00(1)	0.0(1)	0.0(1)	0.4(1)	0±0(2)	47±6(2)	192(1)	16±3(2)	0.0±0.0(2)	0.0±0.0(2)	0.0±0.0(2)	0(1)
Route 29	438±117(3)	18±10(3)	0.53±0.66(3)	1.3±2.1(3)	0.3±0.4(3)	1.8±1.9(3)	193±83(3)	72±17(3)	436(1)	28±6(3)	0.0±0.0(3)	0.0±0.0(3)	2.3±2.3(3)	2(1)
Sawmill	218±35(3)	23±7(3)	0.00±0.00(3)	0.0±0.0(3)	0.3±0.2(3)	1.0±0.2(3)	0±0(3)	37±6(3)	697(1)	11±3(3)	0.0±0.0(3)	0.0±0.0(3)	0.0±0.0(3)	0(1)

Table 2.3. Accuracy assessment calculations for the 1997 wetland water chemistry measurements. Replicate sample names are indicated by bold lettering. n.t indicates the parameter was not tested and n.c. indicates that no calculation was possible.

Replicate ID and Paired Sample Site	Sample Location	Sample Date	Non-Filtered Suspended Solids (mg/L)	Total Solids (mg/L)	Total Organic Carbon (mg/L)	Ammonia (mg/L)	Nitrate+Nitrite (mg/L)	Total Phosphorus (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Total Aluminum (ug/L)	Total Calcium (mg/L)	Total Iron (ug/L)	Total Magnesium (mg/L)	Total Cadmium (ug/L)	Total Copper (ug/L)	Total Lead (ug/L)	Total Selenium (ug/L)	*Site Accuracy (Rep./Sample)*
Blank Swamp	Center	6/17/97	<5	<10	<2	<.05	<.1	<.05	<.2	<200	<2	nt	<1	<2	<2	<2	nt	
Sawmill	Center	6/17/97	<5	180	17	<.05	<.1	0.27	0.9	<200	31	nt	9	<2	<2	<2	nt	
Site-Parameter Accuracy (Rep./Sample)			n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.
Corn Swamp	Center	8/9/97	nt	188	10	<.05	<.1	0.74	0.5	<200	38	nt	12	<2	<2	<2	nt	
Keller Low	Center	8/9/97	nt	188	10	<.05	<.1	0.69	0.5	<200	38	nt	11	<2	<2	<2	nt	
Site-Parameter Accuracy (Rep./Sample)			n.c	1.0	1.0	n.c	n.c	1.1	1.0	n.c	1.0	n.c	1.1	n.c.	n.c	n.c	n.c	1.0
HQ Swamp	Center	6/16/97	nt	216	21	<.05	<.1	0.4	0.8	<200	36	nt	11	<.2	<2	<2	nt	
Sawmill	Center	6/16/97	nt	224	21	<.05	<.1	0.42	0.9	<200	37	nt	11	<2	<2	<2	nt	
Site-Parameter Accuracy (Rep./Sample)			n.c	1.0	1.0	n.c.	n.c	1.0	0.9	n.c.	1.0	n.c	1.0	n.c	n.c	n.c	n.c	1.0
Lopez Bog	Center	6/9/97	nt	164	14	<.05	<.1	0.34	0.7	<200	29	nt	9	<2	<2	<2	nt	
Hebron	Center	6/9/97	nt	164	14	<.05	<.05	0.42	0.6	<200	29	nt	9	<2	<2	<2	nt	
Site-Parameter Accuracy (Rep./Sample)			n.c	1.0	1.0	n.c	n.c	0.8	1.2	n.c	1.0	n.c	1.0	n.c	n.c	n.c	n.c	1.0
Lopez Swamp	Center	4/29/97	nt	316	31	0.06	<.1	0.15	1.8	<200	44	687	14	<.2	<2	<2	<2	
Sawmill	Center	4/29/97	nt	250	30	<.05	<.1	0.09	1.3	<200	43	697	14	<2	<2	<2	<2	
Site-Parameter Accuracy (Rep./Sample)			n.c	1.3	1.0	n.c	n.c.	1.7	1.4	n.c	1.0	1.0	1.0		n.c	n.c	n.c	1.2
Road Pool	Center	6/19/97	<5	210	16	0.11	<.1	0.22	1.3	216	39	nt	14	<2	<2	<2	nt	
Lawrence Low	Center	6/19/97	<5	210	16	0.09	<.1	0.29	1.3	230	38	nt	14	<2	2	<2	nt	
Site-Parameter Accuracy (Rep./Sample)			n.c.	1.0	1.0	1.2	n.c	0.8	1.0	0.9	1.0	n.c	1.0	n.c	n.c	n.c	n.c	1.0
Schoolhouse Marsh	Center	6/12/97	nt	264	8.8	0.17	9.97	0.08	0.7	276	36	nt	14	<2	<2	<2	nt	
Ackerman	Center	6/12/97	nt	250	7.1	0.2	10	<.05	0.8	263	37	nt	14	<.2	<2	<2	nt	
Site-Parameter Accuracy (Rep./Sample)			n.c.	1.1	1.0	0.9	1.0	n.c	0.9	1.0	1.0	n.c	1.0	n.c	n.c	n.c	n.c	1.0
Wendy Swamp	Center	6/17/97	8	168	9	<.05	<.1	0.15	0.7	453	32	nt	11	<2	<2	<2	nt	
Dover	Center	6/17/97	10	182	10	<.05	<.1	0.2	0.8	369	30'	nt	10	<.2	<2	<2	nt	
Site-Parameter Accuracy (Rep./Sample)			0.8	0.9	0.9	n.c.	n.c.	0.8	0.9	1.2	1.1		1.1	n.c.	n.c.	n.c.	n.c.	1.0
1997 Mean Parameter Accuracy (Rep./Sample)			0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.0	1.0	1.0	n.c	n.c	n.c	n.c	1.0

= 1997 Mean Project Accuracy

Table 2.4. Mean values ± std. dev. for soil chemistry measurements in 20 central Ohio depressional wetlands. Soil chemistry measurements were not performed at County Road 200 due to site access denial (N = 3; n.t. indicates that the parameter was not tested.

Wetland Site	% Solids	pH	Total Organic Carbon (%)	Concentration (mg/kg) Total Phosphorus	Total Calcium	Total Magnesium	Total Ammonia	Total Copper	Total Lead	Total Cadmium
Ackerman	45.8±8.6	7.39±0.51	4.3±0.8	1867±400	6077±1153	5617±366	89.0±72.7	30.7±1.5	22.6±9.3	0.810±0.119
Blanchard Oxbow	63.6±6.4	6.15±0.39	4.2±1.0	16473±107	4750±251	5987±1028	67.8±13.9	24.3±5.4	22.4±12.2	0.717±0.059
Calamus	57.2±23.1	7.03±0.75	5.8±2.0	1733±475	9653±3087	4927±873	97.6±144.4	30.6±8.1	39.4±21.2	0.643±0.200
Callahan	33.9±11.3	6.0±0.2	10.6±6.0	1395±552	9837±2393	5380±849	246.0±80.6	36.9±2.1	35.0±14.3	1.008±0.484
Cessna	n.t.	6.4±1.0	20.3±9.5	3245.0±1944.5	17600.0±10040.9	5600.0±2616.3	92.1±62.1	31.2±8.2	32.4±24.0	0.9±0.2
Dever	60.1±5.6	6.8±0.4	3.7±.05	1990.0±381.6	10346.7±2396.8	7686.7±1564.7	107.3±81.1	43.5±1.8	38.5±18.7	0.746±0.124
Flowing Well	64.6±6.4	6.59±0.50	2.3±1.9	757±396	6243±1781	5860±866	39.8±17.1	30.1±9.8	21.5±9.0	0.930±0.300
Gahanna Woods	52.7±24.0	6.05±0.32	9.7±3.3	1660±548	5283±2523	3690±351	45.3±29.7	35.1±18.8	35.3±22.9	1.550±0.885
Hebron	49.8±9.3	6.71±0.30	4.2±1.4	1489±860	5433±803	5277±1793	120.5±68.9	36.4±4.2	39.3±22.9	1.140±0.640
Hempelman	55.2±11.8	6.14±0.35	4.4±0.9	1823.3±746.7	8370.0±3150.8	7636.7±4045.1	78.7±37.1	55.7±23.6	58.9±21.4	2.223±0.657
Keller High	37.8±8.3	6.50±0.25	8.5±2.7	841.3±190.0	4987±2703	2187±479	83.3±20.9	20.7±5.8	20.8±15.4	0.949±0.299
Keller Low	61.1±22.0	7.11±0.10	4.6±2.7	1343±219	8527±4567	5097±1262	103.9±131.8	33.7±4.8	25.9±9.6	1.113±0.194
Lawrence High	18.6±9.6	6.54±0.28	31.4±15.1	2960±615	16400±4804	4557±2975	269.3±95.5	69.4±76.1	45.4±19.7	1.885±1.029
Lawrence Low	67.2±9.3	6.40±0.36	4.5±2.1	1983±336	7097±1258	6487±782	54.5±10.9	35.1±6.6	18.1±4.4	0.787±0.314
Leafy Oak	n.t.	6.2±0.3	17.2±2.5	2806.7±597.5	12733.3±2739.2	6713.3±2603.1	64.9±28.4	44.8±1.7	21.0±7.3	1.2±0.4
McKinley	72.8±24.9	7.4±0.3	n.t.	801±252	22603±21748	13333±6223	24.2±21.1	25.1±9.4	24.3±6.2	0.373±0.099
Mishne	68.1±5.8	6.7±0.5	n.t.	972±343	5333±1329	5507±61	57.0±44.2	23.5±2.3	20.3±9.3	0.422±0.012
Rickenbacker	64.3±1.7	5.73±0.63	3.1±0.3	3310±3603	2547±716	3327±805	24.0±17.2	28.0±10.9	26.8±3.1	0.822±0.405
Route 29	37.2±16.4	6.38±0.75	14.8±9.1	2267±318	10033±306	4507±1187	109.8±71.6	34.0±1.8	23.4±10.1	0.653±0.142
Sawmill	66.8±10.9	6.27±1.39	5.8±3.0	1333±326	13210±13388	6340±5424	87.2±60.9	20.4±1.4	37.8±8.4	0.559±0.337

Table 2.5. Mean percent of soil separates in 20 central Ohio depressional wetlands (± std. dev.). VFS = very fine sand (0.10 - 0.05 mm diameter), silt = 0.05 - 0.002 mm diameter, and clay < 0.002 mm diameter particles.

Wetland Site	Percent VFS	Percent Silt	Percent Clay
Ackerman	49±35	31±21	20±14
Blanchard	19±7	55±4	25±7
Calamus	12±8	57±15	31±9
Callahan	30±14	42±14	27±9
Cessna	35±3	49±8	17±10
Dever	15±4	57±2	28±2
Flowing Well	24±9	54±7	22±3
Gahanna Woods	35±4	48±2	16±5
Hebron	26±6	48±3	27±5
Hempelman	23±6	49±8	28±4
Keller High	24±13	49±11	27±15
Keller Low	25±12	56±5	19±12
Lawrence High	40±9	48±2	13±8
Lawrence Low	21±2	58±3	21±2
Leafy Oak	23±7	59±3	18±6
McKinley	10±2	60±15	30±16
Mishne	11±3	69±5	21±2
Rickenbacker	19±6	61±5	19±2
Route 29	48±7	35±6	17±1
Sawmill	27±6	64±7	9±10

Section 2.2: Evaluation of the Gradient of Disturbance

A range of wetlands spanning the gradient from least-impacted to impaired were chosen in the site selection process. In order to determine the relative level of disturbance that each site has sustained, a flow chart was developed describing the general types and levels of disturbance that are typical of wetlands in Ohio (Figure 2.2). Each wetland was assigned a disturbance rank based upon the surrounding land use (forest or natural grassland, fallow agricultural land, row crops or urban land use), the type of buffer in the 100 m immediately adjacent to the wetland (forested, grass, or none), and whether or not there was evidence of hydrological modification (i.e., ditching, drain tiles, etc.). This scheme was used as a means to increase the objectivity with which wetlands could be assigned a quantitative disturbance (Karr and Chu 1997). The rank that each site received as a result is shown on Table 2.6. The sites judged to be the least impacted (e.g., Leafy Oak, Lawrence High, Hempleman) were forested wetlands left relatively undisturbed in large woodlots. All were high quality sites, and Lawrence High is notable in that it is located in a 500 acre woodlot, the largest remaining forested parcel in northwestern Ohio (Dan Rice, pers.comm.). Some of the most disturbed sites were those wetlands completely surrounded by either row crops (e.g., County Road 200) or urban development (e.g., Sawmill).

The disturbance rank genereated for each site was used to evaluate the performance of both the Washington Rating system (sites sampled in 1996) and the Ohio Wetland Assessment Method (sites sampled in 1997). Figure 2.3 shows the results of the correlation between the rapid methods and disturbance rank. There is a highly significant correlation ($R = 0.70$; $p = 0.004$). Rapid assessment scores fall as the level of disturbance to a give site increases. This is an indication that the rapid assessment methods are sensitive to the wetland degradation that occurs as disturbance to a site increases. Figure 2.4 shows the results for the Ohio method (OWAM) only. Again, the relationship is highly significant ($R = 0.66$, $p = 0.01$). These results provide a preliminary indication that the OWAM can be used to reliably evaluate site disturbance, and, in doing so, provide a reliable indication of wetland quality.

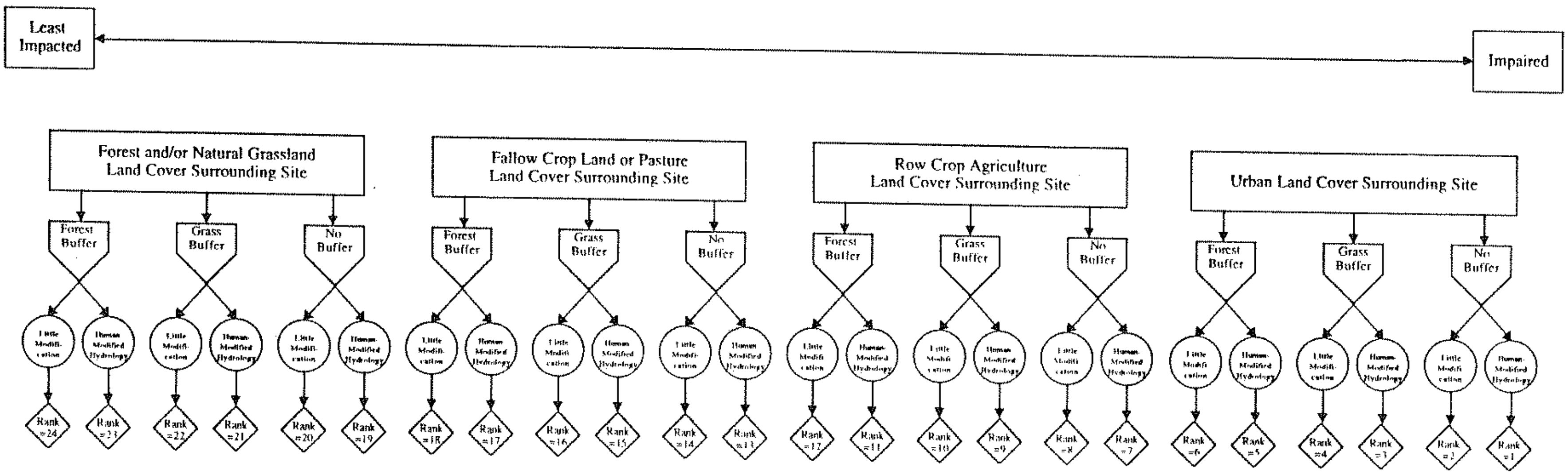


Figure 2.2. A three tiered flow chart used to rank the 21 central Ohio depressional wetlands from least impacted to impaired. Tier 1 indicates the adjacent land cover that surrounds the wetland; tier 2 indicates the extent and type of buffer that encompasses the wetland site; tier 3 indicates the degree of hydrologic alteration present at the wetland site.

Table 2.6. Results of the ranking of 21 central Ohio depressional wetlands using the three tiered flowchart in Figure 2.2. A rank of 24 is the least impacted and a rank of 1 is the most impaired

Wetland Site	**Disturbance Rank**
Sawmill	5
Ackerman	7
County Road 200	7
Dever	8
Keller Low	8
Mishne	8
Blanchard Oxbow	11
McKinley	11
Route 29	11
Calamus	12
Callahan	12
Cessna	12
Lawrence Low	14
Rickenbacker	15
Gahanna Woods	17
Keller High	18
Hebron	21
Flowing Well	23
Hempelman	24
Lawrence High	24
Leafy Oak	24

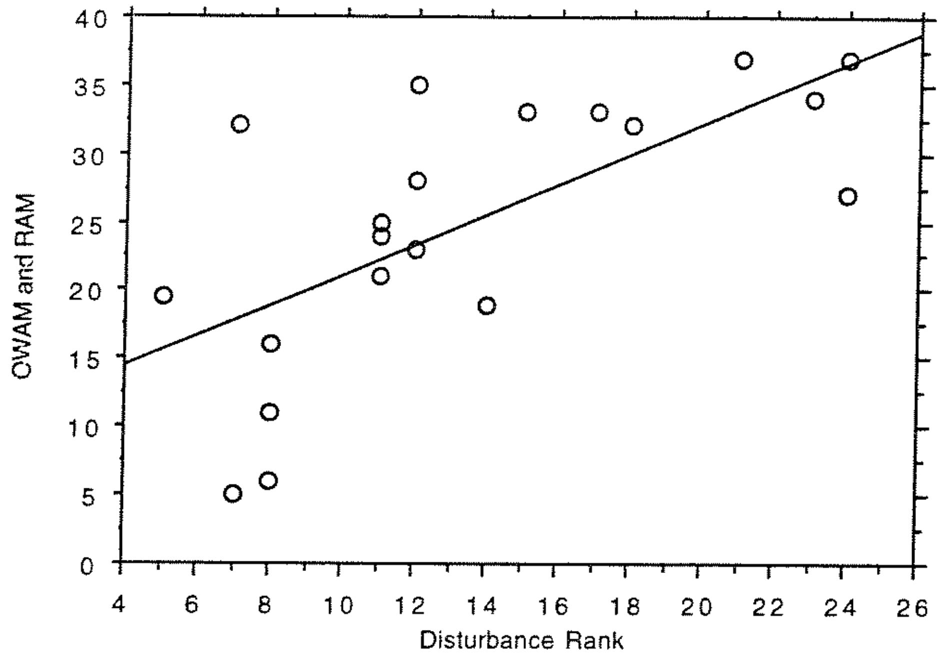


Figure 2.3. Correlation between wetland disturbance rank and the results of the Washington Method (1996)/OWAM (1997) for all wetlands included in this study. $y = 9.95 + 1.115 * x$, $R = 0.702$, $p = 0.0004$.

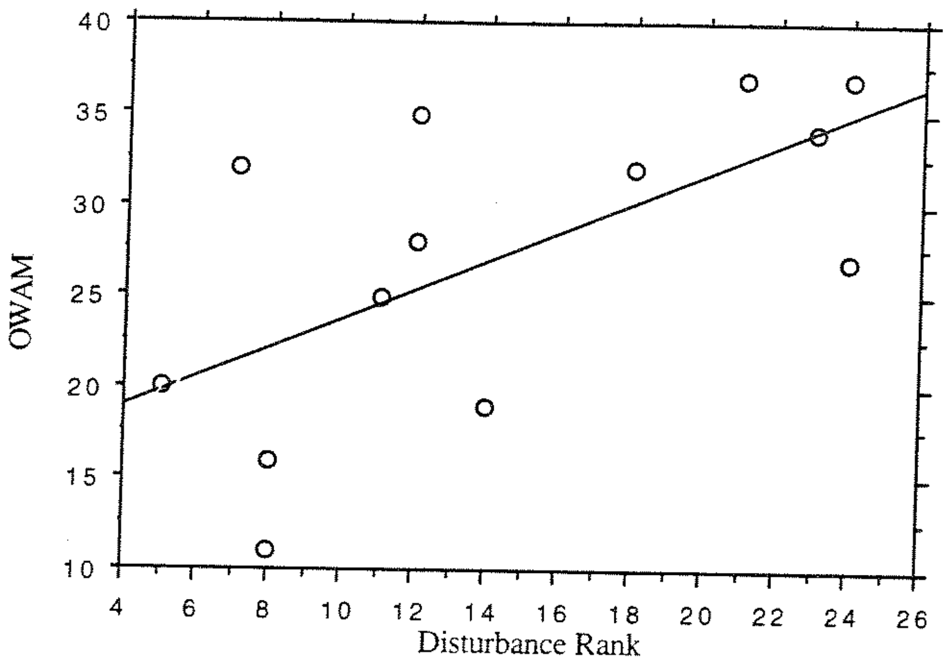


Figure 2.4. Correlation between wetland disturbance ranks and the OWAM results (1997). $y = 15.82 + 0.798 * x$, $R = 0.661$, $p = 0.01$.

Section 2.3: Ecological Assessment of Wetlands using the Floristic Quality Assessment Index

1996 FQAI Results - The floristic measurements taken at each site in the 1996 field season are summarized in Table 2.7. Sampling of the wetland sites took place between July and mid-October. Two site visits were performed at each site so that vegetation could be surveyed in mid-summer and autumn, and comparisons could be made as to the effect of sampling season on FQAI values. Autumn vegetation surveys were also used to verify the identity of some late-flowering plant species, i.e., diagnostic flowering parts in some genera do not emerge until later in the growing season. FQAI scores ranged from 13.5 (Mishne site) to 33.6 (Leafy Oak) for summer-only floristic sampling and from 14.5 (Mishne site) to 37.1 (Cessna) for the combined summer-autumn floristic sampling.

At the Leafy Oak site a large population of an endangered plant species, *Carex crus-corvi* (Raven-foot Sedge), was found. This species was added to the Ohio Department of Natural Resources Natural Heritage Database, and voucher specimens were place in the herbarium at the Cleveland Natural History Museum. The discovery of this population also made the "Best Plant Finds of 1996" list published by ODNR (1997), who cite this species as on of the rarest species of wetland monocots in Ohio.

As a result of the repeat surveys conducted in the fall, total plant species richness at each site increased by an average of 15 new species. Although FQAI scores increased by an average of 2.8 points as a result, there was little change in the relative ranking of the sites between the two seasons. Of the 10 sites sampled, the relative FQAI ranking of the top 40% of sites (Cessna, Leafy Oak, Calamus, and Gahanna) and the bottom 20% of sites (Mishne and County Road 200) did not change between the summer and the summer-autumn combined sampling.

We were concerned that vegetation data collected during the summer sampling period compared to the combined summer-autumn data might result in substantially different FQAI values. To test for the existence of such a problem we compared the FQAI values obtained for summer alone and

Table 2.7. Summary of 1996 floristic assessment of 10 central Ohio depressional wetlands. a) July and August censuses only; b) Combined data from July, August, September, and October censuses. N/A = the parameter was not applicable to the wetland site

a)

Wetland Site	Summer Sampling Date	Summer FQAI	Summer Perennial/Annual Ratio (Emergent)	Summer Percent Native Species	Summer Total species richness
Blanchard Oxbow	8/27/96	23.9	N/A	94%	34
Calamus	8/14/96	31.3	2.7	78%	85
Cessna	8/27/96	33.6	N/A	98%	64
County Road 200	8/15/96	16.8	5.0	88%	24
Gahanna	8/30/96	28.3	N/A	92%	51
Leafy Oak	8/12/96	32.3	N/A	95%	66
McKinley	7/25/96	23.7	N/A	80%	40
Mishne	8/7/96	13.5	1.4	79%	34
Rickenbacker	7/19/96	25.6	6.4	93%	59
Sawmill	7/17/96	20.5	N/A	85%	48

b)

Wetland Site	Fall Sampling Date	Fall and Summer FQAI	Fall and Summer Perennial/Annual Ratio (Emergent)	Fall and Summer Percent Native Species	Fall and Summer Total species richness	Plants With Special Status; T=Threatened E=Endangered
Blanchard Oxbow	10/2/96	26.4	N/A	94%	47	0
Calamus	9/9/96	33.6	2.4	81%	96	2(T)
Cessna	10/2/96	37.1	N/A	97%	78	1(T)
County Road 200	10/2/96	18.1	5.2	90%	31	0
Gahanna	9/26/96	30.1	N/A	90%	59	0
Leafy Oak	10/2/96	36.8	N/A	96%	89	2(T), 1(E)
McKinley	7/25/96	25.0	N/A	81%	52	0
Mishne	9/10/96	14.5	1.8	74%	39	0
Rickenbacker	9/26/96	27.6	4.6	89%	79	1(T)
Sawmill	9/25/96	28.1	N/A	87%	84	0

summer and autumn combined (Figure 2.5). The summer-only and the combined summer-autumn FQAI values were strongly correlated (R = 0.96), with Sawmill Wetland as a conspicuous outlier (summer score was 20.5, summer plus fall was 28.1). Sawmill Wetland had a substantially higher number of new species added in the autumn (43% of the total plant species collected) than any of the other wetland sites, perhaps due to the fact that Sawmill Wetland was the earliest summer site visit conducted during 1996, making the identification of late germinating or late flowering species more difficult. Based on this relationship, as well as the results presented in Fennessy et al, (1998) which also showed a high correlation between summer and autumn FQAI scores in forested riparian wetlands, the decision was made to sample in the summer sampling period only (June 15 - August 31) in subsequent field seasons.

The impact of sampling vegetation in more than once was also investigated using the Kruskal-Wallis test to determine whether sampling at different times during the year, and in different years, significantly affected the FQAI score. Minitab Version 9.2 was used to calculate the Kruskal-Wallis test. A total of eight sites sampled more than once were included in this test. If the species lists from multiple samples are combined, the FQAI score for the site increases. However, this increase was not statistically significant using the Kruskal-Wallis test (H=5.18, df=3, p=0.160). The conclusion is that the FQAI score is relatively robust when sampling of sites occurs in different years or by different investigators.

Although FQAI scores did increase with repeated sampling, there appears to be no advantage to repeated sampling in terms of differentiating between sites (i.e., using the FQAI to differentiate site quality). There was no increase in the biological signal provided by the FQAI by sampling in the autumn as well as summer. Therefore, in order to conserve staff time and resources, the FQAI sampling index period was set for between June 15 and August 31. This time period was used to sample vegetation in the 1997 growing season.

1997 FQAI Results - The results of the 1997 vegetation sampling effort are shown on Table 2.8. FQAI scores ranged from a low of 12.0 at the Ackerman site to a high of 34.0 at the Lawrence

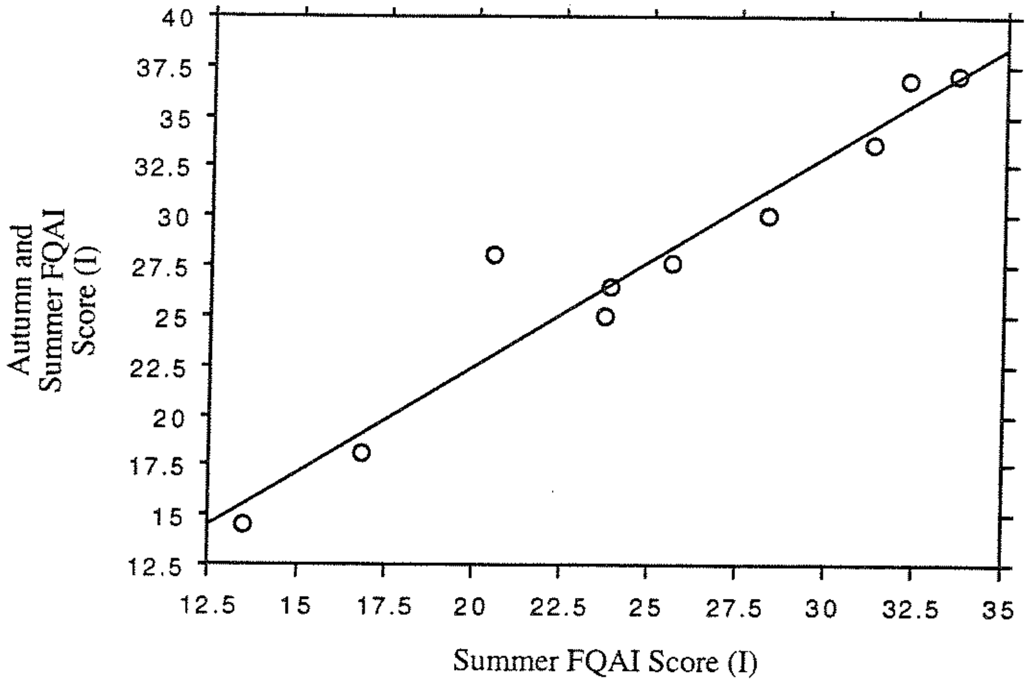


Figure 2.5. Relationship between the FQAI score for plant species collected during the summer and autumn, 1996 and the plant species collected during the summer only. $y = 1.213 + 1.063x$, $R = 0.964$.

Table 2.8. Summary of floristic assessment parameters calculated at 14 cental Ohio depressional wetlands during 1997

Wetland Site	Sampling Date	FQAI	Perennial/Annual Ratio	Percent Native Species	Total Species Richness
Ackerman	7/1/97	12.0	17.00	89	18
Calamus	8/6/97	27.2	3.47	80	85
Callahan	8/19/97	26.4	3.64	94	51
Dever	6/26/97	17.7	6.50	71	45
Flowing Well	7/8/97	31.3	3.07	95	61
Hebron	7/24/97	27.6	5.50	90	78
Hempelman	7/22/97	31.5	3.77	94	62
Keller High	7/15/97	27.1	5.00	92	48
Keller Low	7/17/97	17.6	6.40	89	37
Lawrence High	8/13/97	34.0	4.50	94	66
Lawrence Low	8/5/97	19.6	2.88	81	31
Leafy Oak	7/29/97	33.2	3.71	96	80
Route 29	8/26/97	23.1	3.36	85	48
Sawmill	6/25/97	31.4	4.13	84	77

High site. The Leafy Oak site was a close second with a score of 33.2. This range of scores is very similar to the one obtained for the 1996 field season. Ackerman also had the lowest species richness of any wetland included in this study, with a total of 18 taxa recorded. The highest species richness was found at the Leafy Oak site, with 80 species recorded. The percent native species ranged from 71 percent at the Dever site (an emergent wetland heavily impacted by agriculture) to a high of 96 percent at Leafy Oak.

FQAI Scores versus Disturbance Rank - The disturbance rank determined for each site was used to evaluate the performance the Floristic Quality Assessment Index. A correlation analysis was conducted for FQAI as a function of the relative disturbance rank, and the results show a highly significant correlation (Figure 2.6; $R = 0.76$, $p < 0.001$). FQAI scores increase as disturbance level decreases. This indicates that the FQAI is providing a biological signal of the relative level of wetland degradation. The FQAI has also been found to be a sensitive measure of the degree of disturbance in forested riparian wetlands (Fennessy et al. 1998). Incorporation of the FQAI into a wetland biological monitoring and assessment program appears to have merit as a reliable means to assess wetland condition.

FQAI Scores versus Rapid Assessment Method Results - Figure 2.7 shows the relationship between the results of the Washington State Wetlands Rating System (RAM) and the FQAI scores for all 1996 reference sites (Figure 2.7(a)). The correlation between these two scoring systems was high ($R = 0.80$, $p = 0.006$). This is significant in that it indicates that biological data collected and evaluated using an Ohio-based assessment technique (the FQAI) is highly correlated to a rapid assessment method developed for the state of Washington, i.e., it appears that the ecological basis of the Washington RAM has merit in the Ohio. These findings in part led to the decision to base a rapid assessment method for Ohio on the approach used in the Washington State Rating System. It also formed the basis to evaluate aspects of the macroinvertebrate and amphibian data (see Section 3.1).

As part of this analysis, sites were divided into two groups based on their dominant vegetation be

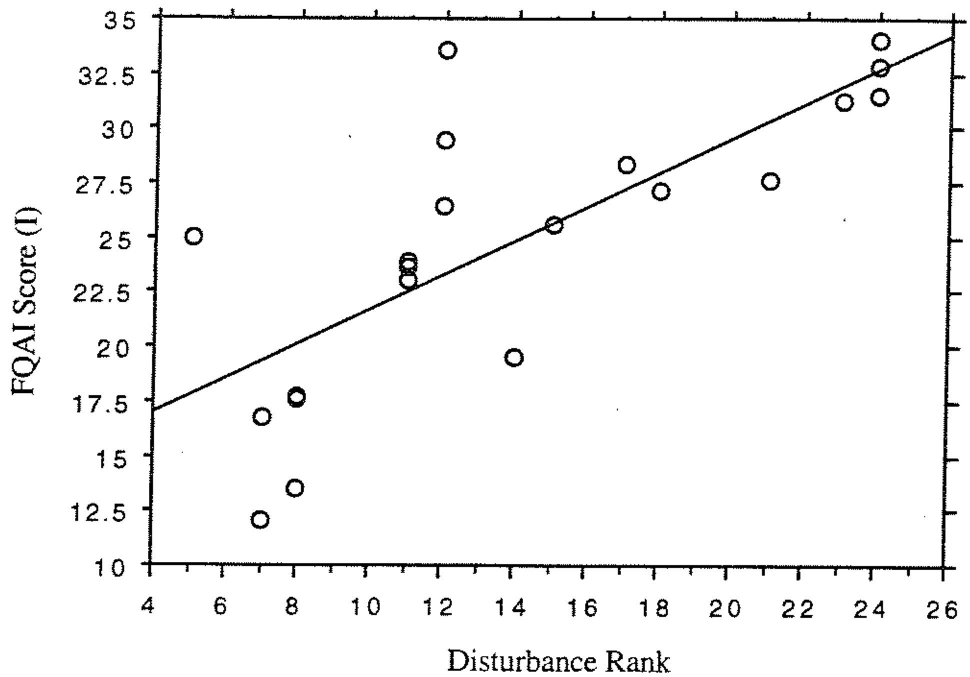


Figure 2.6. Correlation between wetland disturbance rank and FQAI score (I) for wetland sites sampled in 1996 and 1997. For sites sampled in both years, an average FQAI score was calculated. $y = 13.83 + 0.788 * x$, $R = 0.755$, $p < 0.0001$.

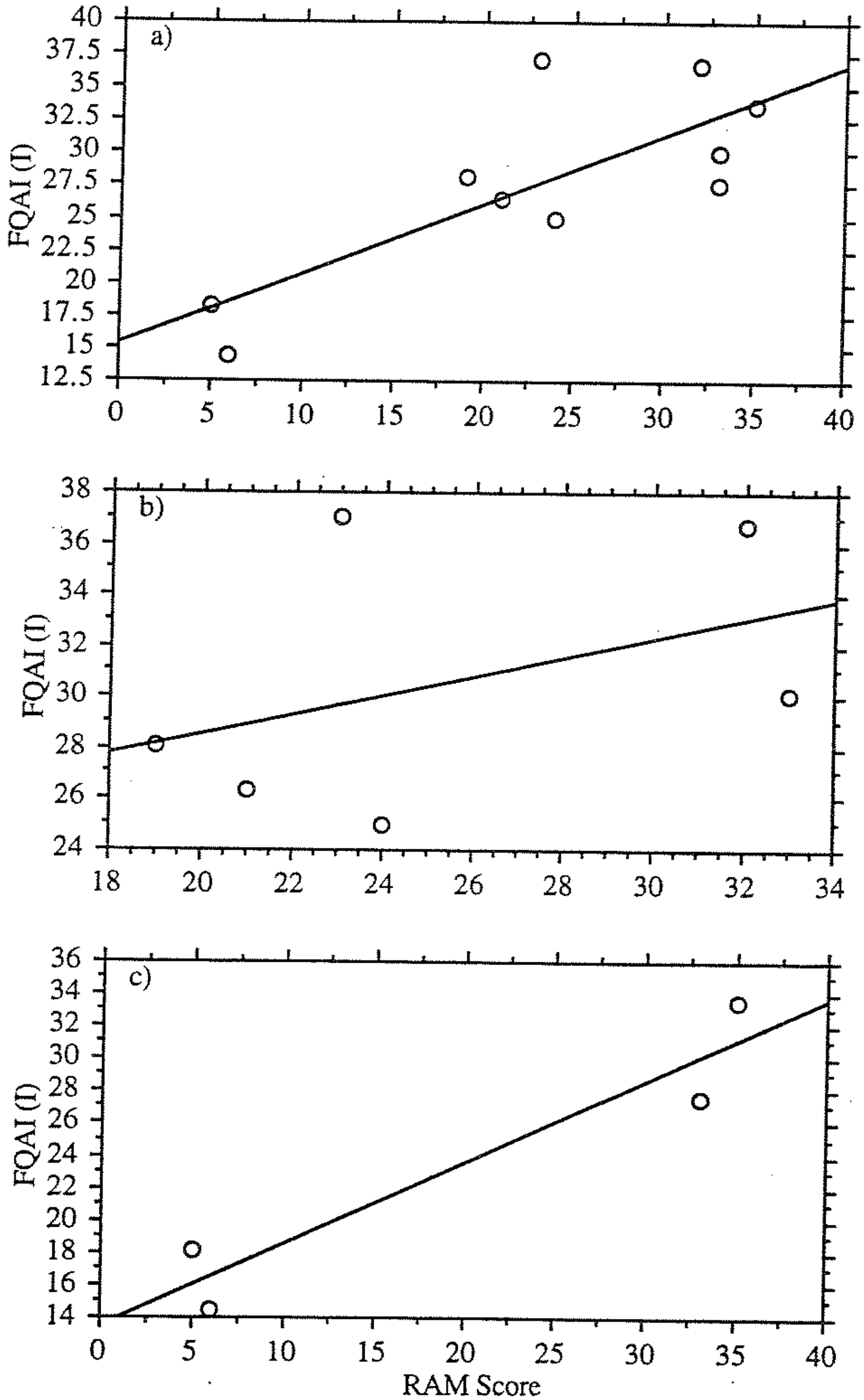


Figure 2.7. Relationships between the Washington State Wetlands Rating System (RAM) score and the Floristic Assessment Index (FQAI) score (I) for the central Ohio depressional wetlands studied in 1996. a) The 10 wetland sites: $y = 15.3 + 0.54x$, $R = 0.80$, $p = 0.0060$. b) The 6 forested wetlands: $y = 21.0 + 0.38x$, $R = 0.34$, $p = 0.41$. c) The 4 emergent wetlands: $y = 13.5 + 0.51x$, $R = 0.95$, $p = 0.05$.

it emergent or forested. The correlation between FQAI and RAM data for emergent sites was high ($R = 0.95$, $p = 0.05$). The data from forested sites shows much more scatter with a correspondingly weaker correlation ($R = 0.3$, $p = 0.41$). Figure 2.8 shows the same relationships for the results of the Ohio Wetland Assessment Method. Again, the correlation between all sites was significant ($R = 0.76$, $p = 0.003$), as it was for emergent wetlands only ($R = 0.996$, $p = 0.004$). However, the data collected from forested sites was weak and not significant ($R = 0.30$, $p = 0.43$).

One explanation for the lack of significant findings for the forested sites is the fact that it was difficult during the site selection process to find forested wetland sites which fully spanned the range of disturbance from least-impacted to impaired. Forested depressional wetlands in Ohio tend to remain on the landscape because they were too wet to drain effectively for agricultural production. Thus nearly all of the forested sites in this study were found located in woodlots in agricultural settings. Although these sites have been impacted to some degree by human activities in the surrounding lands, most were left relatively undisturbed. Thus the range of condition of the forested sites was relatively narrow. Emergent sites on the other hand, were more representative of the full range of condition, both least-impacted and very impaired sites (as well as those in between) were found for inclusion as reference sites.

<u>Comparison of the FQAI Data with OWAM Categories</u> - Two analyses were performed using the Jonchkeere-Terpstra directional comparison test. The first compared Category 1 to Category 2 to Category 3 wetlands (as proposed). This necessitated assigning wetlands which had OWAM scores in the intermediate range (i.e. 12-16 and 30-34) to one of these three categories. This was done using other information of the site in question and the best professional judgment of the investigators. The second test compared four groups: Category 1 to Category 2 to "Category 2+" (RAM of 30-34) to Category 3. Note that since only site had a RAM score that fell within the 12-16 intermediate zone, a "Category 1+" group was not included.

Both Jonckheere-Terpstra analyses yielded highly significant results (Table 2.9a). Thus, the FQAI

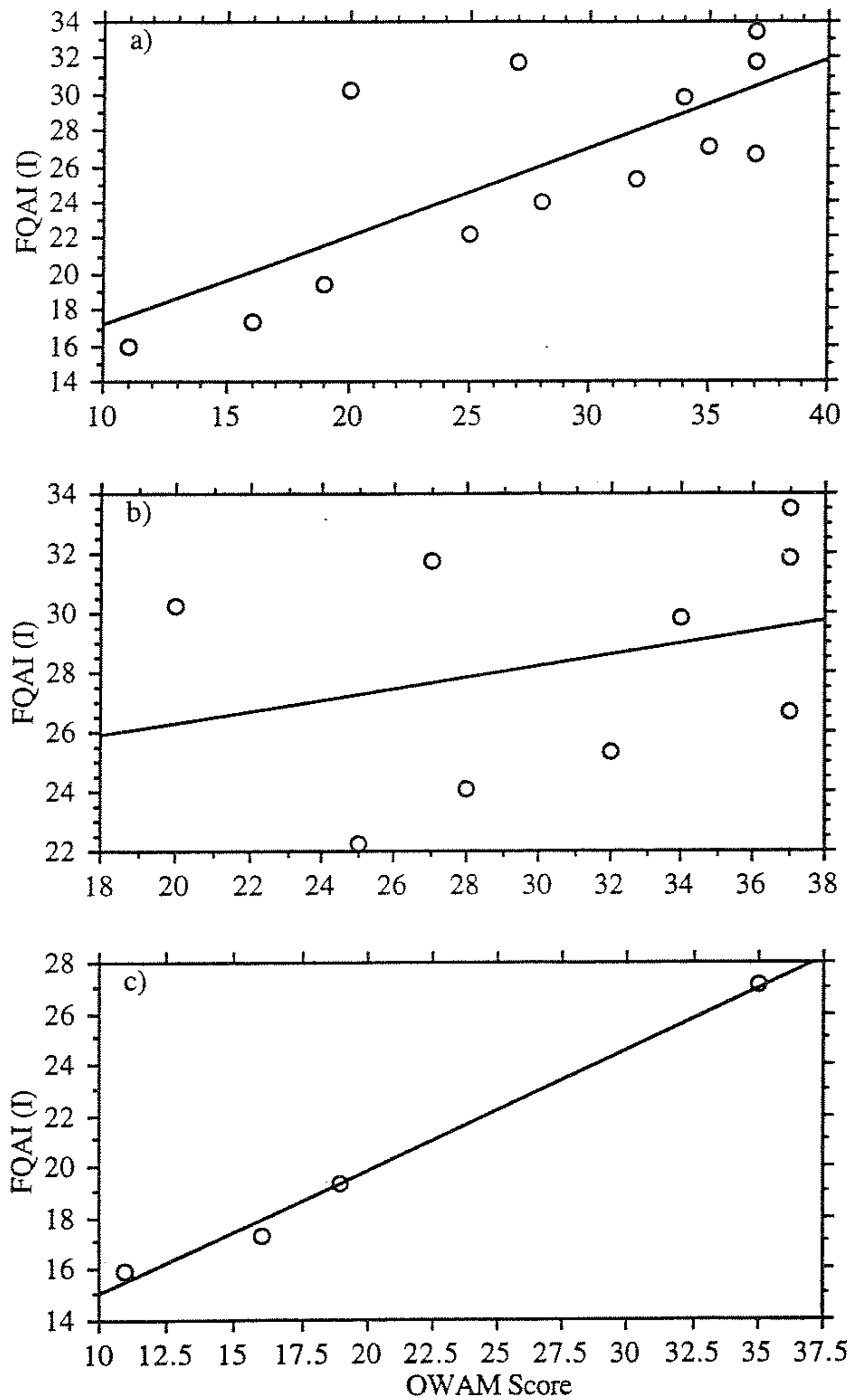


Figure 2.8. Relationships between the Ohio Wetland Assessment Method (OWAM) score and the Floristic Assessment Index (FQAI) score (I) for the central Ohio depressional wetlands studied in 1997. a) The 13 wetland sites: y = 12.2 + 0.49x, R = 0.76, p = 0.003. b) The 9 forested wetlands: y = 22.4 + 0.19x, R = 0.30, p = 0.43. c) The 4 emergent wetlands: y = 10.3 + 0.48x, R = 0.996, p = 0.004.

Table 2.9(a). Summary table of results of Jonckheere-Terpstra Test for 3 and 4 category analyses. Results from Kruskal-Wallis Test are included for comparison. J is the Jonckheere-Terpstra statistic, J* is the large sample approximation Jonckheere-Terpstra statistic.

comparison	N	J	J*	p	p Kruskal-Wallis
I < II < III	20	103	3.70813	<.0002	0.011
I < II < II+ < III	20	112	3.51876	<.0002	0.031

Table 2.9(b). Summary table for Critchlow-Flinger multiple comparison test for three and four wetland category analyses. Wij is Wilcoxon rank sum for second category of each category compared and W*ij is Critchlow-Flinger statistic.

comparison	n	mean rank	Wij	W*ij
I	3	3.3	95	1.434
II	10	8.6		
I	3	2.0	49	3.384*
III	7	7.0		
II	10	7.6	88	2.484
III	7	12.6		

*significant at alpha = .05 with overall experimentwise error rate = 0.15

comparison	n	mean rank	Wij	W*ij
I	3	2.3	71	3.269
II	9	7.9		
I	3	2.0	30	3.162
II+	5	6.0		
I	3	2.0	15	2.777
III	3	5.0		
II	9	6.4	47	2.168
II+	5	9.4		
II	9	5.7	27	1.961
III	3	9.0		
II+	5	4.2	15	0.632
III	3	6.0		

* no comparisons significant at alpha = .05

scores increased as the wetland category increased. This provides support for the rapid assessment method and the breakpoints in the RAM scores (i.e., the categories are significantly different as measured by the FQAI data). The same data were analyzed using the Kruskal-Wallis test with both the 3 category and 4 category comparisons significant, although the alpha levels were lower for the Jonckheere-Terpstra test. This is the expected result, since if the *a priori* ordering is correct, the Jonckheere-Terpstra test is more powerful than the more general Kruskal-Wallis test (Hollander and Wolfe 1997).

Because of the computational complexity of the Hayter-Stone test which is the multiple comparison method recommended by Hollander and Wolfe (1997) to follow significant results from the Jonckheere-Terpstra test, the individual differences between the median FQAI scores for the categories was analyzed using the Kruskal-Wallis test followed by the Critchlow-Fligner multiple comparison test. For the three category analysis, Category I to III was significantly different (Table 2.9b). In the four category analysis, no comparisons were significantly different. The Critchlow-Fligner test is not as sensitive as the Hayter-Stone method given ordered differences (Hollander and Wolfe 1997). Given the highly significant results from the Jonckheere-Terpstra test it is likely that more of the pairwise comparisons would be significant if the Hayter-Stone test could have been used. In addition the small sample size within the categories may probably negatively impacted this analysis. These conclusions will be restested when a larger sample size becomes available.

<u>The Relationship between FQAI Scores and Biomass Production in Emergent Wetlands</u> - Estimates of aboveground plant biomass production in the emergent wetlands in each year is shown on Table 2.10. Biomass estimates ranged in each year from approximately 250 to 1500 $g \cdot m^{-2}$. This is a typical range for biomass production in emergent wetlands (Mitsch and Gosselink 1993). Biomass was sampled in both years at the Calamus wetland and the results were very consistent (243 and 281 $g \cdot m^{-2}$). Table 2.11 shows total litter fall biomass in the forested sites. Estimates of litter fall ranged from 2717 to 4642 $kg \cdot ha^{-1}$. The majority of total litter was

Table 2.10. Mean peak biomass production at 7 predominantly emergent depressional wetlands assessed in 1996 and/or 1997. N = 10 for all sites except County Road 200, where N = 5.

Assessment Year	Wetland Site	Aboveground Plant Biomass ± std. dev. (g/m^2)
1996	Calamus	243±14
1996	County Road 200	469±61
1996	Mishne	1206±59
1996	Rickenbacker	291±35
1997	Calamus	281±13
1997	Dever	1532±47
1997	Keller Low	835±49
1997	Lawrence Low	496±34

Table 2.11. Total litter fall biomass measured beneath the canopy in 11 central Ohio fore: wetlands during Autumn, 1997. Mean values are given ± 1 std. dev. for all sites except Cessna and Callahan, where N = 4. Total Litter Mass = Leaf Litter Mass + Woody Litter Mass.

Wetland Site	Total Litter Mass (kg/ha)	Leaf Litter Mass (kg/ha)	Woody Litter Mass (kg/ha)
Ackerman	2717±1807	1944±1002	773±1207
Calamus	2922±1198	2807±1176	115±106
Callahan	3916±617	3902±606	14±16
Flowing Well	3679±786	3517±650	162±179
Hebron	2071±1945	1567±1441	505±708
Hempelman	3667±505	3598±452	69±60
Keller High	4130±658	4094±667	36±41
Lawrence High	4467±519	4307±495	160±163
Leafy Oak	3415±1262	3056±926	359±495
Route 29	4401±1415	4304±1449	98±110
Sawmill	4642±219	4571±248	71±79

comprised of leaf fall at each site, although the fall of woody debris was significant at several locations.

FQAI scores were plotted against total biomass production in the emergent wetlands (Figure 2.9). The results were fit with an exponential curve and show a strong correlation ($R = 0.85$). FQAI values rapidly decrease as community biomass production increases. FQAI values fall below 20 as biomass reaches approximately 500 $g \cdot m^{-2}$. This is a predictable ecological relationship (Keddy 1995) resulting from the increasing dominance of monoclonal species such as *Typha* spp., as disturbance levels or nutrient enrichment at a site increase. As wetlands become dominated by species such as *Typha* spp., diversity tends to decrease (resulting in lower FQAI scores) and biomass production tends to increase. Figure 2.9 illustrates that the FQAI is responding in an ecologically predictable way and lends support to its use as an indicator of wetland ecosystem integrity.

Landscape Variables and Vegetation Community Characteristics - National Wetland Inventory Maps (NWI) were used to characterize both the distance to nearest neighbor wetlands (using a mean of the three nearest neighbors of the same wetland class) and the wetland density (including wetlands of all classes) within a 1 km radius of each wetland reference site studied in 1997. The results were plotted against FQAI scores for both the forested depressional sites (Figure 2.10) and the emergent depressional sites (Figure 2.11). We predicted that as the mean distance to neighboring wetlands increased, the FQAI scores would tend to decrease (i.e., as the wetland becomes more isolated by human dominated land use, and as the distance to a source of propagules increases). As wetland density in the area surrounding the reference wetalnd increases, we predicted that FQAI scores would increase. Figure 2.10 shows just these relationships for the forested sites. Patterns in the FQAI data are responding to landscape level patterns of wetland distribution. This data provides evidence that the FQAI responds to landscape level effects, and indicates it may reliably be used to monitor wetland condition.

Plots of mean distance to nearest neighbors for emergent wetlands versus FQAI, as well as

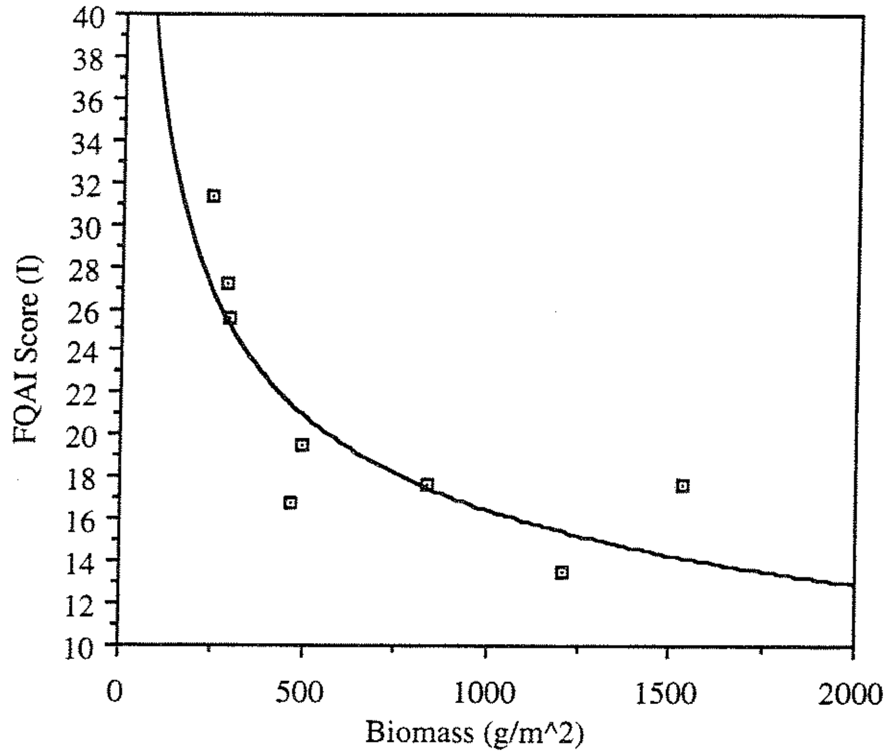


Figure 2.9. Relationship between the Floristic Quality Assessment Index and biomass production in the 8 central Ohio wetlands sampled during 1996 and 1997. $y = 182.71 * x^{-0.348}$, $R = 0.850$.

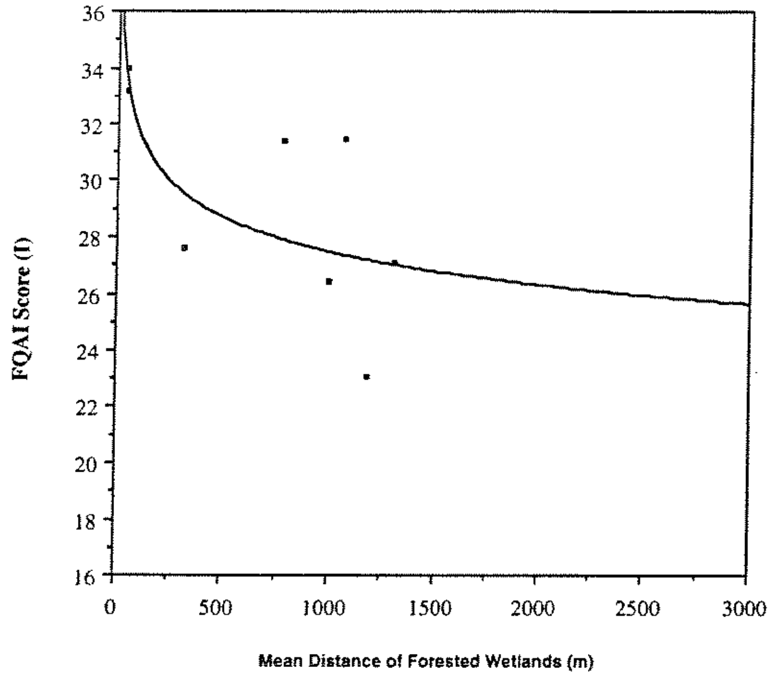


Figure 2.10a. Relationship between the FQAI score and the mean distance (N = 3) of other forested wetlands nearby the 8 forested wetland sites studied during 1997 ($y = 42.38 * x^{-0.063}$; R = 0.680).

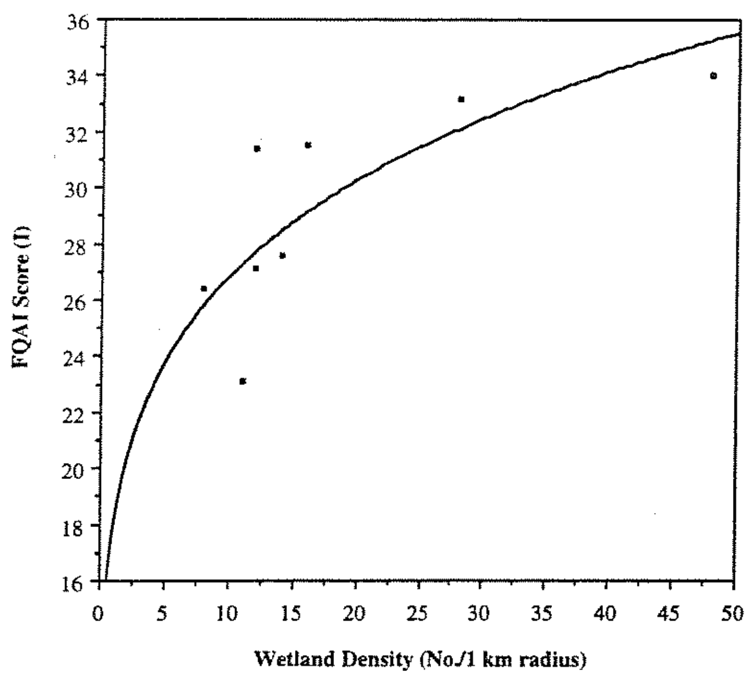


Figure 2.10b. Relationship between the FQAI score and the local wetland density within a 1 km radius of the 8 forested wetland sites studied during 1997 ($y = 17.98 * x^{0.174}$; R = 0.750).

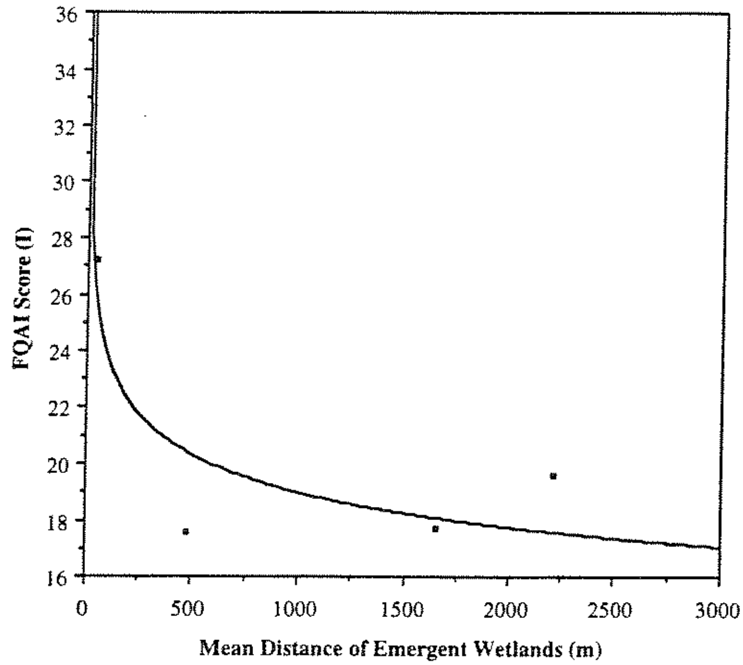


Figure 2.11a. Relationship between the FQAI score and the mean distance (N = 3) of other emergent wetlands nearby the 4 emergent wetland sites studied during 1997 ($y = 37.37 * x^{-0.098}$; R=0.83).

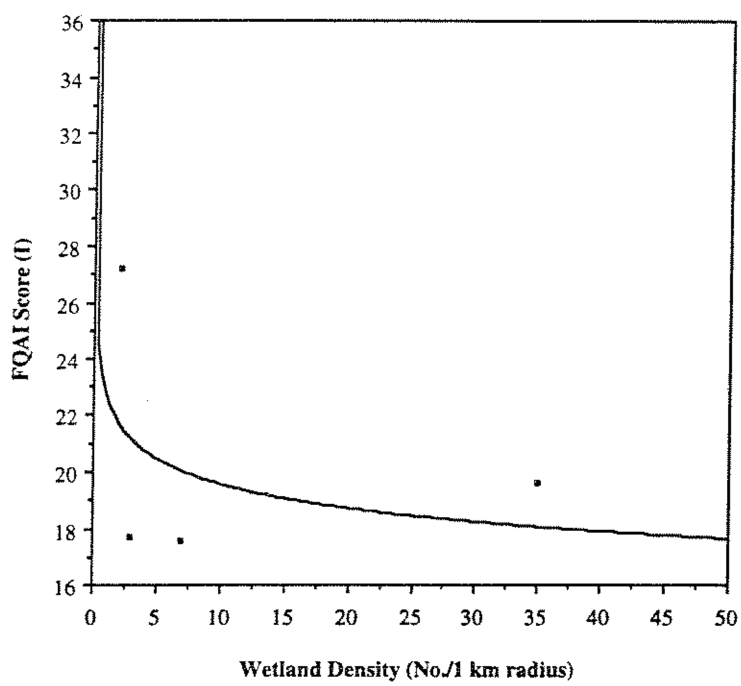


Figure 2.11b. Relationship between the FQAI score and the local wetland density within a 1 km radius of the 4 emergent wetland sites studied during 1997 ($y = 22.70 * x^{-0.064}$; R=0.400).

wetland density versus FQAI are shown in Figure 2.11. The same patterns hold true for the emergent sites, however, the 1997 reference sites included only 4 emergent wetlands. Because of the small sample size this data must be viewed as preliminary.

Figures 2.12 and 2.13 show the same landscape variables plotted against species richness at each site. The forested wetlands show strong correlations in which species richness decreases as the mean distance to nearest neighbor wetlands increases. As wetland density increases, species richness increases. These relationships can be explained in the same way, i.e., as the wetland becomes more isolated by human dominated land use, and as the distance to a source of propagules increases, species richness at a given site will decline. The plots for emergent sites shown in Figure 2.13 should again be viewed as preliminary since only 4 sites were included as reference wetlands. In fact, the plot for species richness versus wetland density for the emergent wetlands shows that as density increases, species richness will decrease. This is contrary to the predictions made above and is largely the result of one site with few neighboring wetlands but with a high number of species. If this site is excluded, the other 3 wetlands in the sample are arranged essentially on a straight line. The collection of more data is warranted to more fully investigate this relationship.

The effect of the surrounding landscape on wetland condition was also evaluated by examining differences that might arise in FQAI scores as a function of the type of buffer area that surrounds the wetlands (Table 2.12). Reference wetlands were divided into two groups: those surrounded by agricultural lands (row crop or pasture), and those with a forested or old field buffer in the 100 m zone surrounding the wetland. The results of an unpaired t-test show that mean FQAI scores were significantly higher ($p = 0.001$) at sites with a forested/old field buffer area. The mean FQAI score for sites with no buffer zone (agricultural use up to the wetland boundary) was nearly 50 percent lower. This has potentiallly important implications for land use management. If the provision of a small area of wetland buffer has such a pronounced effect on the quality of the wetland (as measured by the FQAI), then landscape level planning must take this into account. Recommendations to incorporate wetland buffers could be made in order to offer protection to

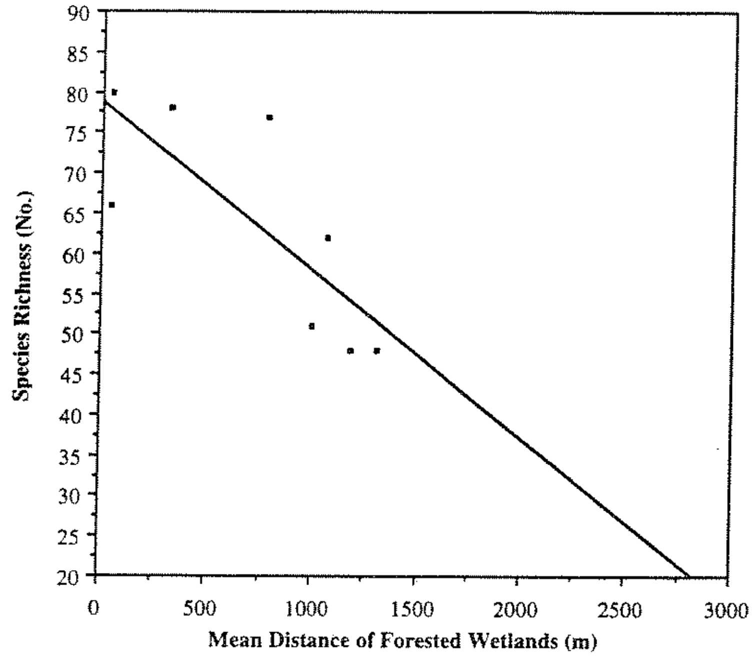


Figure 2.12a. Relationship between the species richness and the mean distance (N = 3) of other forested wetlands nearby the 8 forested wetland sites studied during 1997 ($y = 78.74 - 0.019x$; $R=0.780$).

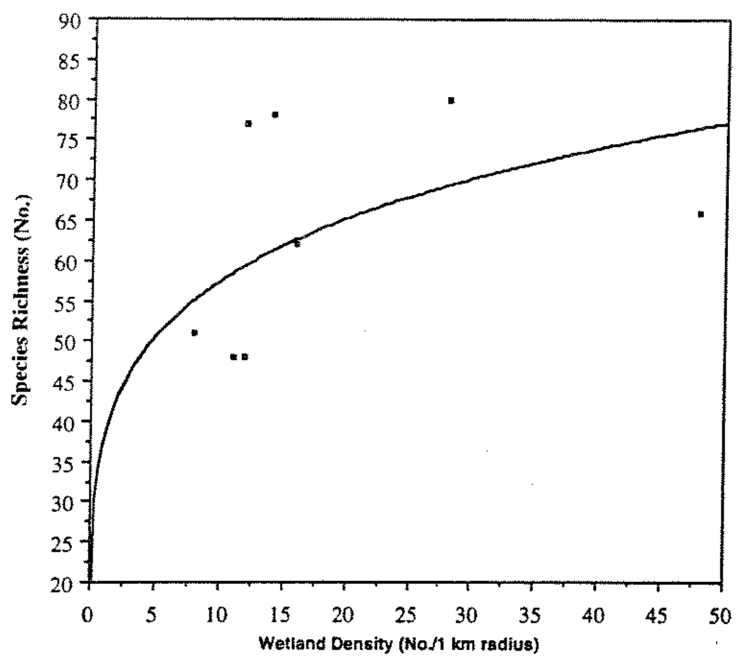


Figure 2.12b. Relationship between the species richness and the local wetland density within a 1 km radius of the 4 emergent wetland sites studied during 1997 ($y = 37.74 * x^{0.183}$; $R=0.830$).

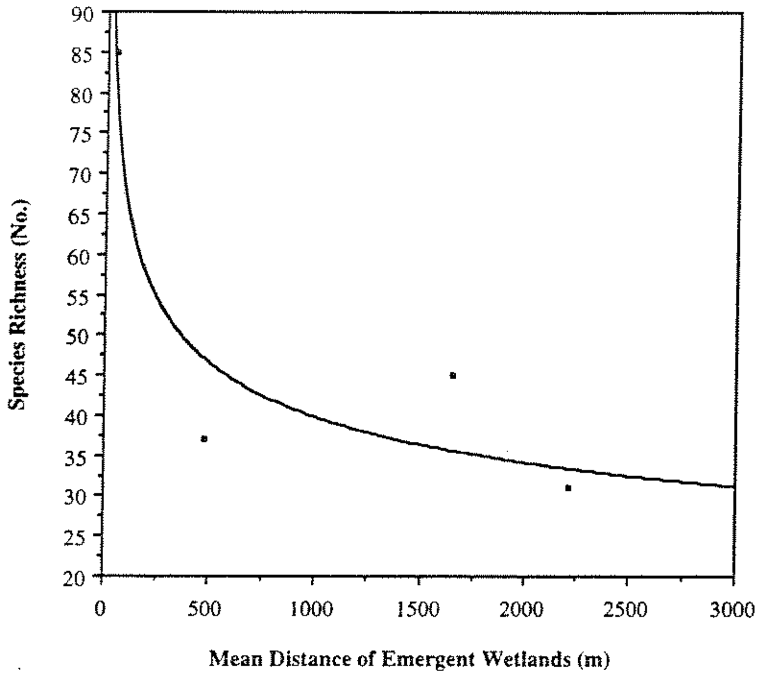


Figure 2.13a. Relationship between the species richness and the mean distance (N = 3) of other emergent wetlands nearby the 4 emergent wetland sites studied during 1997 ($y = 77.40 * x^{-0.288}$; R = 0.830).

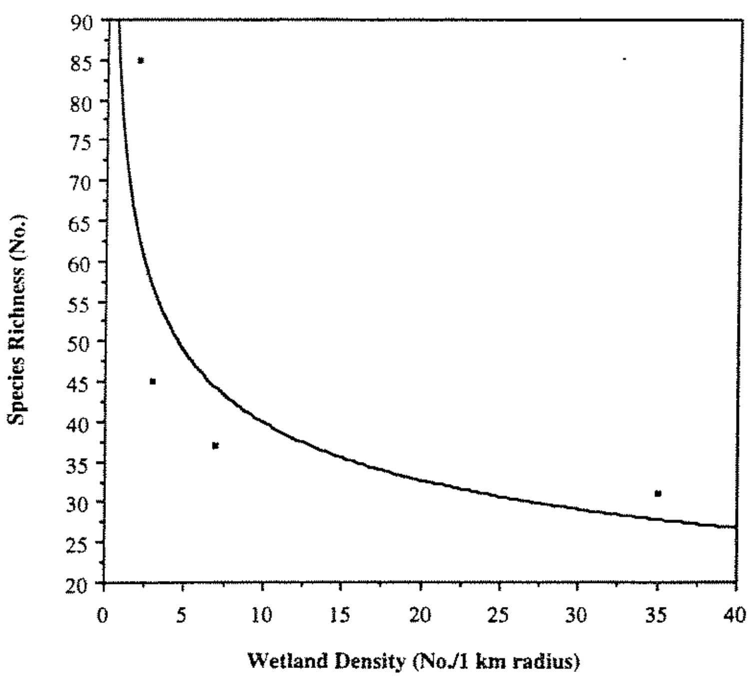


Figure 2.13b. Relationship between the species richness and the local wetland density within a 1 km radius of the 4 emergent wetland sites studied during 1997 ($y = 186.72 *x^{-0.224}$; R=0.890).

Table 2.12. Results of t-test comparing mean FQAI values in wetlands surrounded by agricultural land (row crop or pasture) to those surrounded by forested/old field areas

Surrounding Land Cover	Mean FQAI (I)
Agricultural Land	16.5 ± 1.1 (N=6) *
Forest/Old Field	30.9 ± 1.2 (N=11)

* significant at $p = 0.001$

wetland ecosystems. This could help both to increase the success of efforts to restore wetlands, as well as to protect the quality of those wetlands which remain.

The impact of adjacent agricultural land use was further investigated by examining nutrient levels in the wetland's surface water. Nutrient concentrations at those sites which had FQAI scores under 25 were compared to those with scores higher than 25 (this value was chosen to represent a mid-point in the spread of FQAI scores). Mean nutrient levels in the low scoring sites were higher than in the high scoring sites (Table 2.13). Results of an unpaired t-test show that concentrations of total P and NO_3-NO_2 - N were significantly higher in the low scoring group. This lends further evidence to findings that wetlands in agricultural landscapes with no buffers (to ameliorate the runoff of nonpoint source pollution), will have higher levels of agricultural nutrients, and lower FQAI scores in response. This data also provides an indication that nonpoint source runoff can be detrimental to wetland ecosystems.

Diameter at Breast Height (DBH) in Forested Wetlands - The distribution of tree size classes was plotted for the ten forested depressional wetlands studied in 1997. Six size classes were constructed (Figure 2.14). Little relationship was found between this data and other aspects of the vegetation community such as FQAI values or species richness.

Vegetation Community Sampling Effort - Plant species accumulation curves were plotted for four representative wetlands (two forested, two emeregent, Figure 2.15). Points were added to the figure at the point along the cumulative path length when sampling yielded an increase in the number of plant species recorded. All curves show a leveling off as path length increases. The addition of new taxa rapidly declined in the forested sites beyond a path length of 300 m. In emergent systems the addition of new taxa declined significantly beyond approximately 100 m. In both types of wetlands, the sampling effort expended was satisfactory to capture the point of apparent diminishing returns, i.e., the point where the curves level off. This provides confidence that the sampling effort used in this study was adequate. For this reason, the field protocols developed here will not be modified.

Table 2.13. Results of t-tests comparing nutrient levels in wetland surface water with FQAI values less than 25 and values greater than 25.

	For Sites where:	
Nutrient	**FQAI < 25**	**FQAI > 25**
Total P (mg/l) *	0.25 ± 0.06	0.14 ± 0.04
Nitrate+Nitrite (mg/l) **	2.75 ± 1.95	0.02 ± 0.01
Ammonia (mg/l)	0.19 ± 0.05	0.09 ± 0.06

Significant at *p = 0.10; **p = 0.05

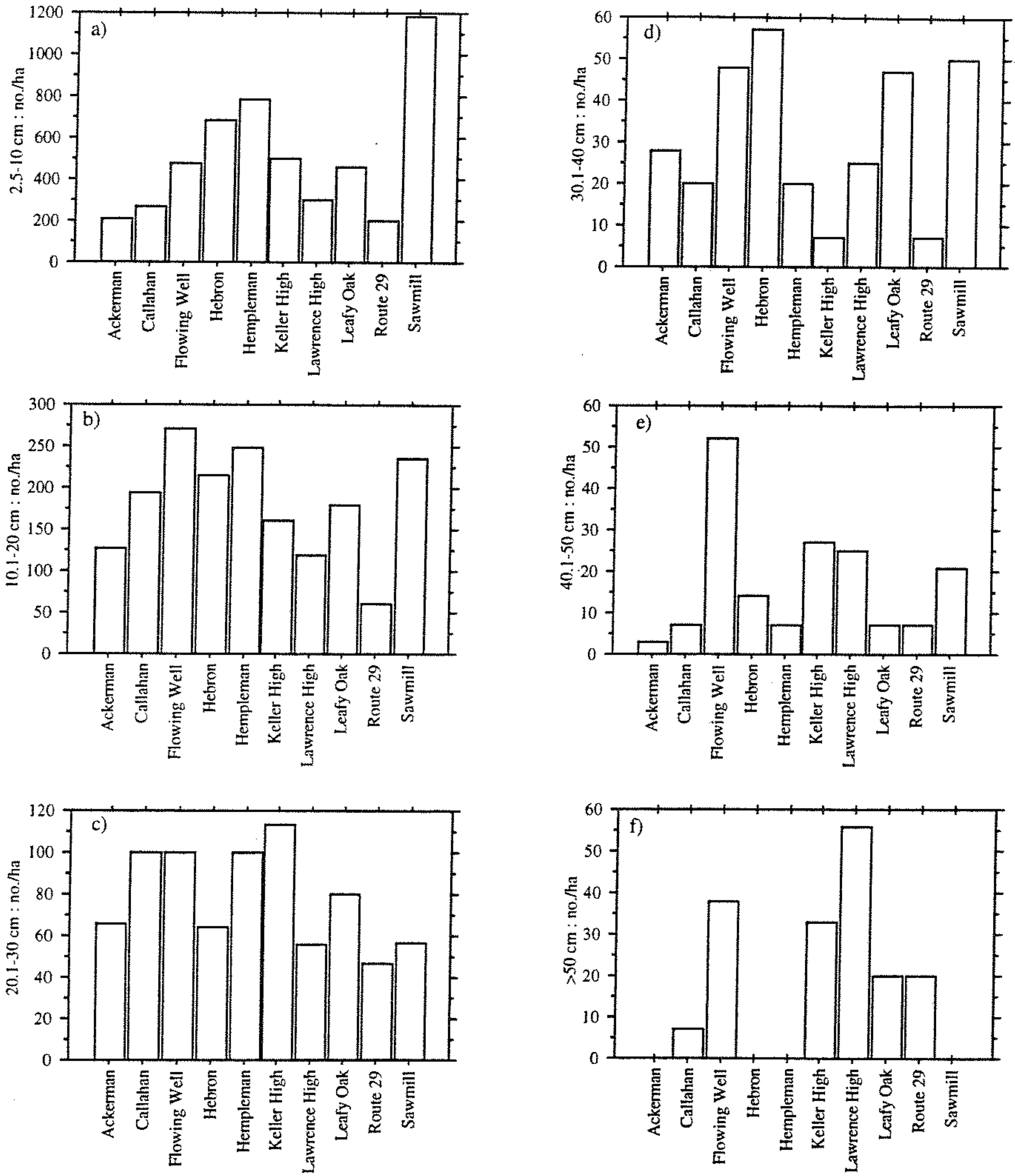
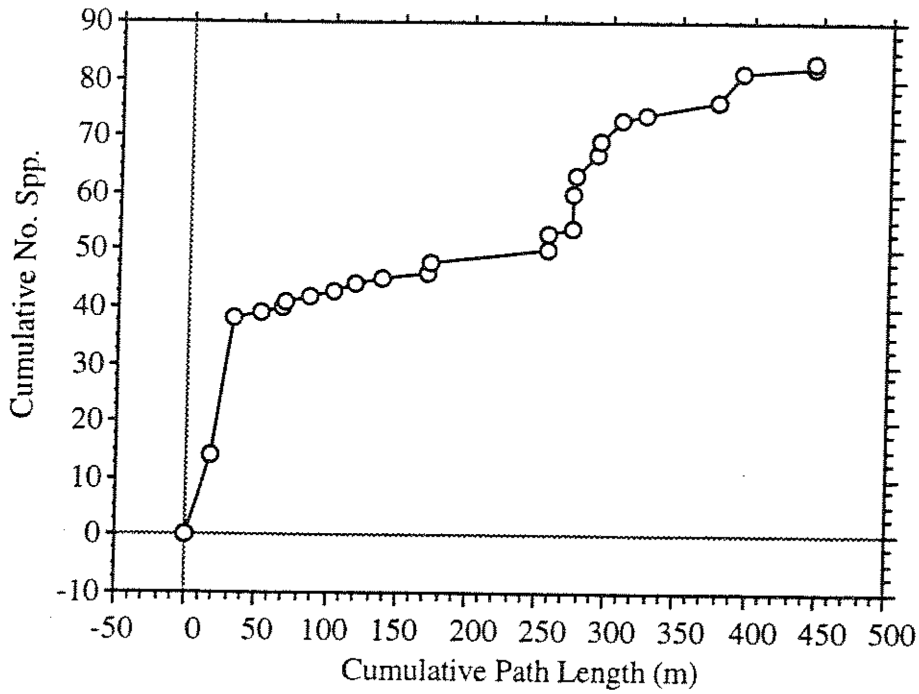


Figure 2.14. Distribution of tree size (DBH) classes in 10 central Ohio depressional wetlands studied in 1997. a) 2.5 - 10 cm DBH class, b) 10.1 - 20 cm DBH class, c) 20.1 - 30 cm DBH class, d) 30.1 - 40 cm DBH class, e) 40.1 - 50 cm DBH class, and f) greater than 50 cm DBH class.

a)



b)

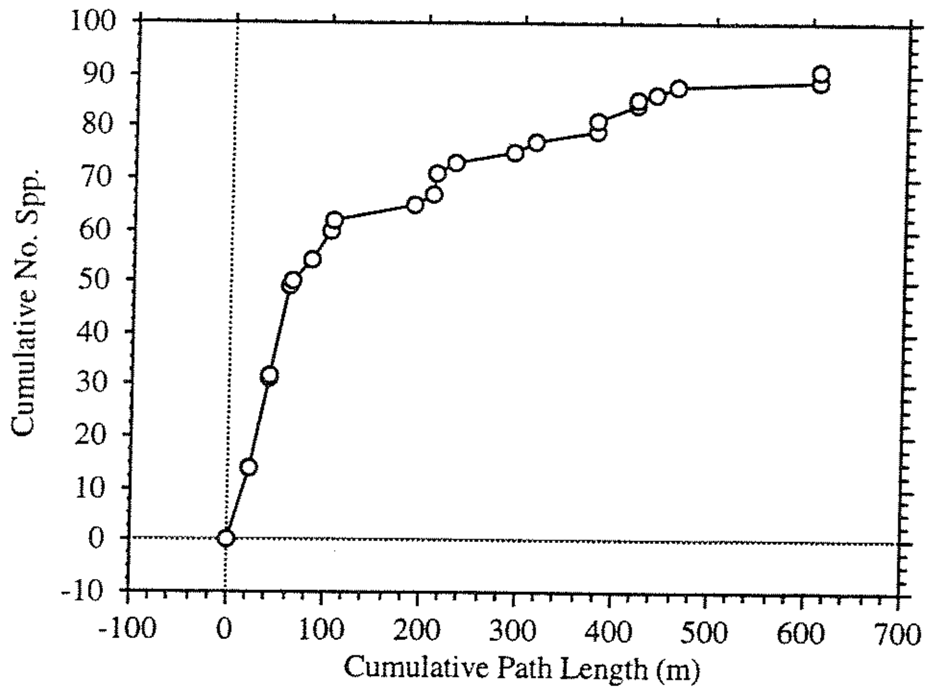
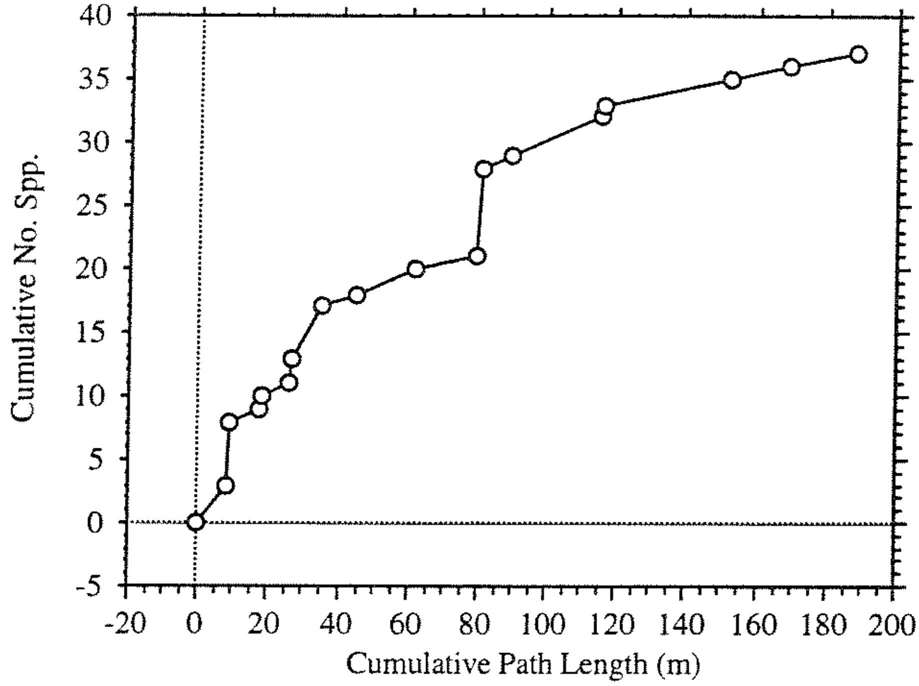


Figure 2.15. Plant species accumulation curves at two of the forested depressional wetland sites sampled during 1997: a) Sawmill and b) Leafy Oak. A point was added to the figure at the end of the cumulative path length when sampling yielded an increase in the number of plant species (continued on next page).

c)



d)

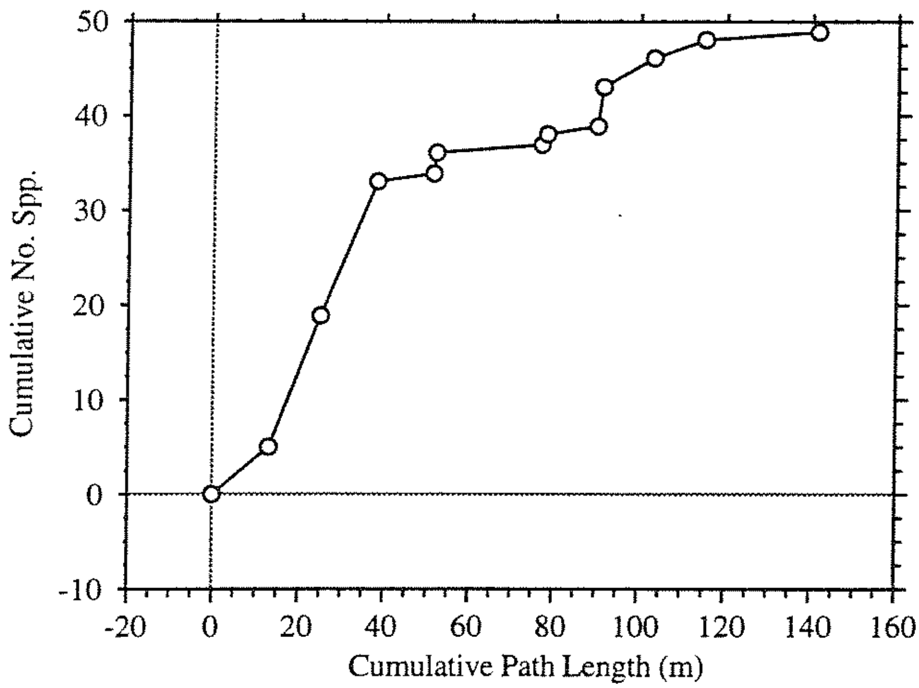


Figure 2.15 (continued). Plant species accumulation curves at two of the emergent depressional wetland sites sampled during 1997: c) Lawrence Low and d) Dever. A point was added to the figure at the end of the cumulative path length when sampling yielded an increase in the number of plant species.

Project 2: Development of Methodology For Sampling Macroinvertebrates and Development And Implementation Of Amphibian Sampling Protocol In Wetlands

Section 3.1. Results of the Macroinvertebrate and Amphibian Surveys

The primary objective of the project was to select an appropriate sampling methodology to assess wetland macroinvertebrate and amphibian fauna. In 1996 we used Hester-Dendy(HD) artificial substrate samplers, qualitative sampling and funnel traps to sample a variety of wetlands. A comparison of the total number of macroinvertebrate taxa collected by each sampling method is summarized in Table 3-1.

Table 3-1. Number of Macroinvertebrate Taxa Collected by Sampling Method

Wetland	Sample Date	HD # Taxa	Qualitative # Taxa	Funnel Trap # Taxa
Blanchard	5/10-23/96	10	21	17
Calamus	5/17-21/96	12	36	43
Calamus	8/21/96	10	33	45
Cessna	5/22-23/96	6	21	37
County Rd. 200	5/10-23/96	7	24	18
County Rd. 200	8/19-20/96	18	39	28
Gahanna Woods	5/21-29/96	11	18	23
Leafy Oak	5/10/96	9	28	25
McKinley	5/17-21/96	10	24	16
Mishne	5/21-27/96	10	29	28
Rickenbacker	5/16-21/96	22	32	42
Rickenbacker	8/21/96	27	20	48
Sawmill	5/21-29/96	9	23	30
AVERAGE		**12.4**	**26.8**	**30.8**

The HD samplers collected the fewest number of taxa. We believe that the HD samplers were ineffective in lentic habitats characteristic of wetlands because much of the fauna is motile and so few organisms colonize the HD. In stream monitoring HD's are an effective sampling tool since many organisms are benthic to avoid transport downstream.

Funnel traps initially designed to collect amphibians were also found to be very effective in collecting a wide variety of macroinvertebrates. All actively swimming and crawling organisms were readily collected in the funnel traps. Trapping collected more taxa than qualitative sampling. Before we adopted one sampling method, we compared results for potential bias against specific taxonomic groups. In 1997 we collected a qualitative sample at each site when we used funnel traps. We used this paired data set of 46 points to compare the methods in collecting total numbers of taxa as well as for specific taxa groups. Figure 3-1 shows that funnel traps collected on average 10 more taxa per site than the qualitative sample (qual mean # taxa=23., funnel trap mean # taxa=33.4). A seasonal analysis of the same data shows that the average number of taxa is consistently greater in the funnel trap samples (Figure 3-2). There is not any seasonal variability in the relative effectiveness of the methods. The fewest taxa were collected in March, with a rapid increase in April. In May the number of taxa collected declined but gradually increased in June and July.

In addition to looking at summary results of the sampling methods, it is useful to look for trends in the raw data set. We plotted the raw data with # of qualitative taxa on the X axis and # of funnel trap taxa on the Y axis. A line of equality divides the plots into an area above the line where the number of taxa collected by funnel traps is greater than qualitative sampling, while the area below the line indicates that qualitative sampling was more effective. A number in ( ) following data points indicates where the number of observations is greater than one. The plot of total macroinvertebrate taxa shows that funnel traps in all but 2 of the 46 observations collected more taxa than qualitative sampling (Figure 3-3).

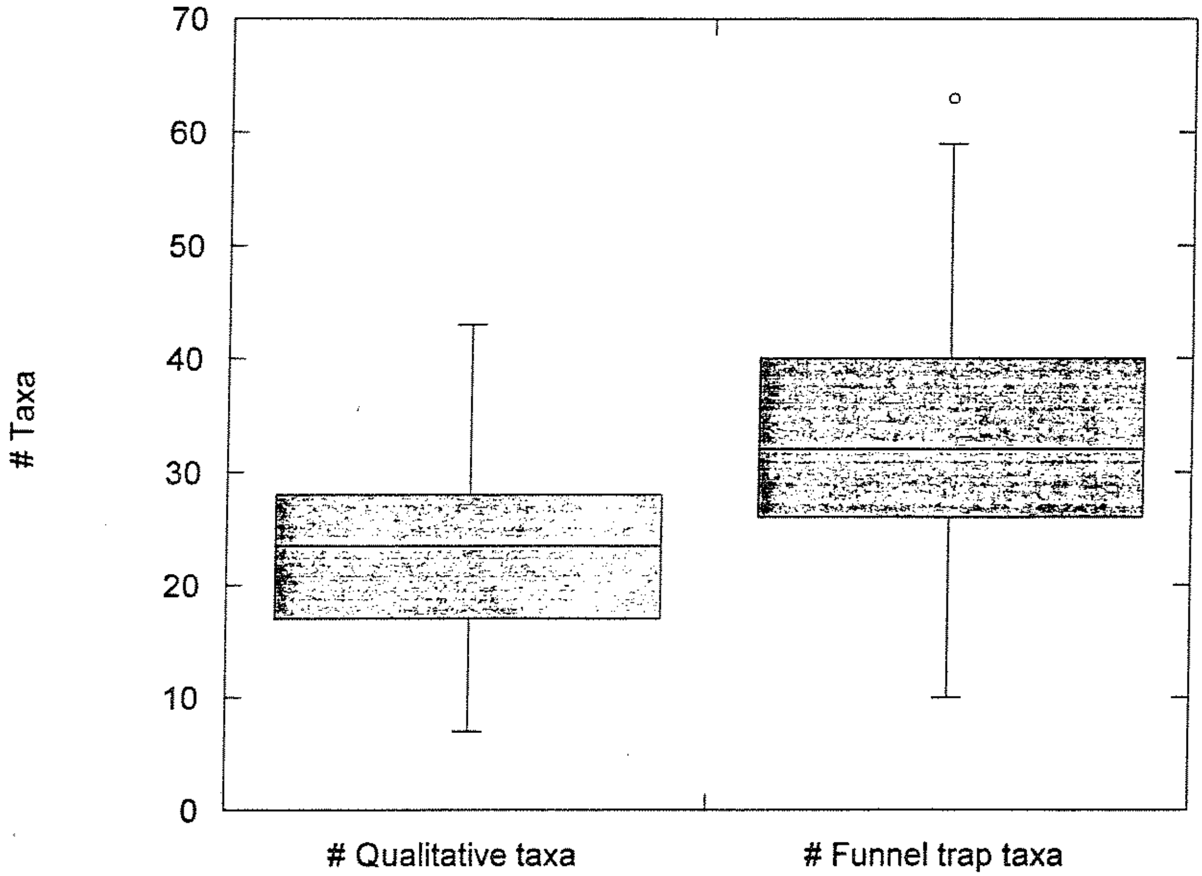


Figure 3-1: Average and Range of # of Taxa Collected by Sampling Method 1997 Data

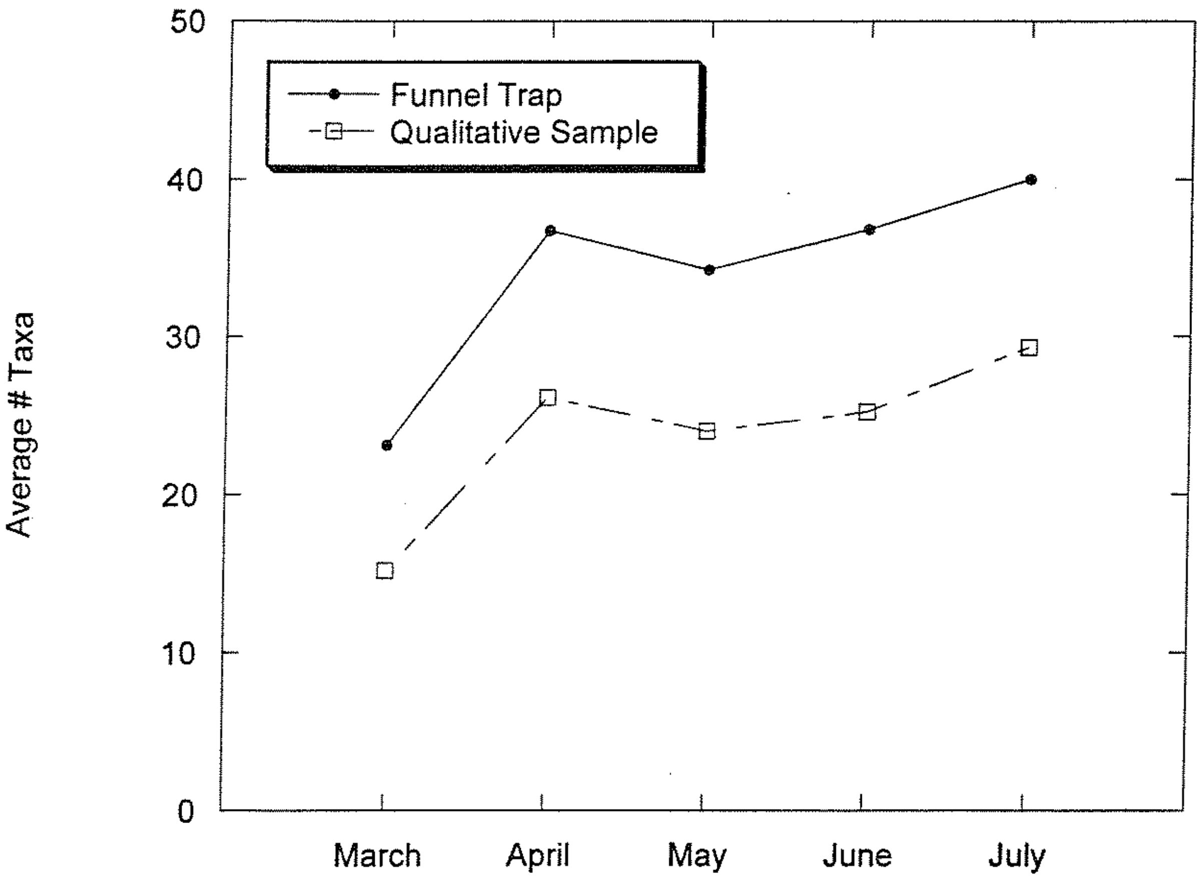


Figure 3-2: Average # Macroinvertebrate Taxa by Month and Sampling Method for 1997

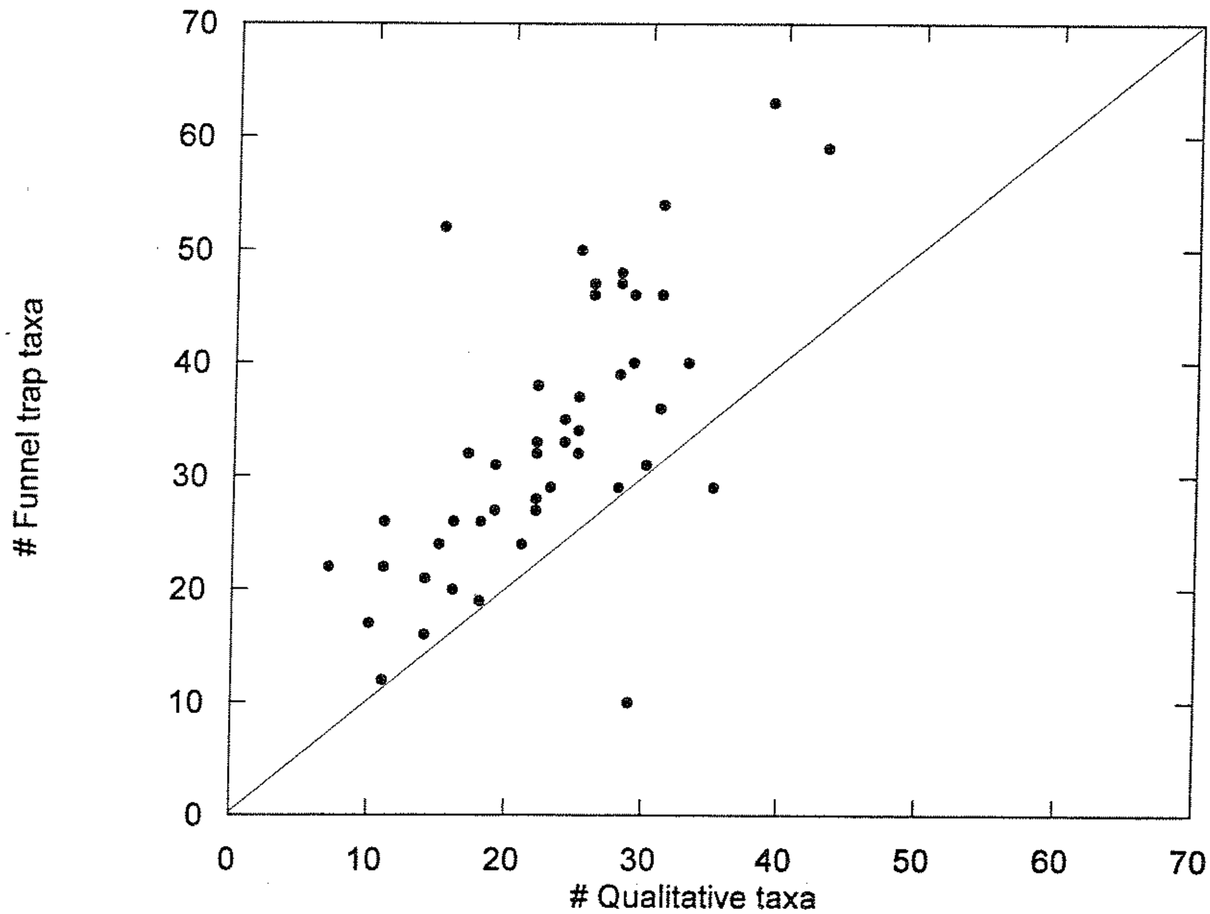


Figure 3-3: Number of Macroinvertebrate Taxa Collected by Sampling Method

We also looked at the data by specific taxonomic groups. By using similar plots we can determine if one sampling method is better than another for any taxonomic groups. Crustacea are more readily collected by funnel traps (Figure 3-4). More mollusca taxa were collected by qualitative sampling (Figure 3-5). Molluscs are not highly motile so it is not surprising that qualitative sampling produces more taxa. We should note that molluscs including fingernail clams were commonly collected in funnel traps. Odonata were more readily collected in the funnel traps than qualitative sampling (Figure 3-6). This is somewhat surprising since many Odonata larvae (except the Zygoptera and Aeshnidae) are rather sedentary ambush type predators. Coleoptera larvae and adults are very active and funnel traps clearly are the most effective way to sample them (Figure 3-7). Diptera show mixed results. For this group each sampling method is about equally effective (Figure 3-8). Phantom midges such as Chaoborus and Mochlonyx are active open water predators while other Diptera such as the Chironomidae are not highly motile. The Chironomidae were somewhat better represented in qualitative samples though large numbers were collected in funnel traps as well (Figure 3-9). Many of the midges in the funnel traps were early instars that probably crawled through the screen mesh of the trap where it was in contact with the bottom. Many of the Hemiptera are active predators and were more readily collected in funnel traps (Figure 3-10). The wetlands we sampled contained relatively few Trichoptera taxa but the two sampling methods were about equally effective (Figure 3-11). Ephemeroptera were more commonly collected in funnel traps though there were relatively few taxa (Figure 3-12). Largely sedentary taxa, Porifera, Turbellaria, Coelenterata and Bryozoa, were lumped together. Surprisingly funnel traps collected more of these taxa than qualitative sampling (Figure 3-13). Many of the Porifera and Coelenterata entered the traps attached to the cases of Limnephilus sp. caddisflies. More leech taxa were collected in funnel traps (Figure 3-14). The predatory species are active swimmers. The parasitic species probably entered the traps attached to fish and amphibians.

In permanently innundated wetlands that had fish populations, funnel traps were effective in collecting them (Figure 3-15). The fish were apparently able to avoid capture in the dipnet. Amphibians were collected in funnel traps far more frequently than with qualitative sampling

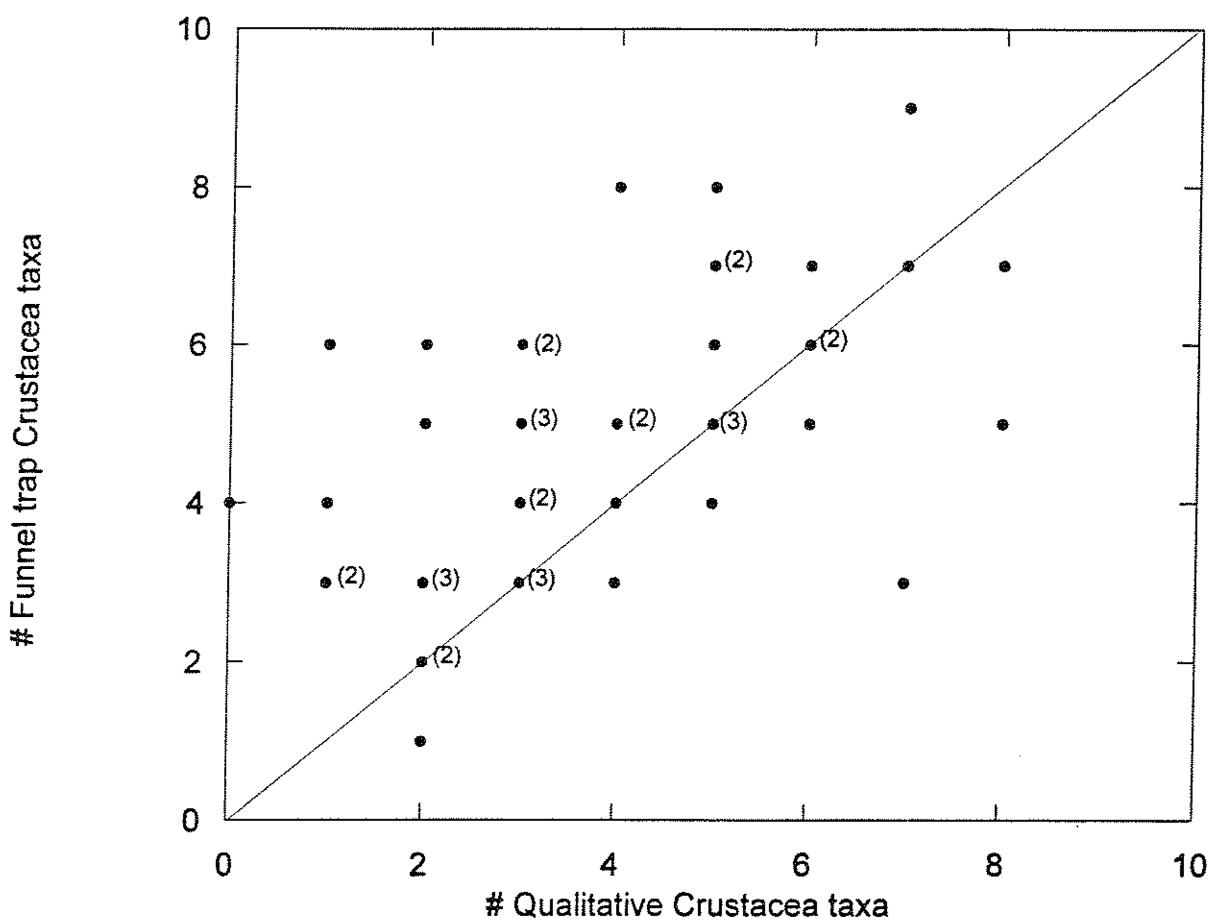


Figure 3-4: Number of Crustacea Taxa Collected by Sampling Method

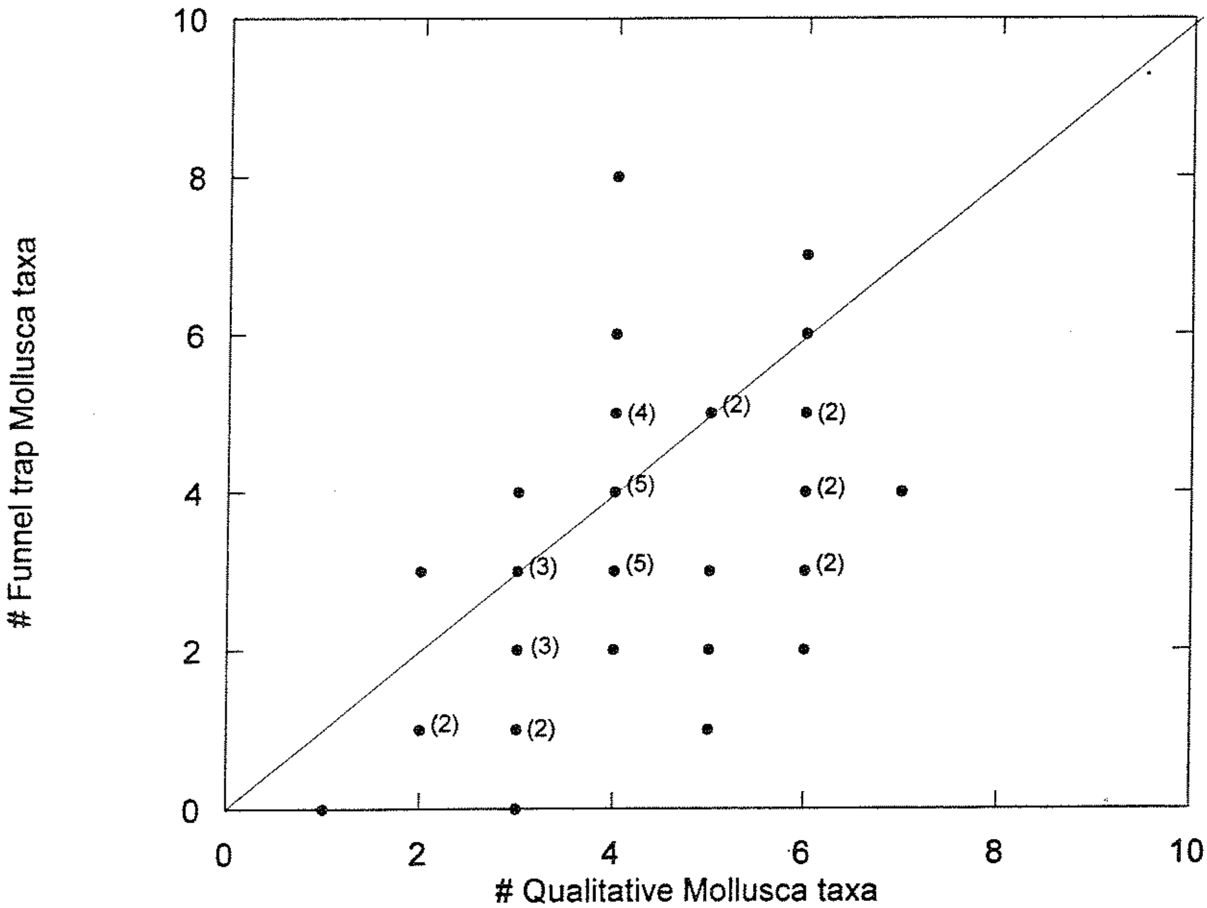


Figure 3-5: Number of Mollusca Taxa Collected by Sampling Method

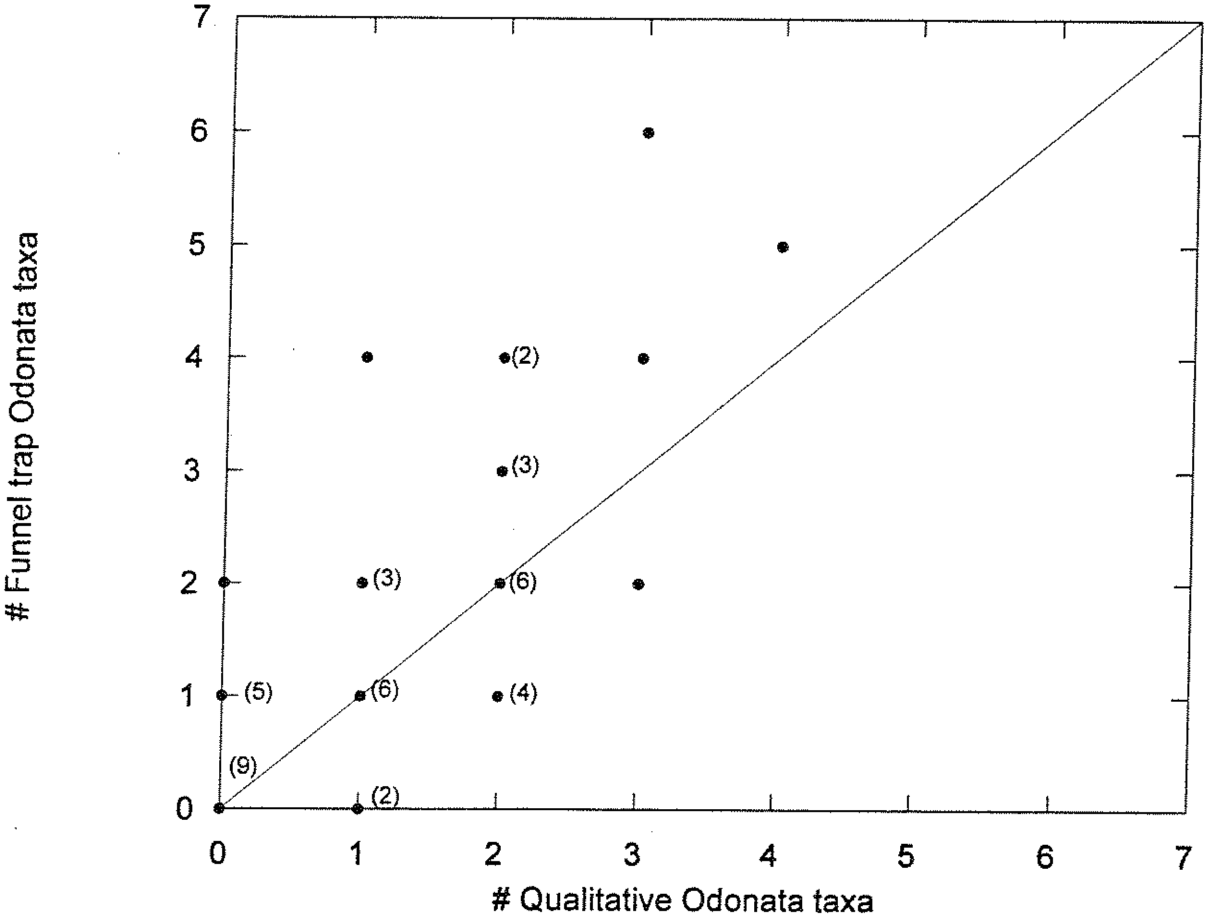


Figure 3-6: Number of Odonata Taxa Collected by Sampling Method

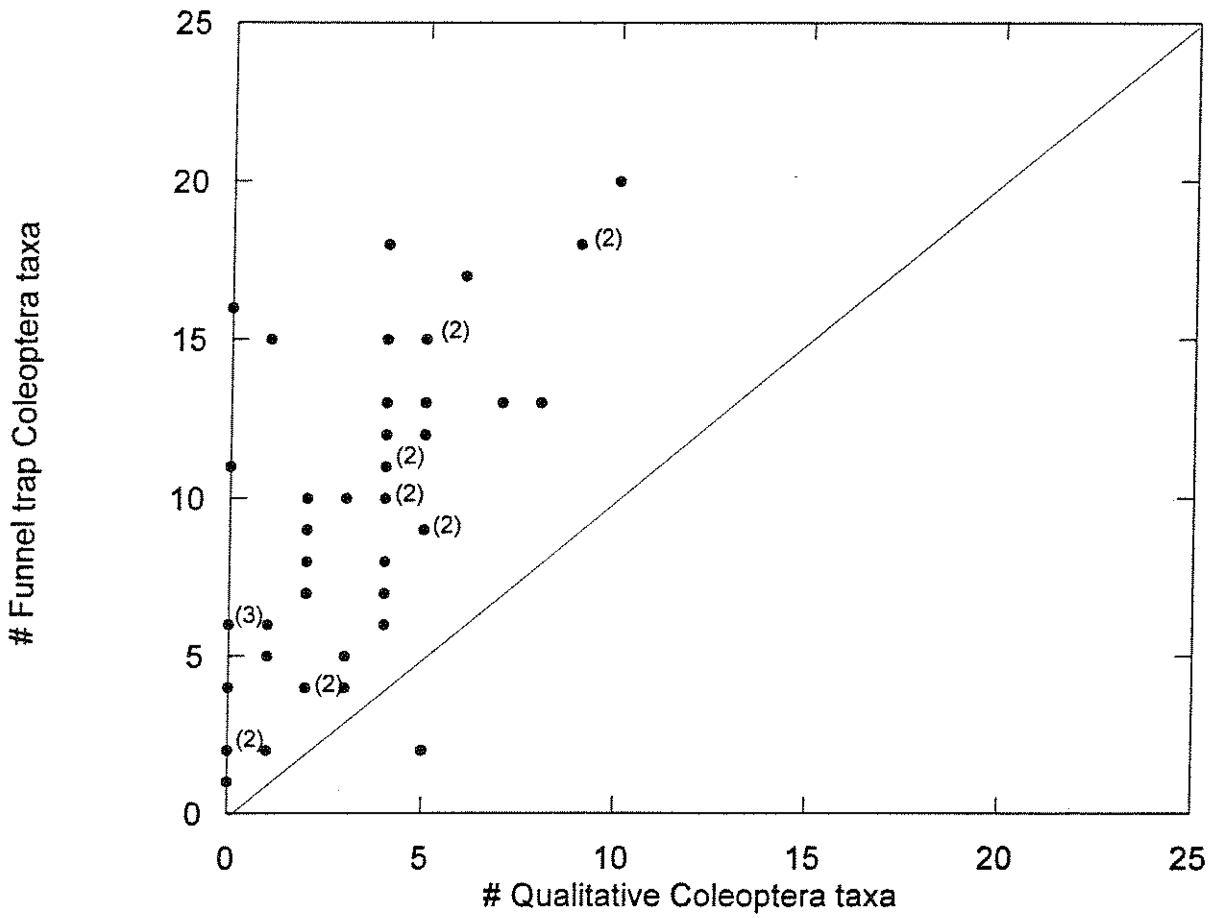


Figure3-7: Number of Coleoptera Taxa Collected by Sampling Method

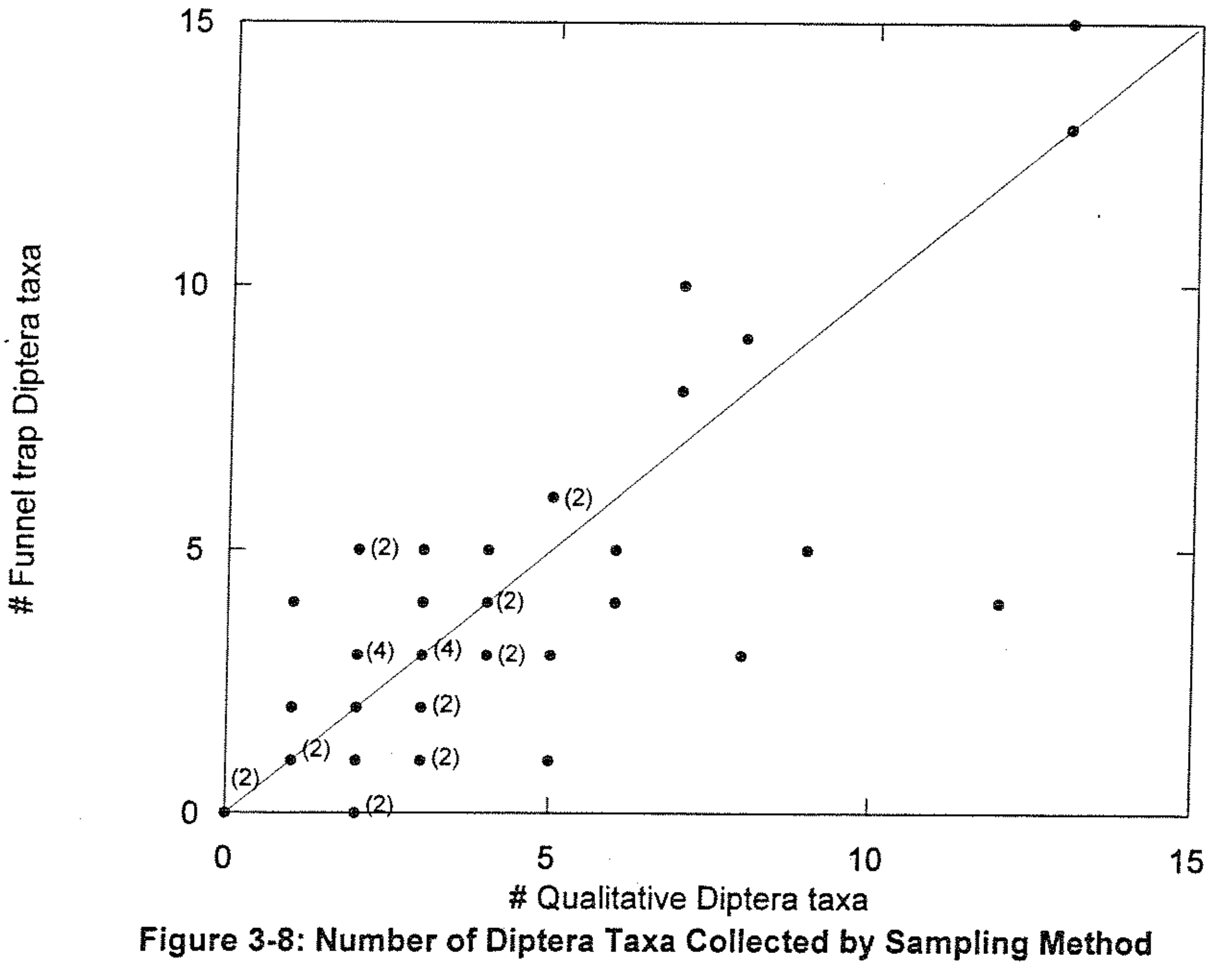


Figure 3-8: Number of Diptera Taxa Collected by Sampling Method

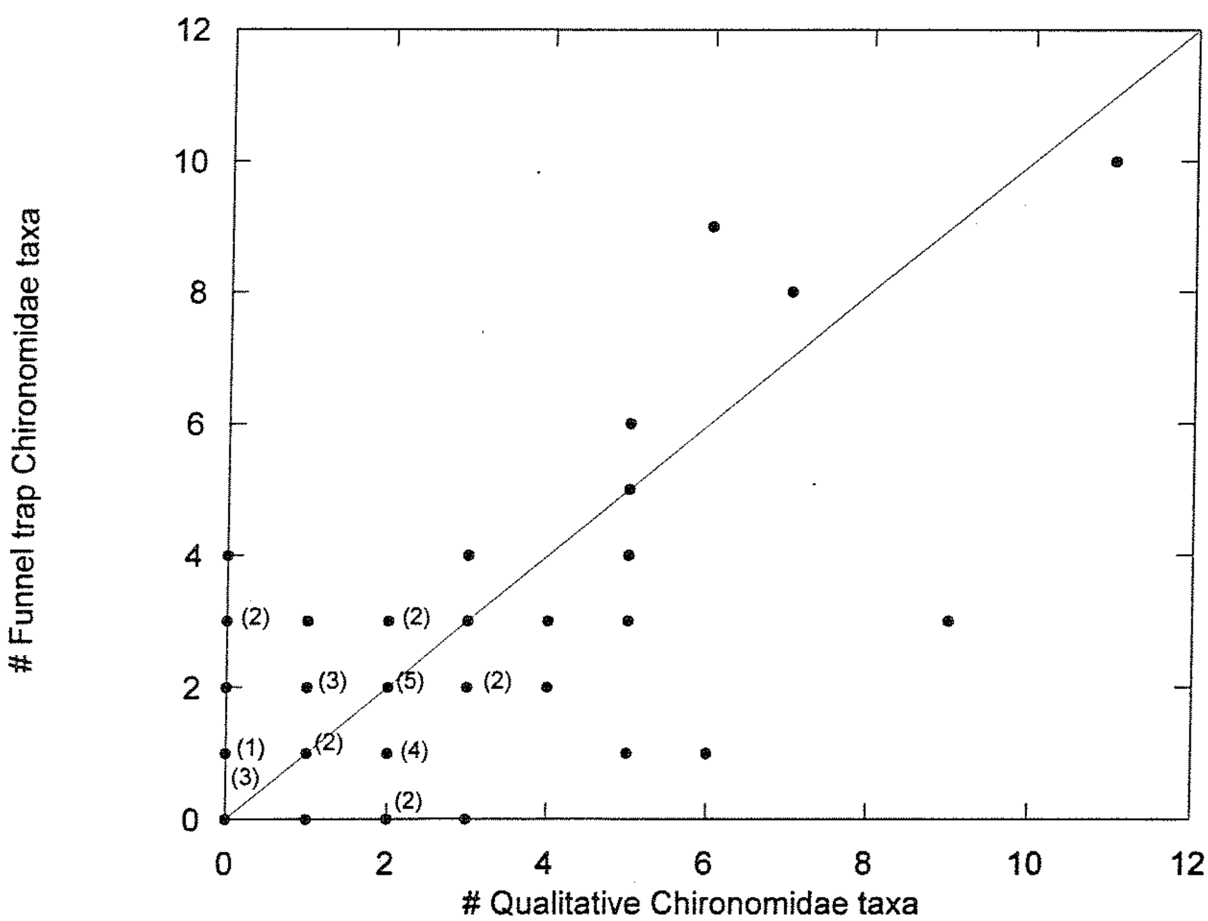


Figure 3-9: Number of Chironomidae Taxa Collected by Sampling Method

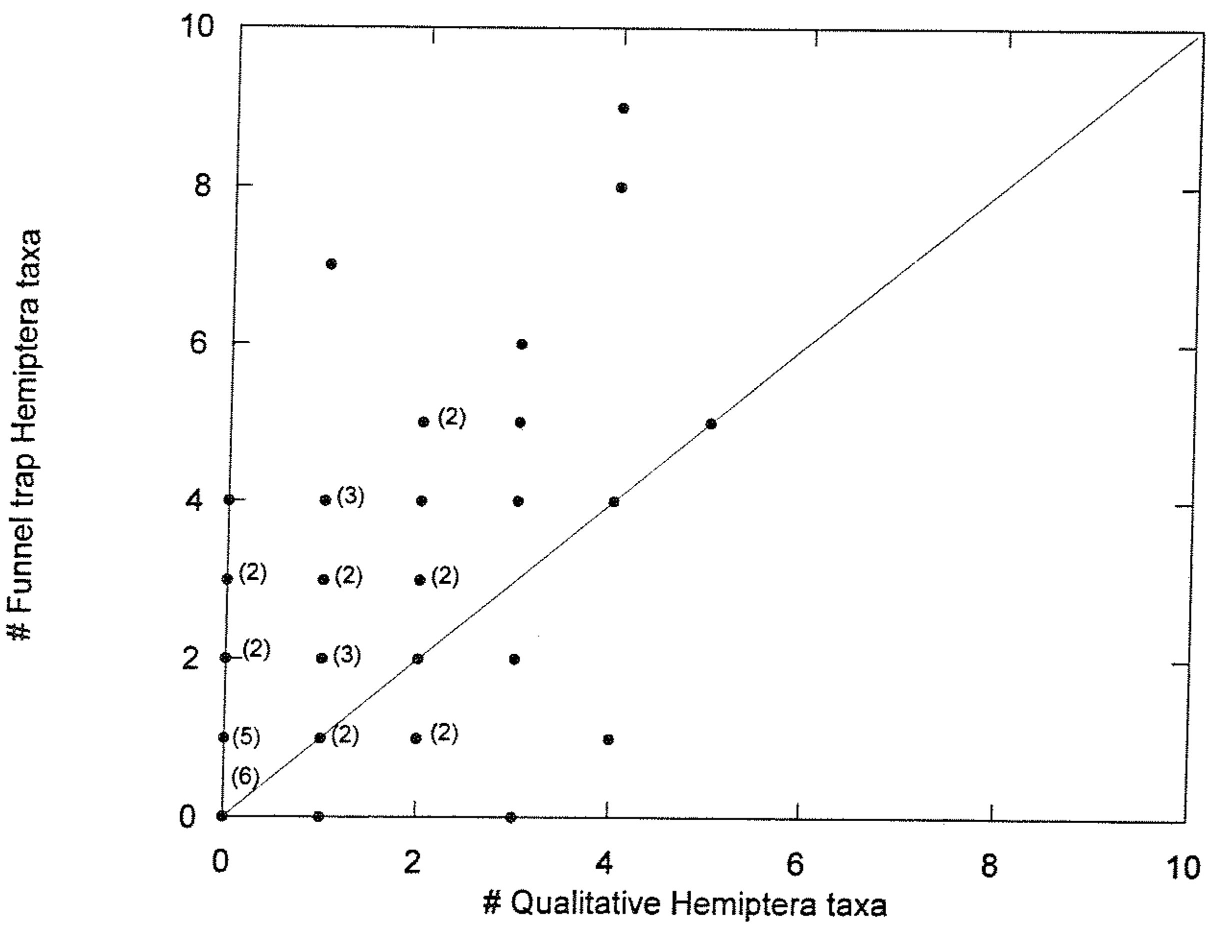


Figure 3-10: Number of Hemiptera Taxa Collected by Sampling Method

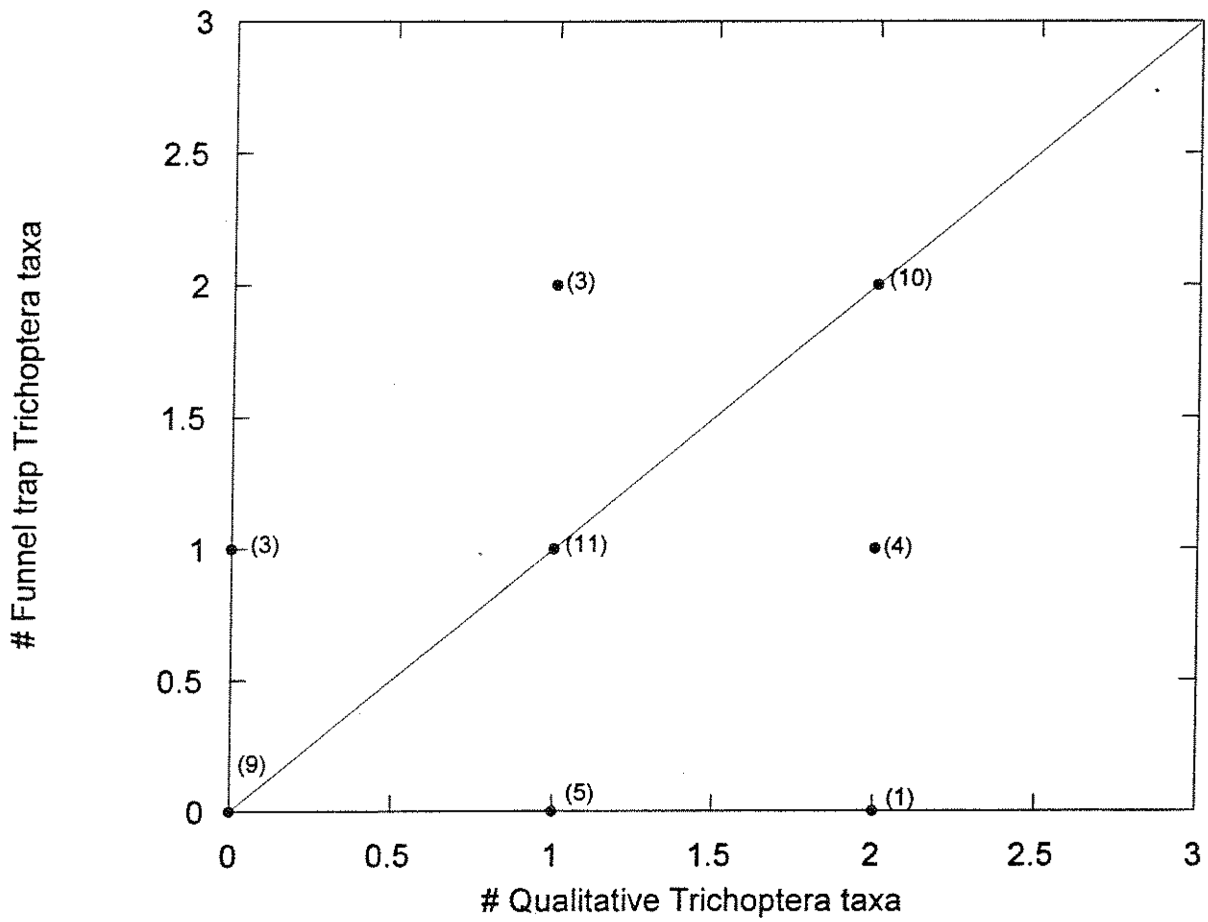


Figure 3-11: Number of Trichoptera Taxa Collected by Sampling Method

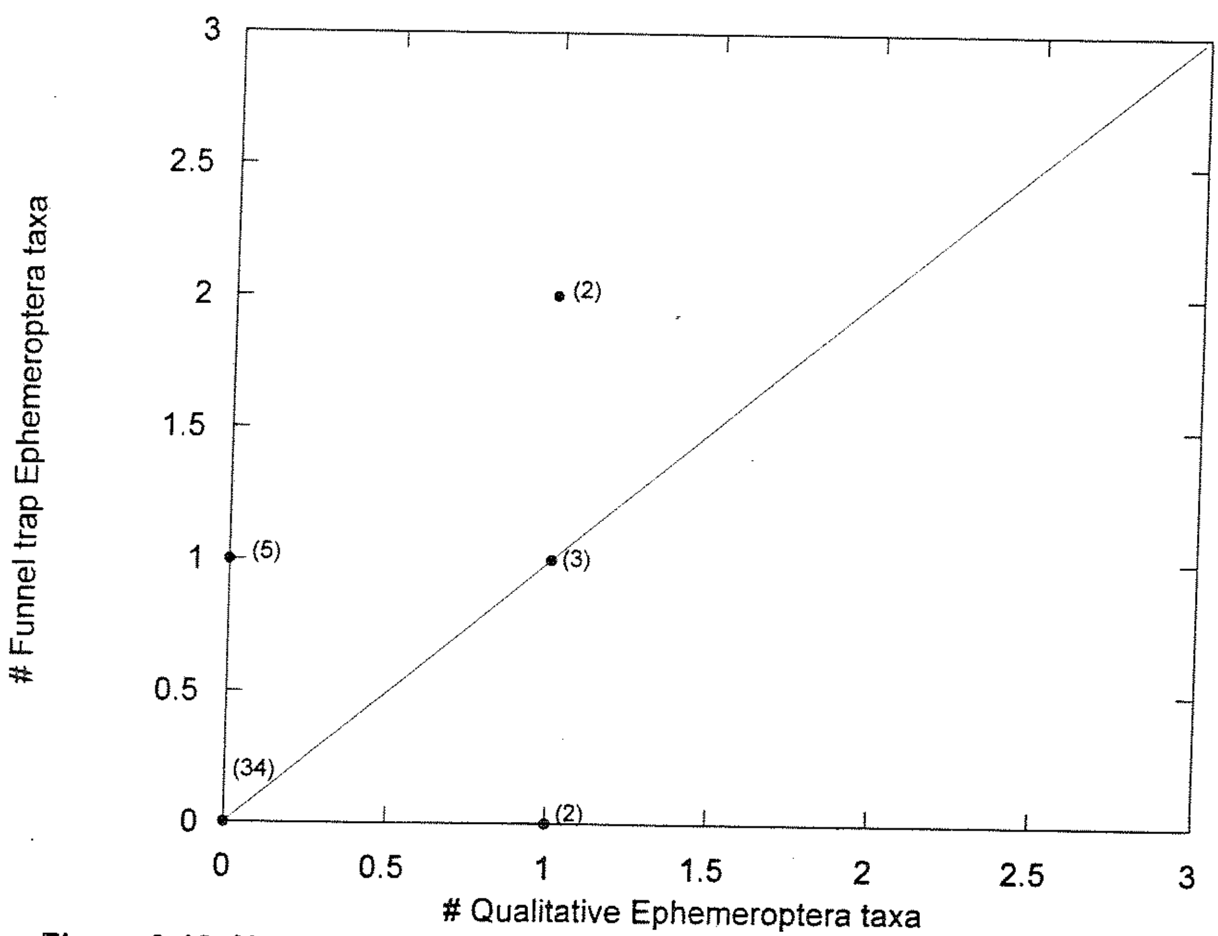


Figure 3-12: Number of Ephemeroptera Taxa Collected by Sampling Method

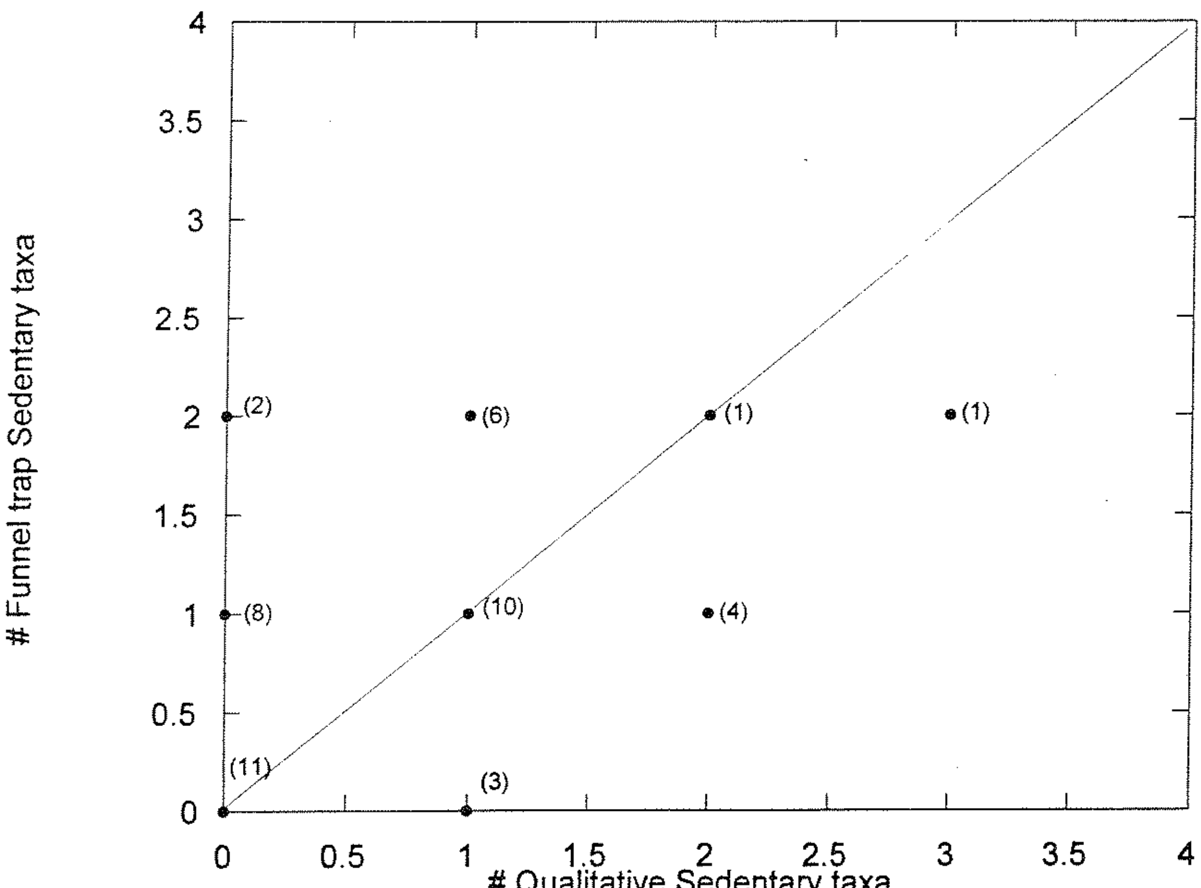


Figure 3-13: Number of Sedentary Taxa Collected by Sampling Method (Porifera, Turbellaria, Coelenterata, and Bryozoa)

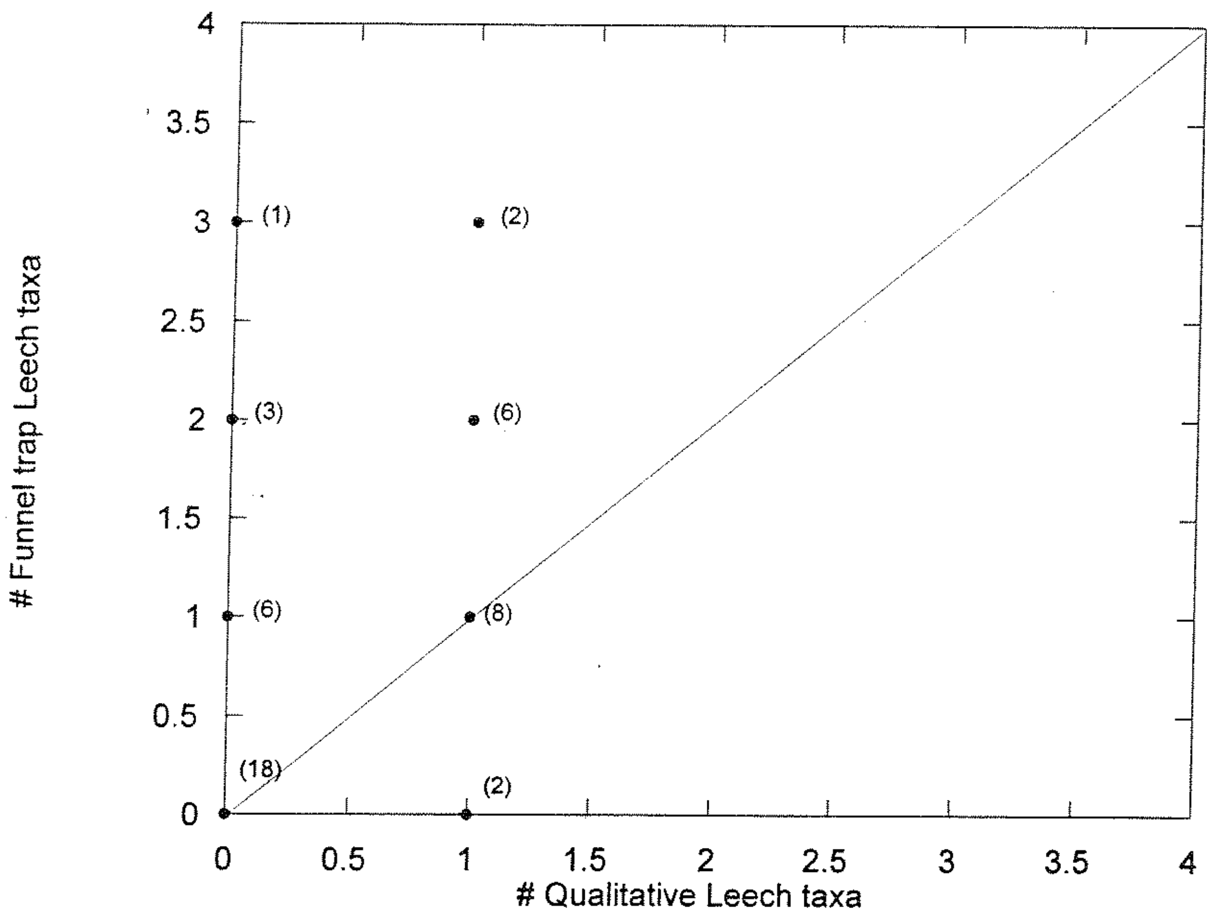


Figure 3-14: Number of Leech Taxa Collected by Sampling Method

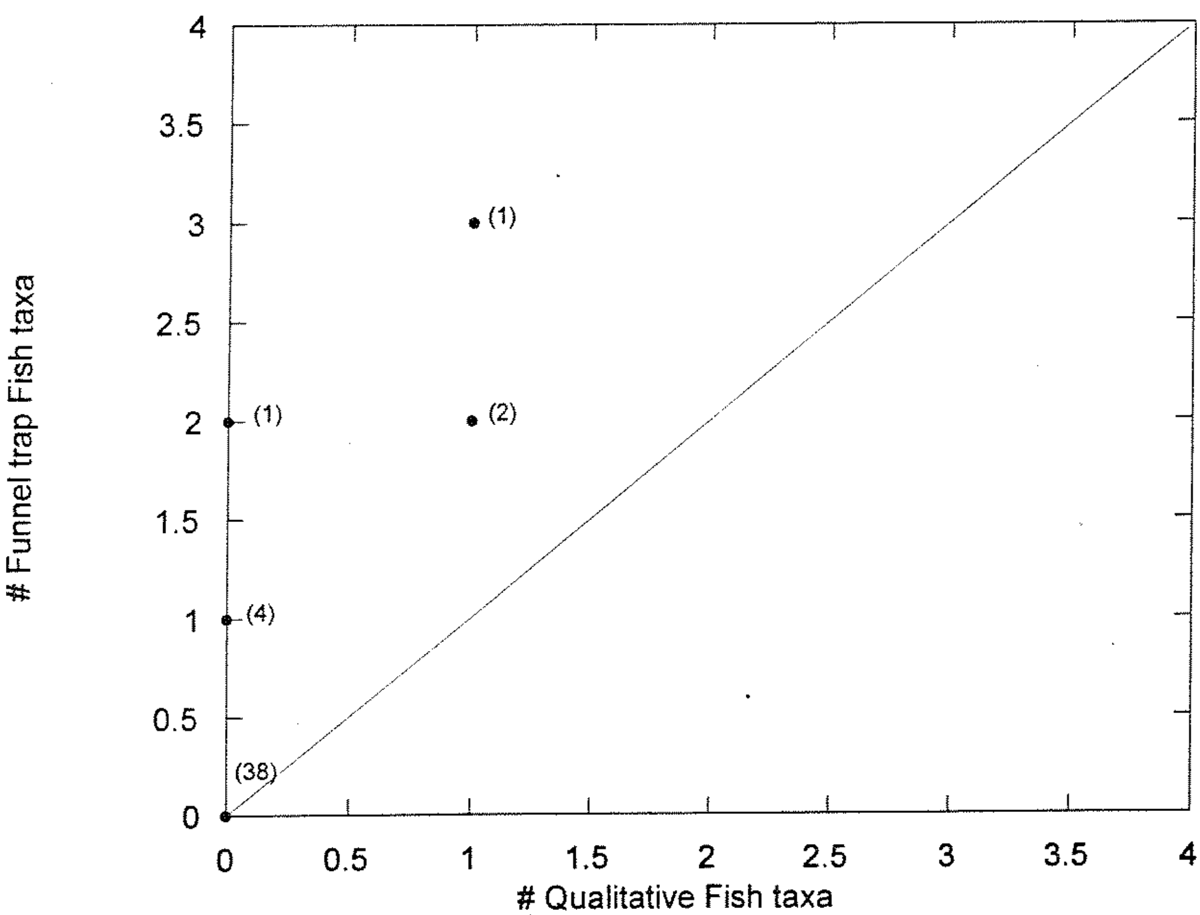


Figure 3-15: Number of Fish Taxa Collected by Sampling Method

(Figure 3-16). Large, active bullfrog and greenfrog tadpoles can avoid the dipnet. Adult salamanders enter wetlands between February - March to breed and are nocturnal so we seldom collected them in qualitative samples. Funnel traps were effective in collecting both adult and larval salamanders as well as adult frogs and tadpoles.

The presence of predators in funnel traps could potentially bias our sampling results. Fish, crayfish and salamanders may consume a variety of taxa in the funnel traps. We compared trap collection results for traps with and without predators collected from the same wetland and date. Thus any observed differences should be from predation and not wetland or seasonal differences. We calculated the average number of taxa and number of organisms per traps with and without predators. We noted the type of potential predator in case this was important. We plotted the number of taxa collected in traps with and without predators and found that traps with predators are as likely to have more taxa per trap as the traps without (Figure 3-17). A plot of the number of organisms per trap shows no bias to the presence or absence of predators (Figure 3-18).

At several sites all the funnel traps contained predators so we were not able to evaluate their impact on trap contents. These sites had large numbers of crayfish in each trap. One way to look at these sites is to compare the number of taxa collected in funnel traps to the number collected in qualitative samples. If predators are consuming prey in the traps, the ratio of the number of taxa in funnel traps to the number of taxa in qualitative samples should be lower for those traps containing predators. Figure 3-19 shows data comparing the number of funnel trap taxa to the number of qualitative taxa in relation to the type of predators in the trap. Only crayfish appear to reduce the number of taxa collected in the traps. The only sampling events where qualitative sampling collected more taxa than the funnel traps were both on occasions when there were large numbers of crayfish in the trap. Funnel traps should be modified to exclude large crayfish when the traps are used in wetlands that have an abundance of crayfish.

In 1996 we examined issues related to sampling effort. We attempted to design a field sampling program to accurately characterize a wetland without wasting resources. The number of

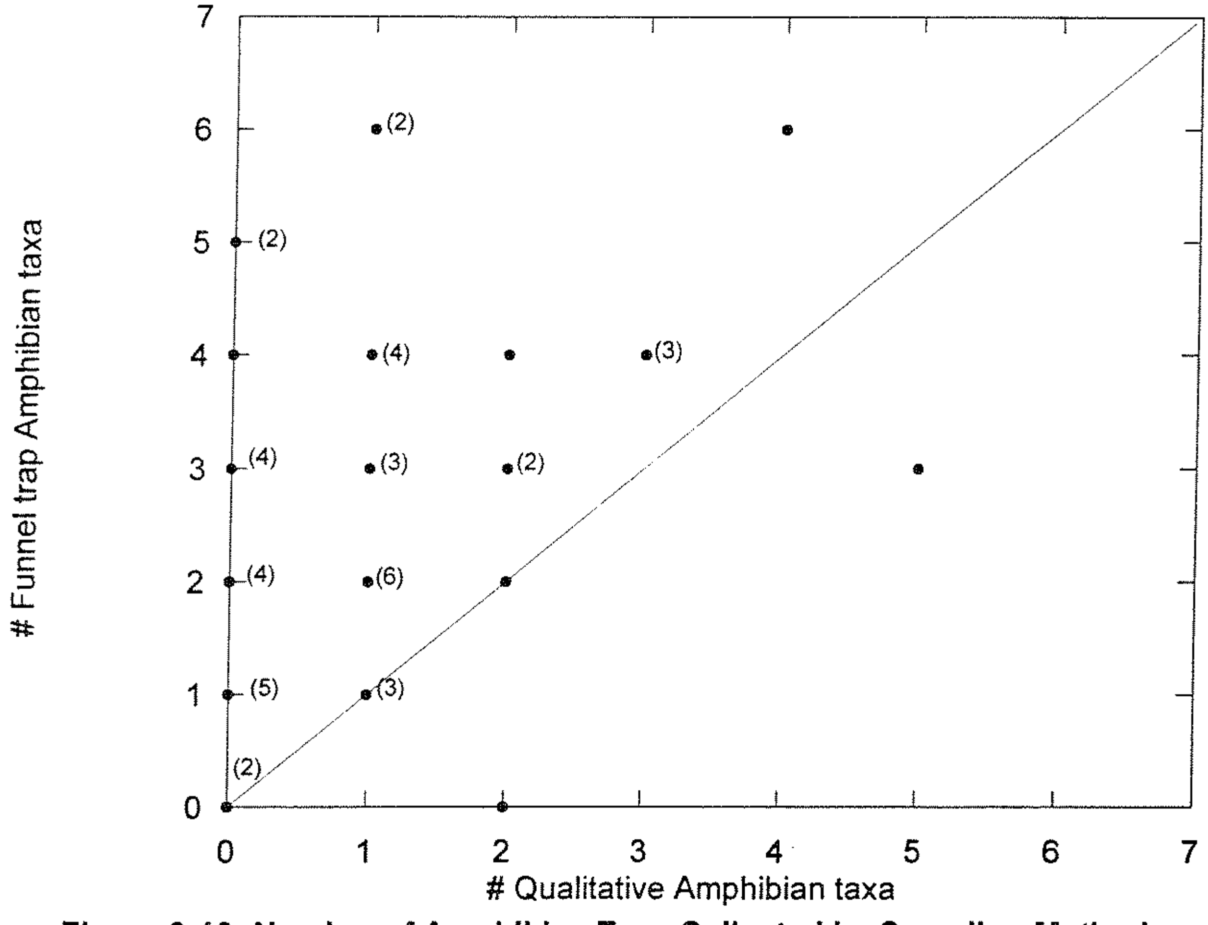


Figure 3-16: Number of Amphibian Taxa Collected by Sampling Method

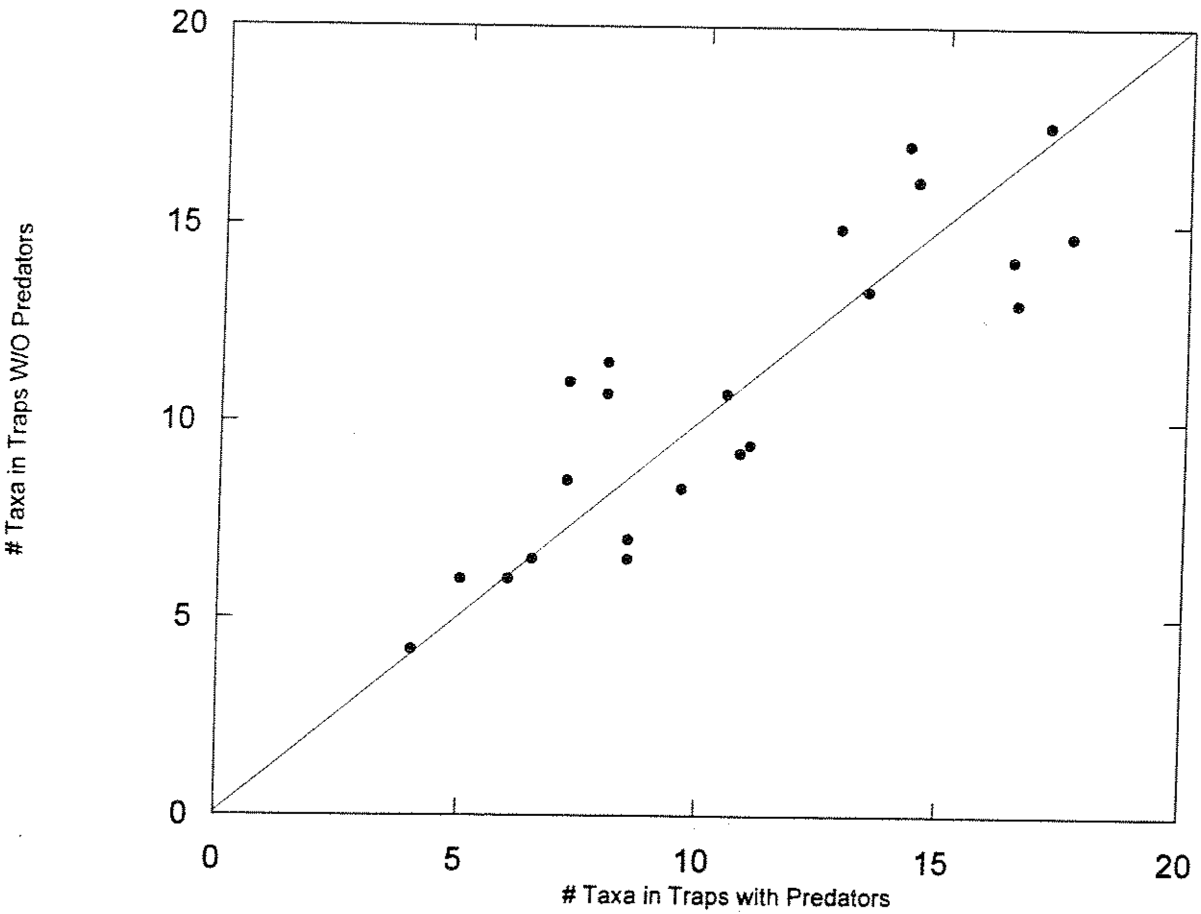


Figure 3-17: Comparison of Average # of Taxa/ Trap with and without Predators

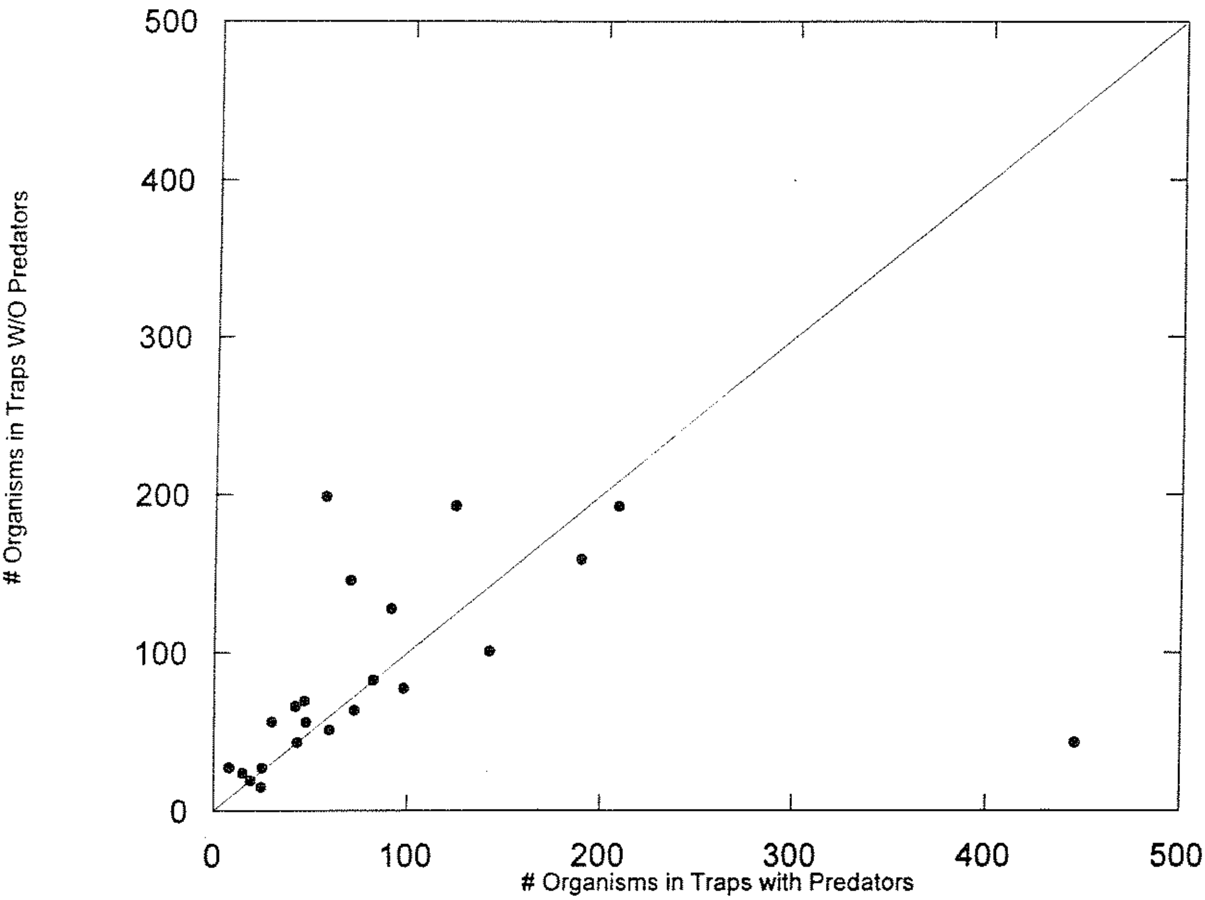


Figure 3-18: Comparison of Average # of Organisms/ Trap with and without Predators

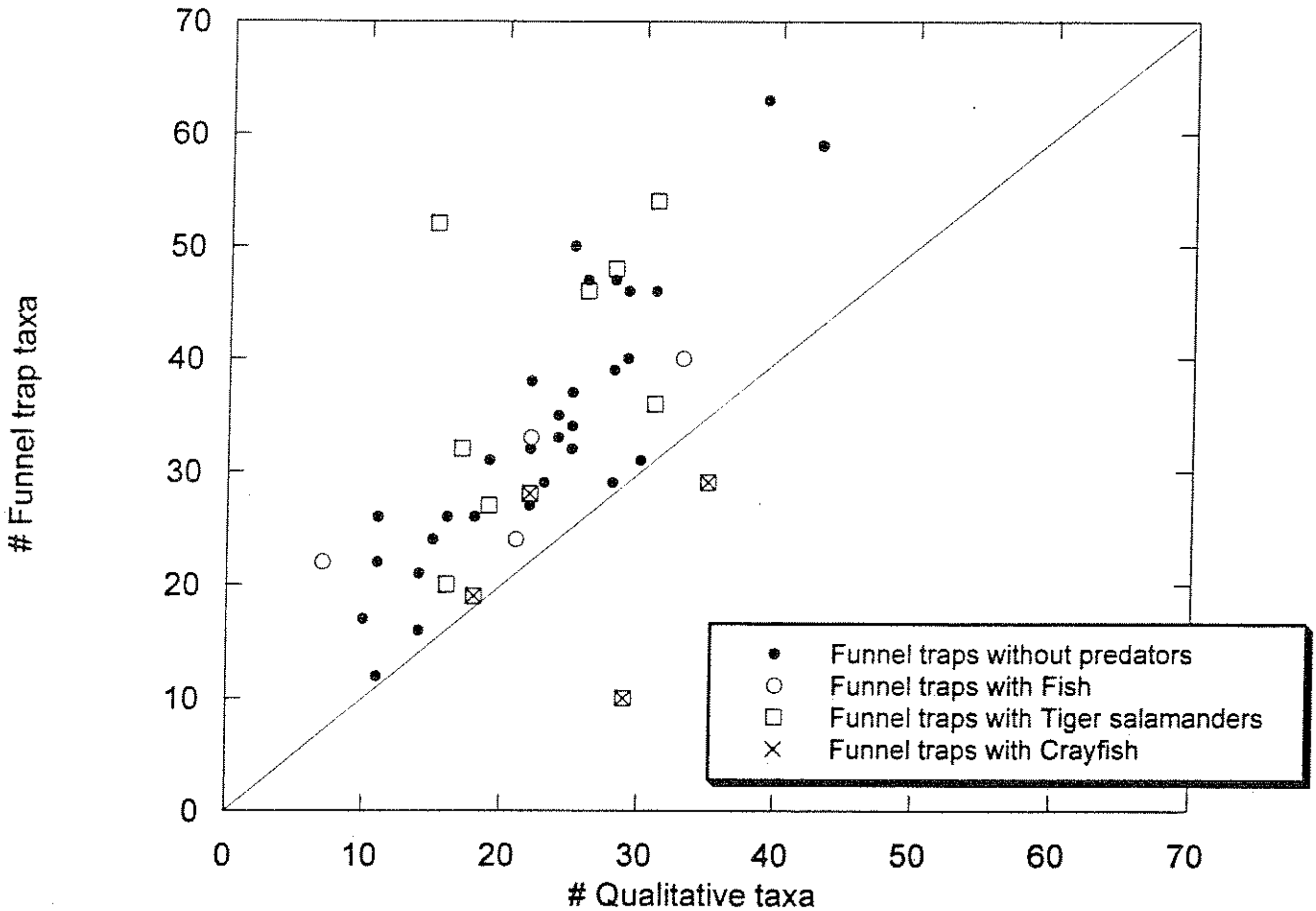


Figure 3-19: Impact of Predators in Funnel Traps on Number of Taxa Collected

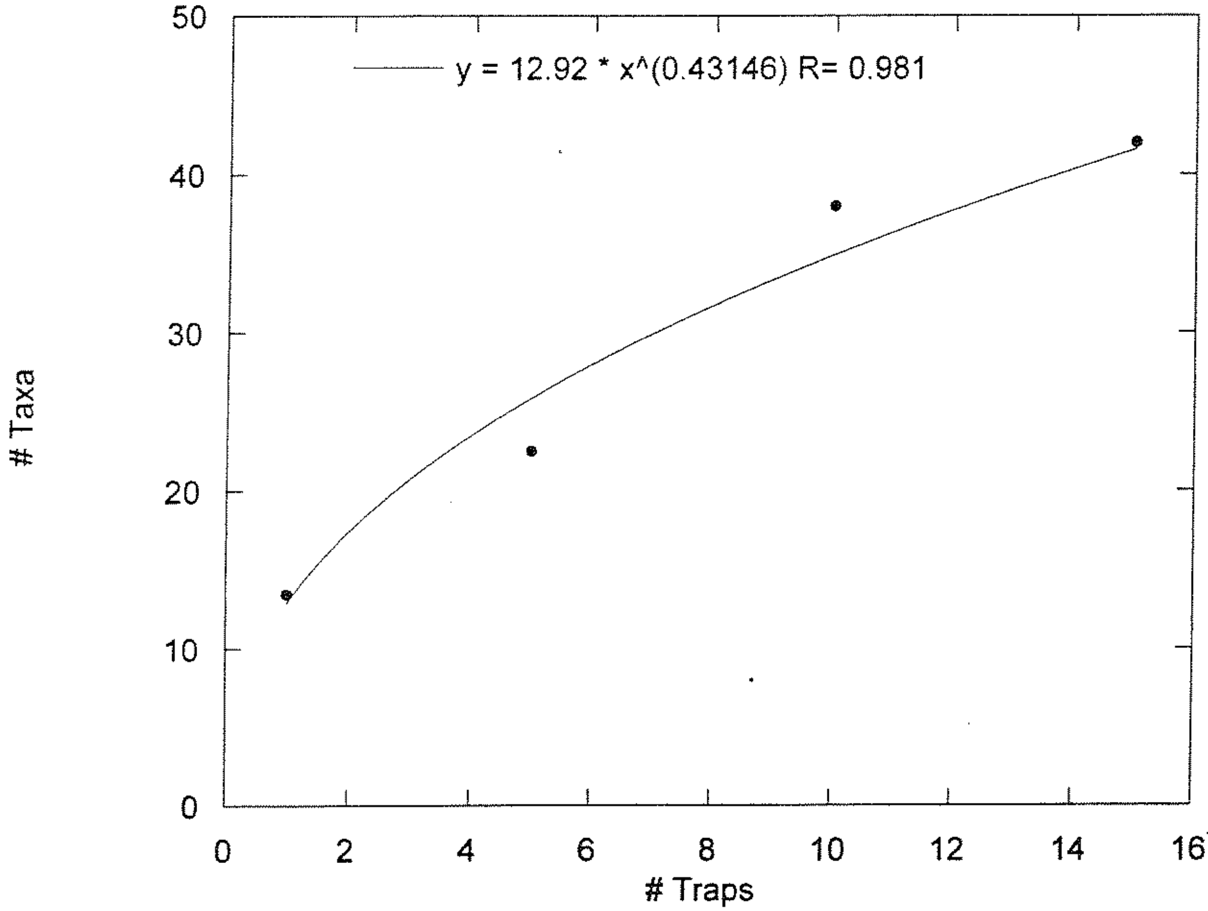


Figure 3-20: Number of Taxa Collected Related to Sampling Effort (Calamas-May)

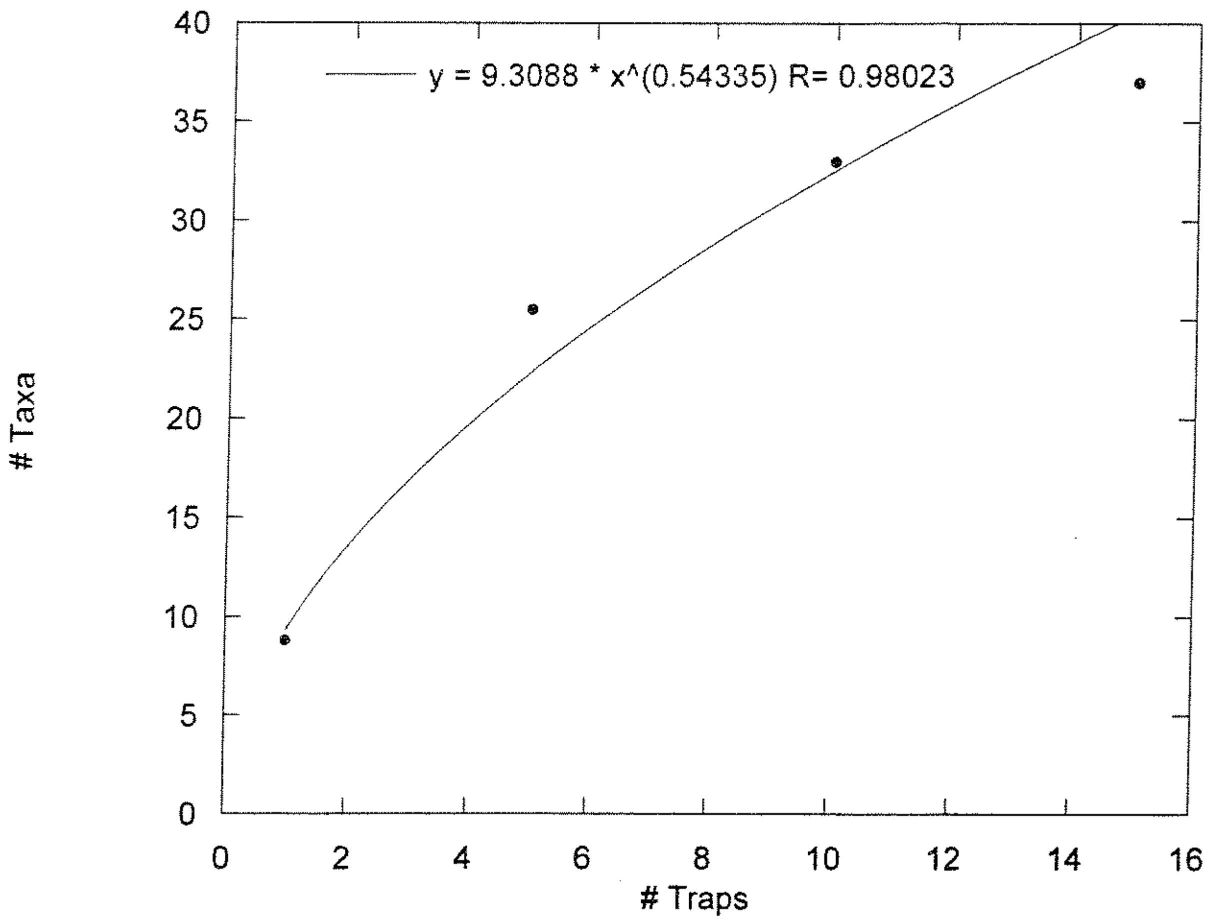


Figure 3-21: Number of Taxa Collected Related to Sampling Effort (Calamas-July)

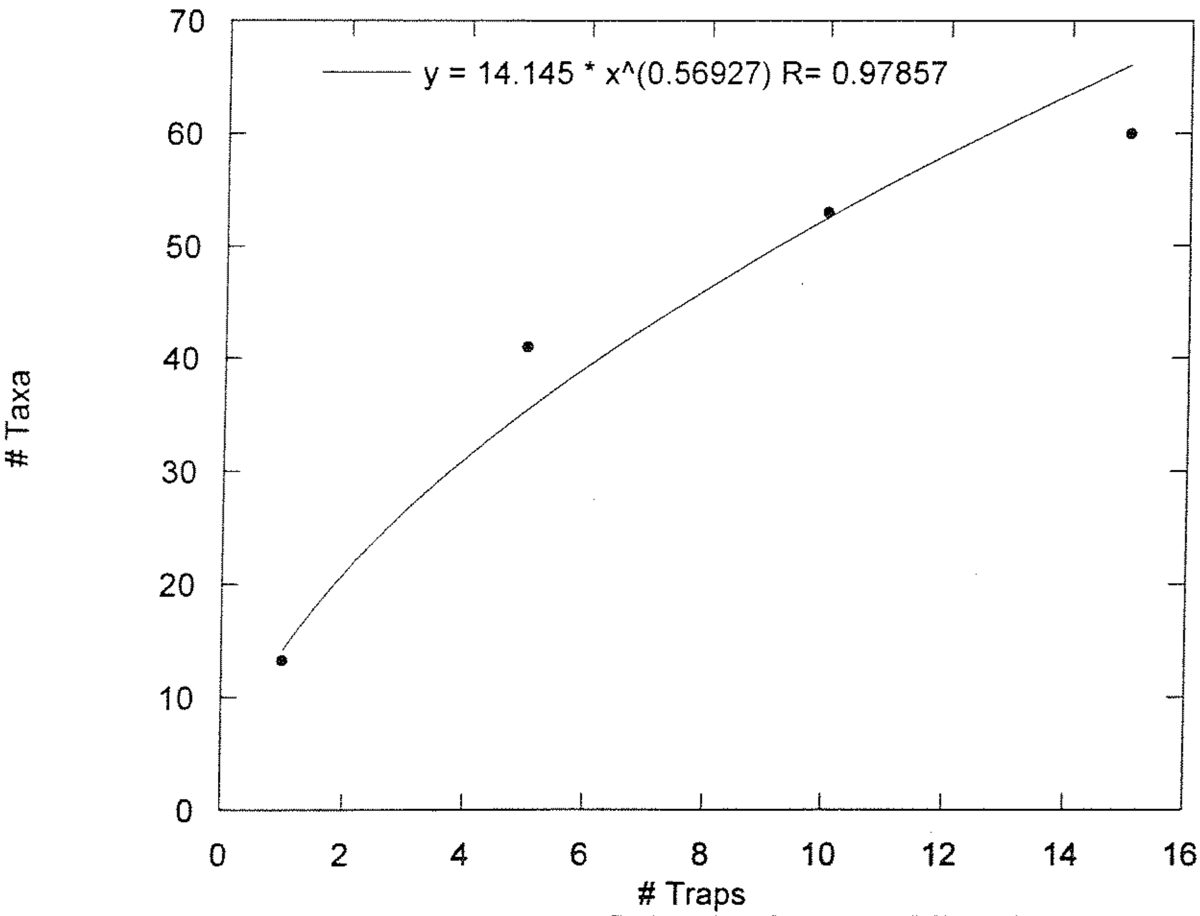


Figure 3-22: Number of Taxa Collected Related to Sampling Effort (Calamas-August)

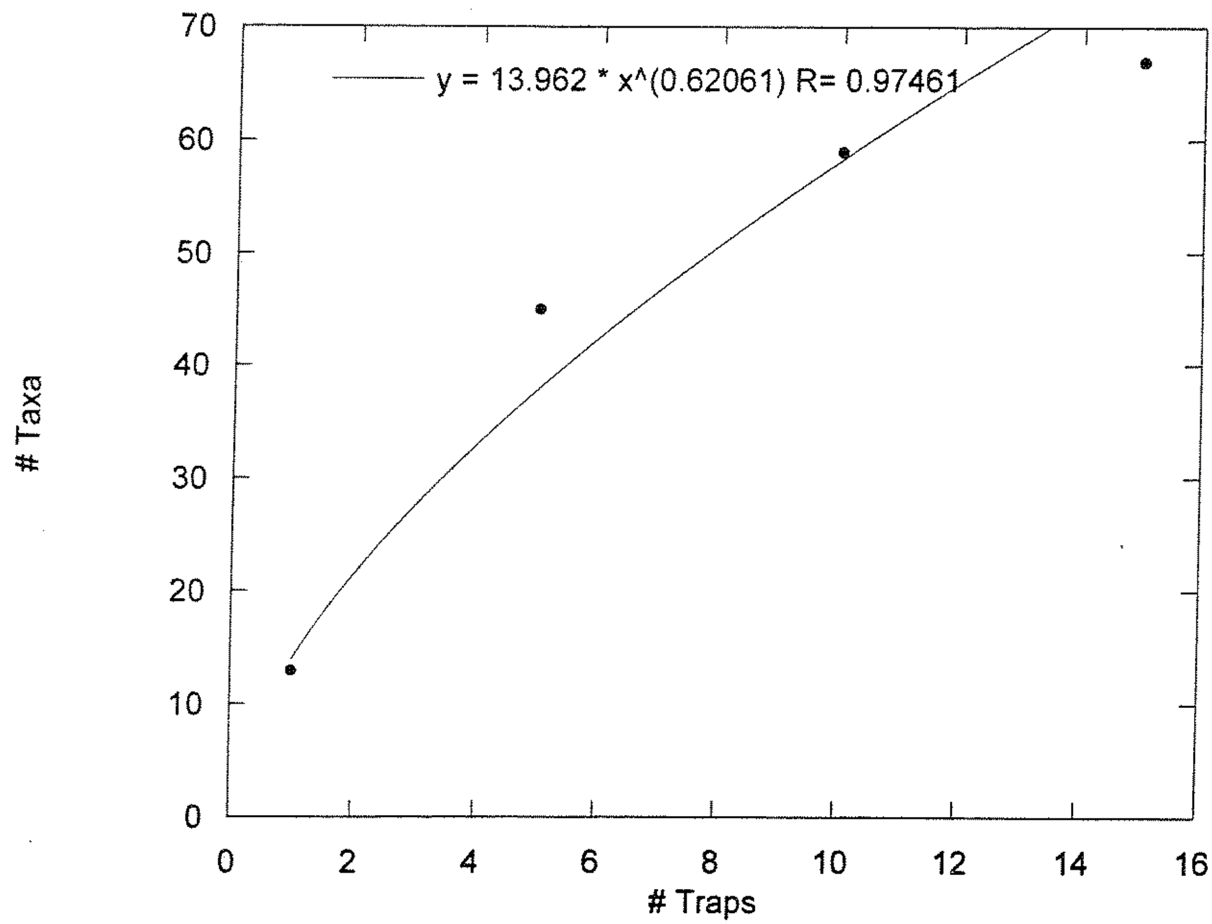


Figure 3-23: Number of Taxa Collected Related to Sampling Effort (Rickenbacker-August)

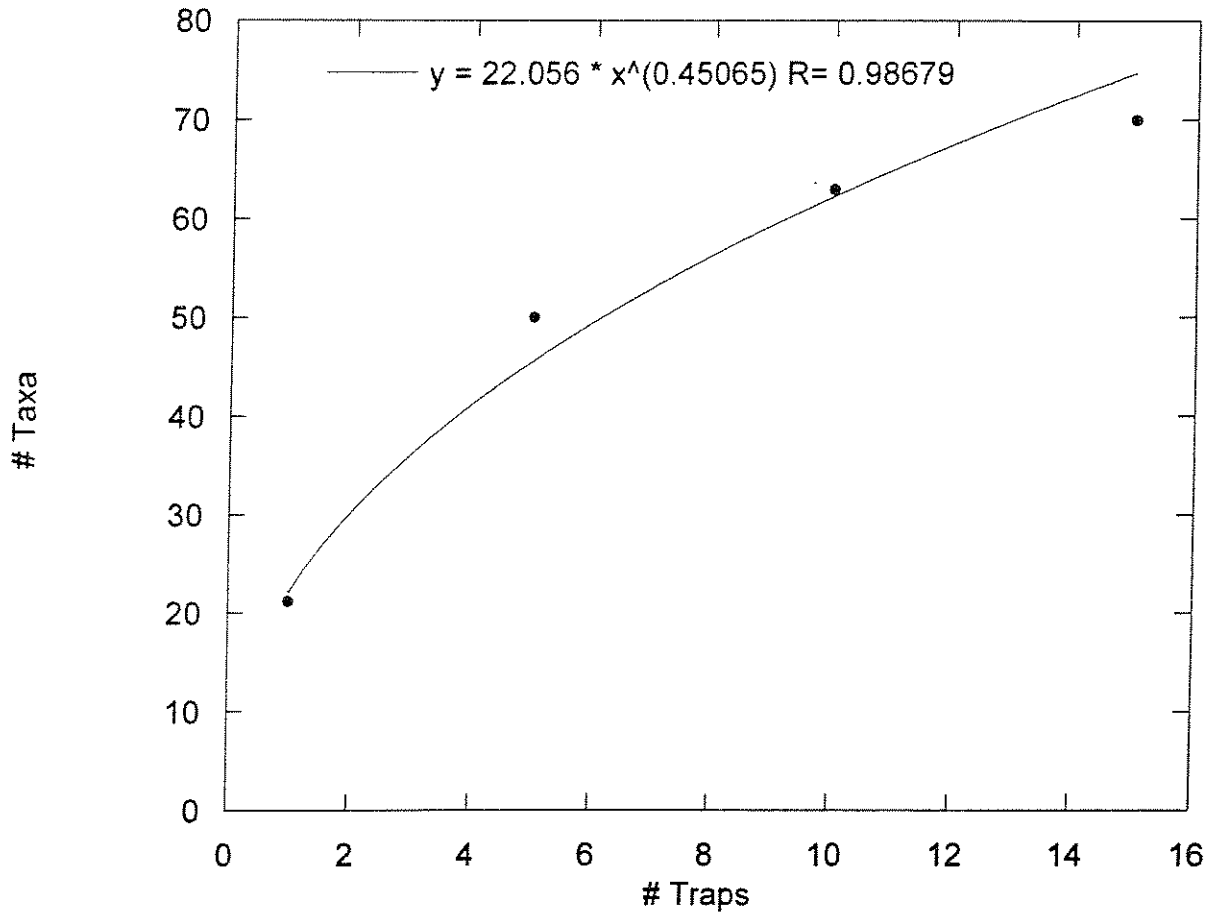


Figure 3-24: Number of Taxa Collected Related to Sampling Effort (Rickenbacker-July)

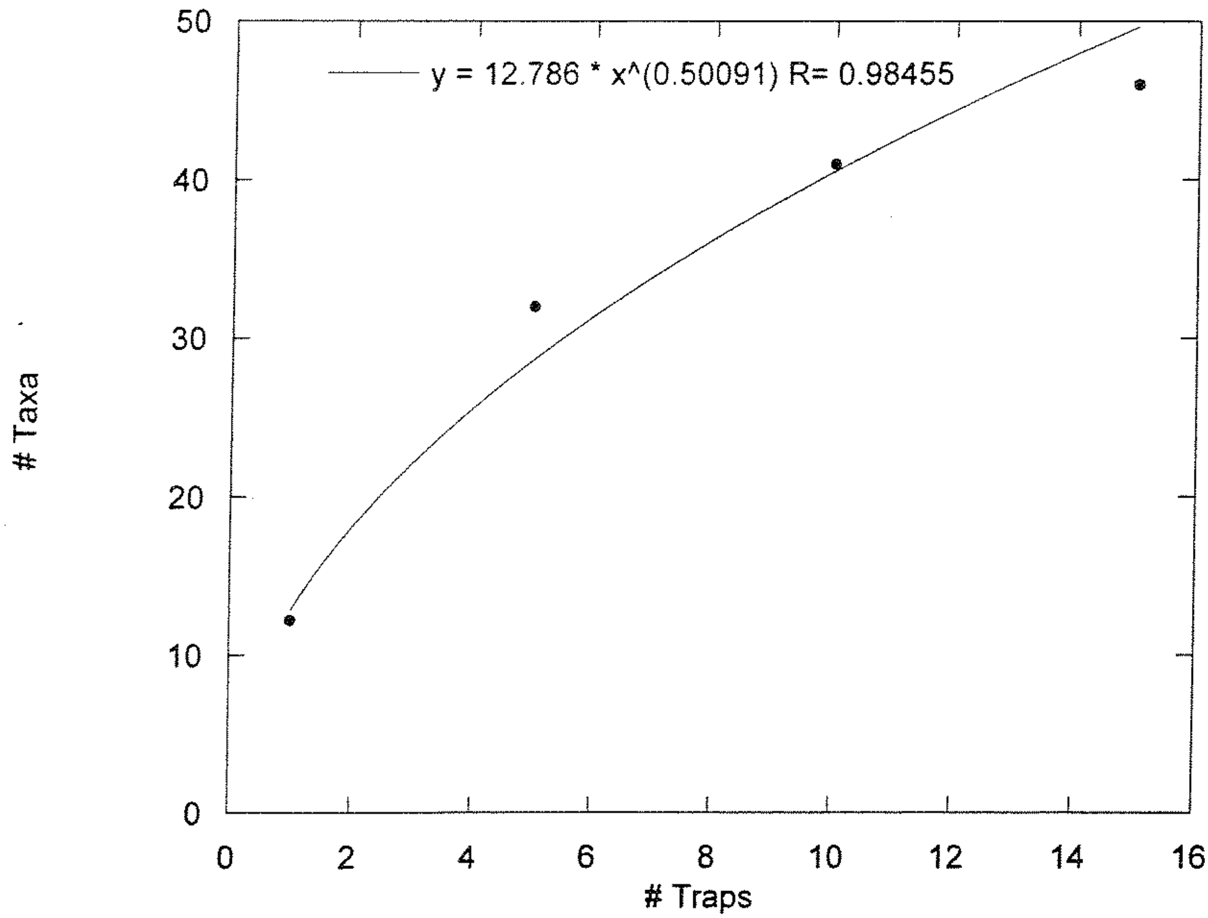


Figure 3-25: Number of Taxa Collected Related to Sampling Effort (Rickenbacker-May)

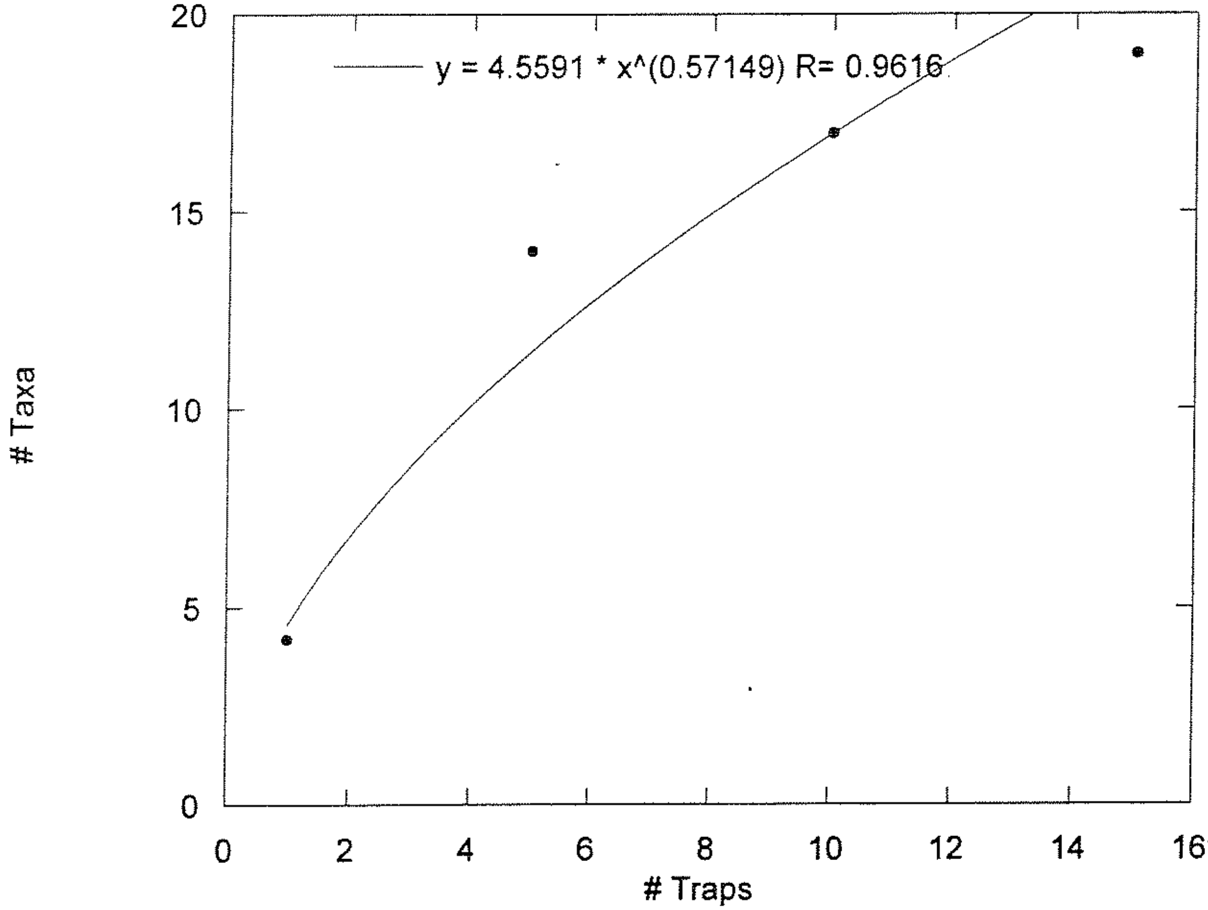


Figure 3-26: Number of Taxa Collected Related to Sampling Effort (Leafy Oak-July)

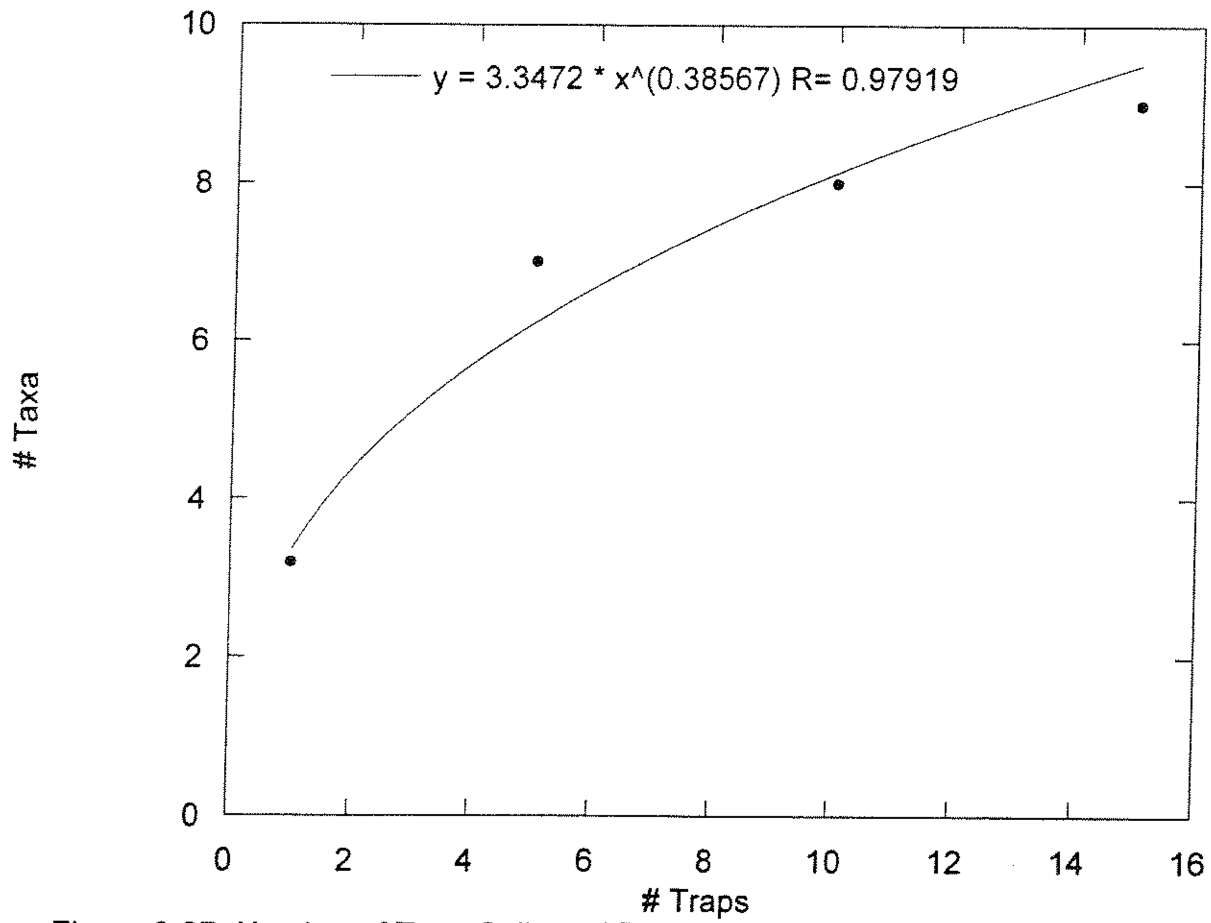


Figure 3-27: Number of Taxa Collected Related to Sampling Effort (Leafy Oak-May)

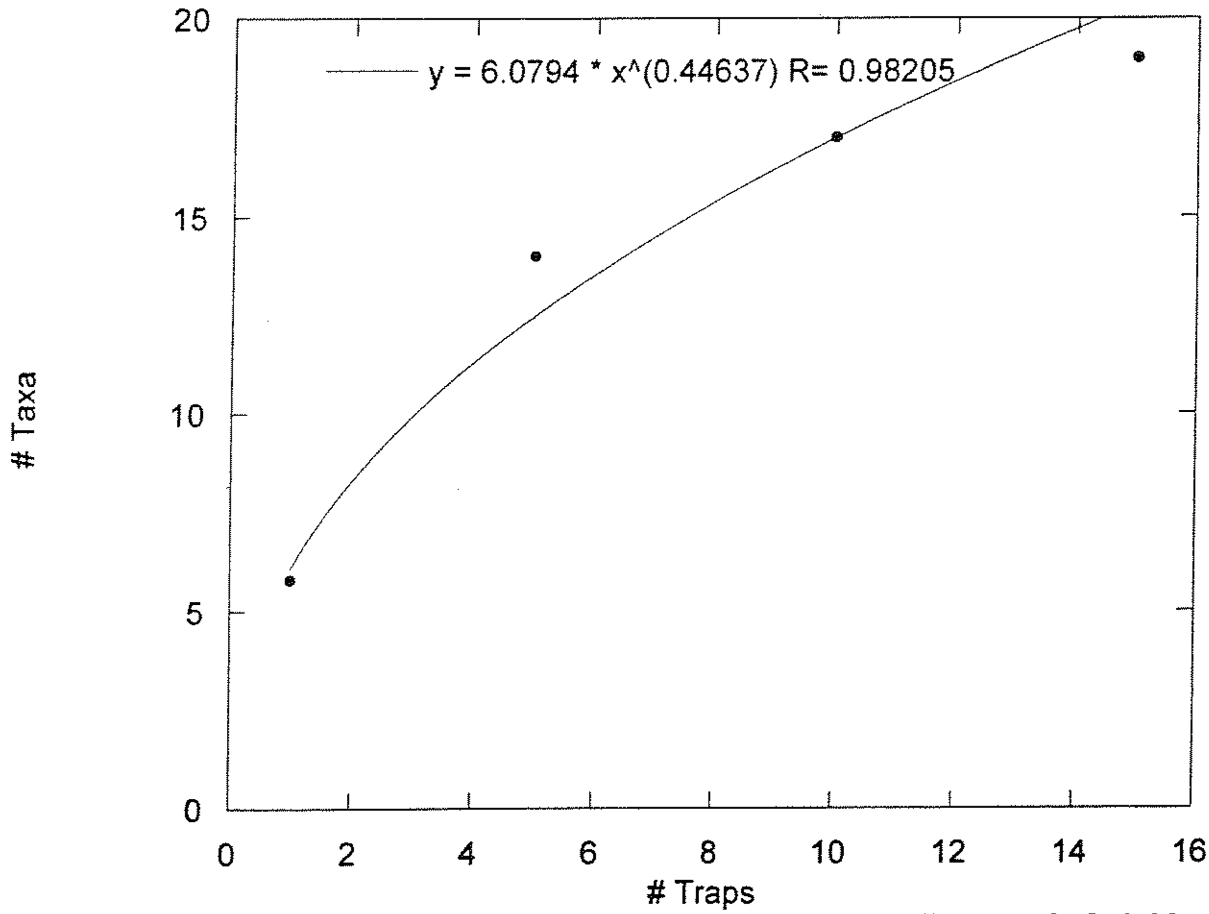


Figure 3-28: Number of Taxa Collected Related to Sampling Effort (Leafy Oak-March)

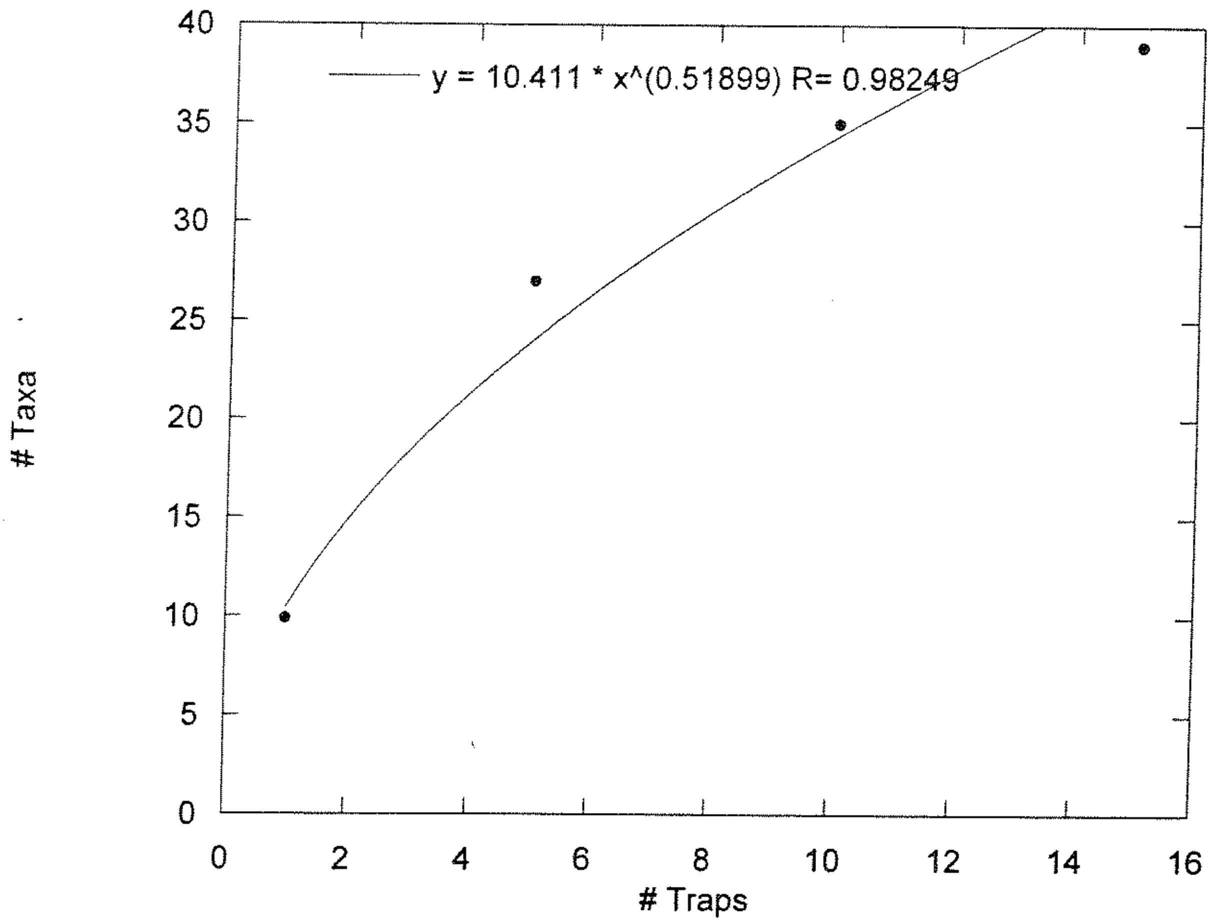


Figure 3-29: Number of Taxa Collected Related to Sampling Effort (Cessna-July)

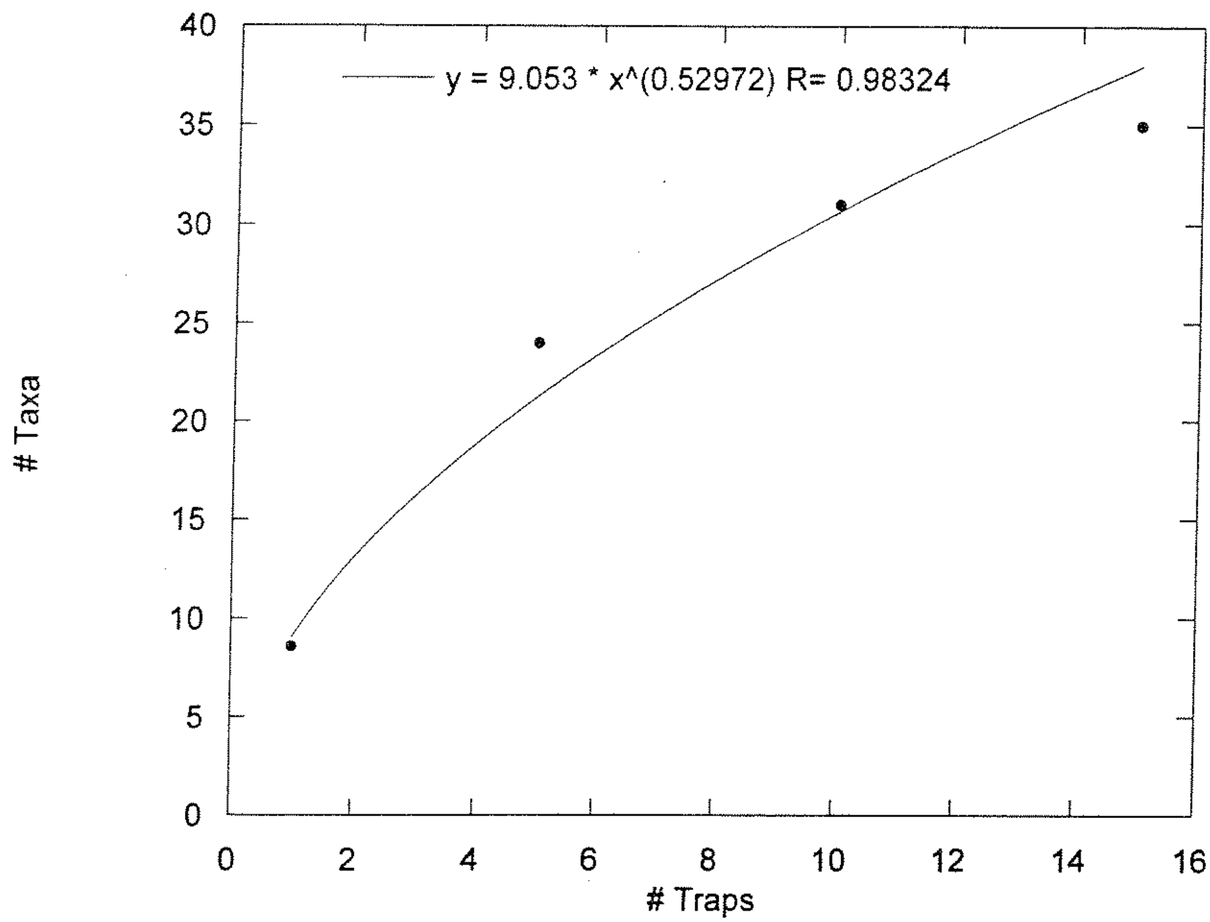


Figure 3-30: Number of Taxa Collected Related to Sampling Effort (Cessna-May)

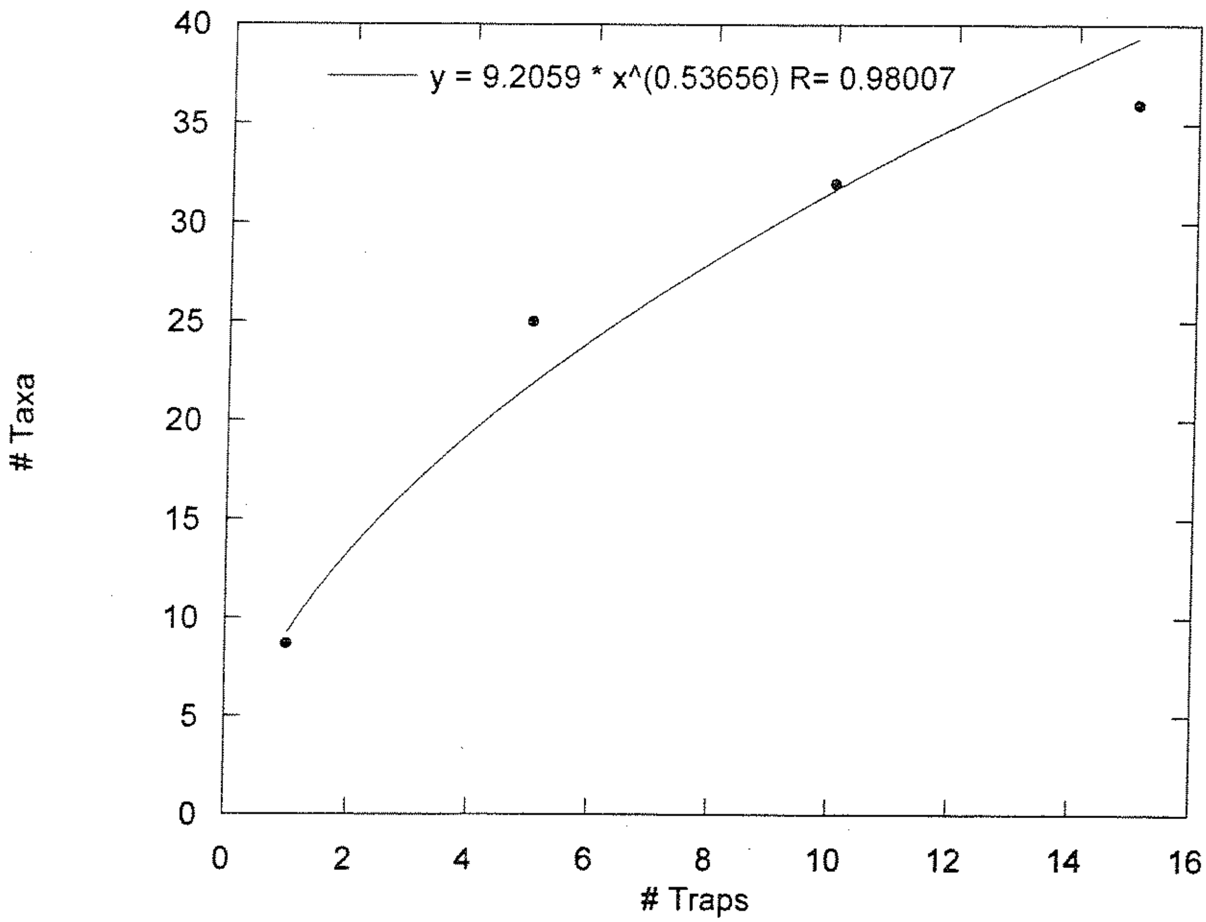


Figure 3-31: Number of Taxa Collected Related to Sampling Effort (McKinley-August)

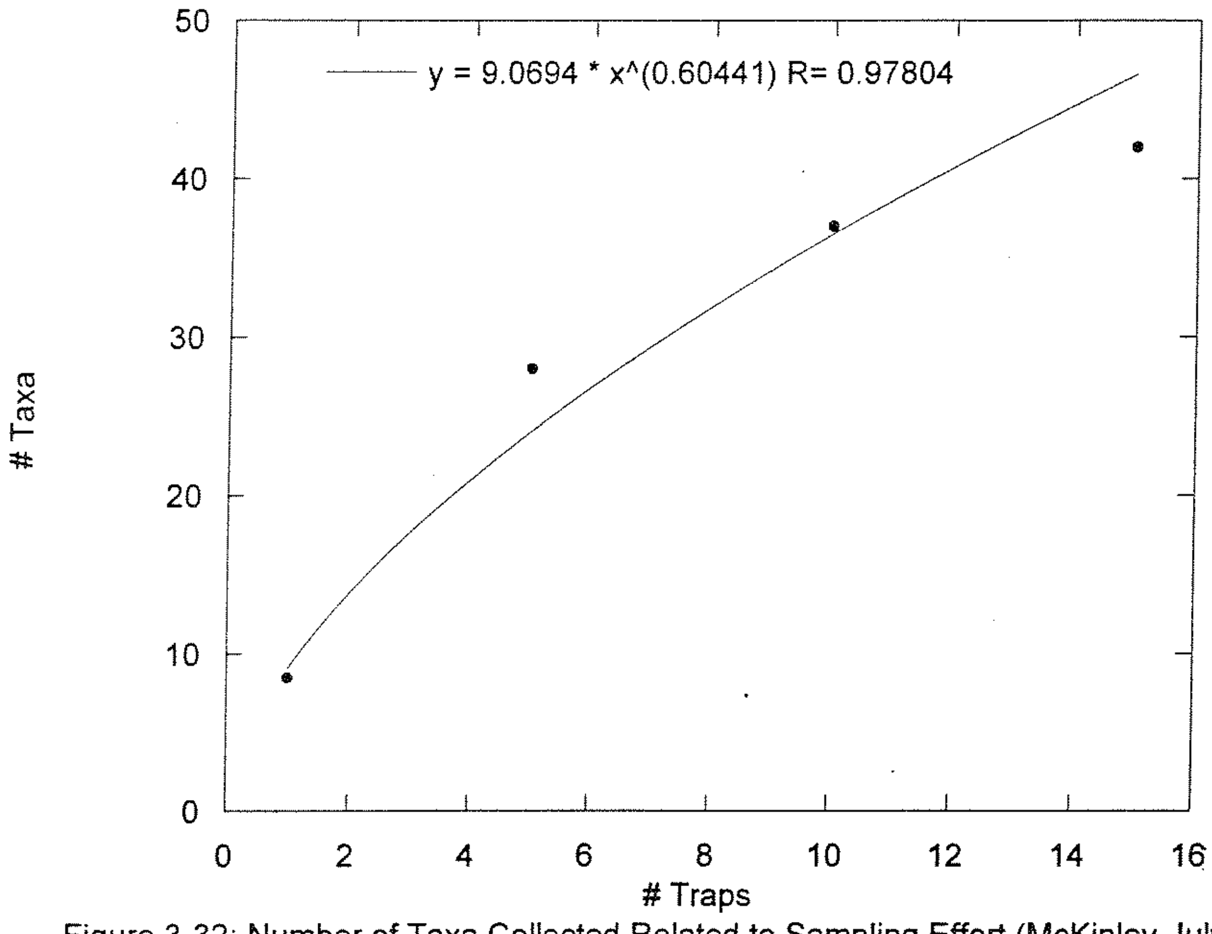


Figure 3-32: Number of Taxa Collected Related to Sampling Effort (McKinley-July)

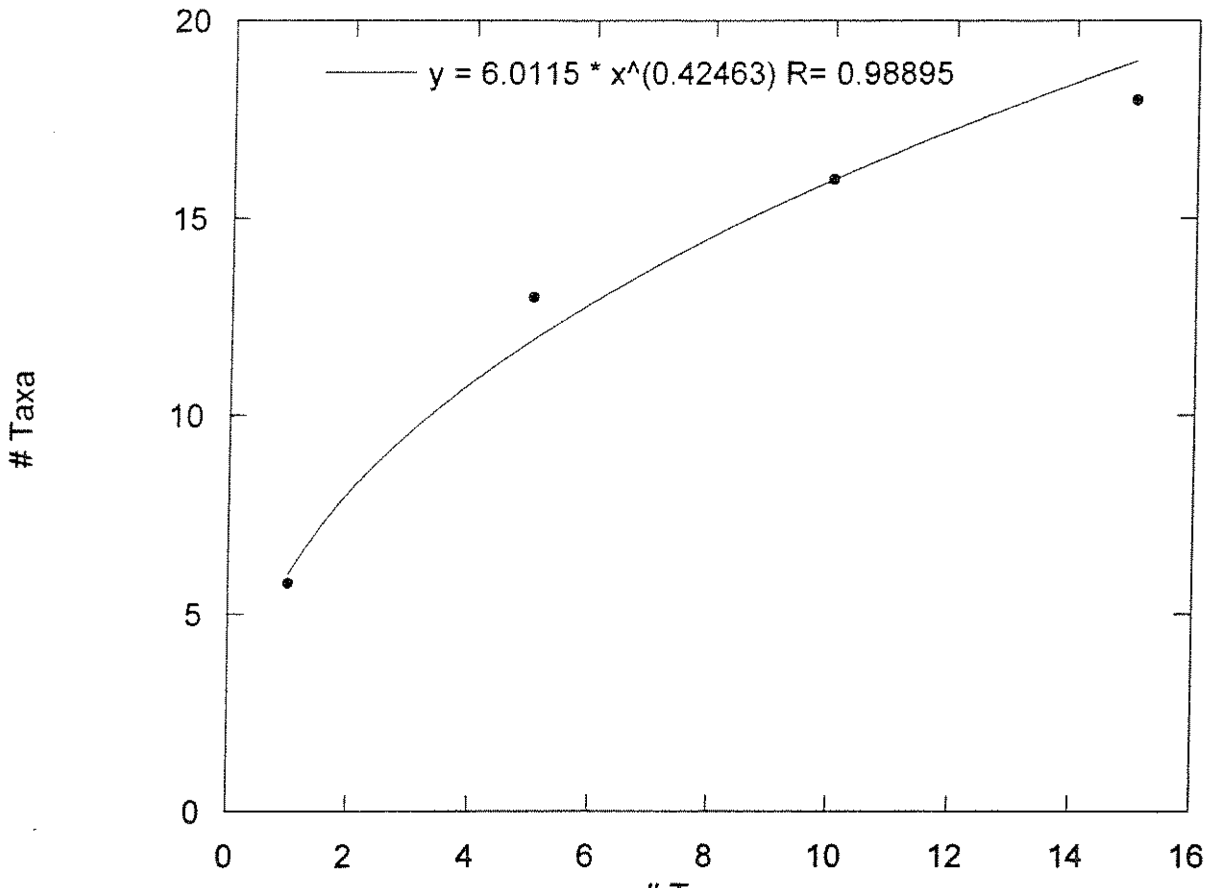


Figure 3-33: Number of Taxa Collected Related to Sampling Effort (McKinley-May)

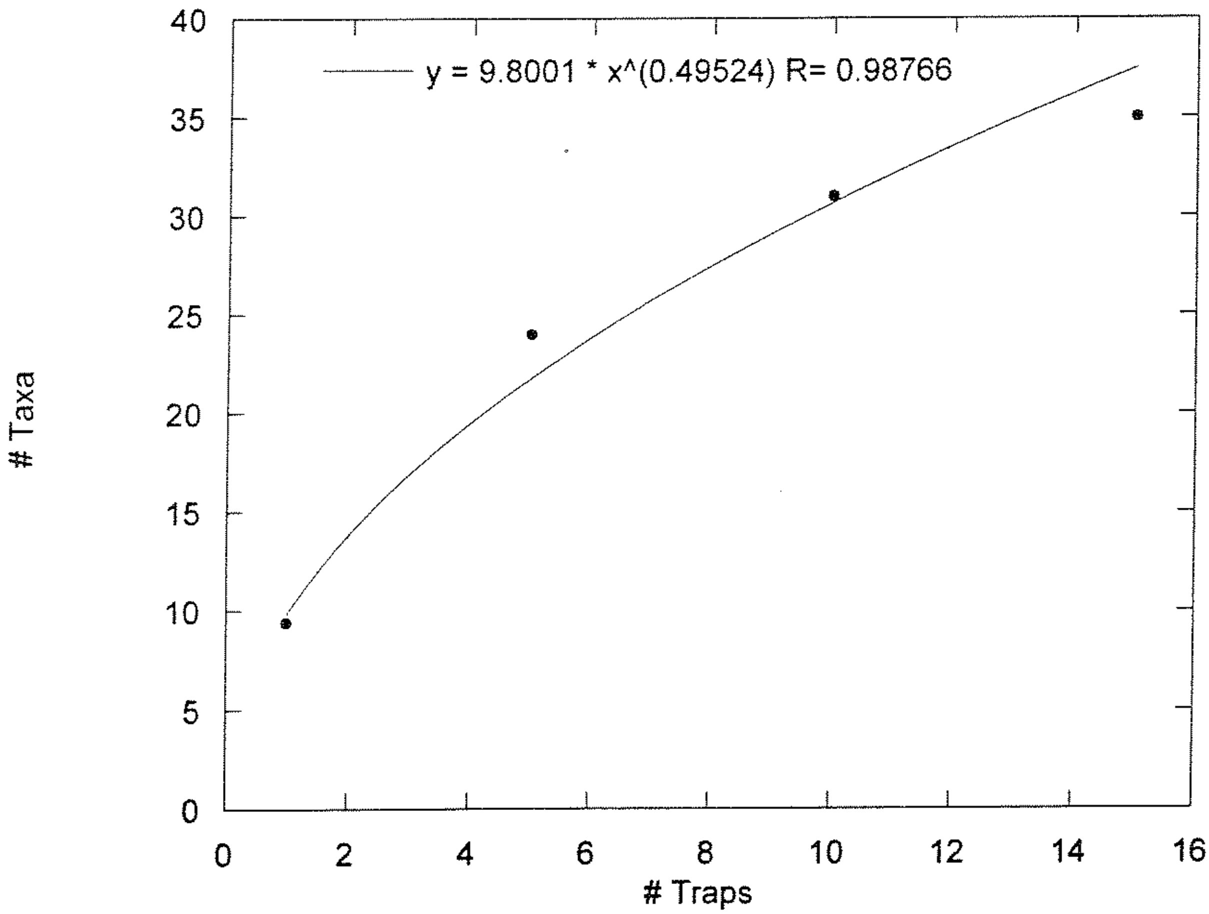


Figure 3-34: Number of Taxa Collected Related to Sampling Effort (Gahanna-July)

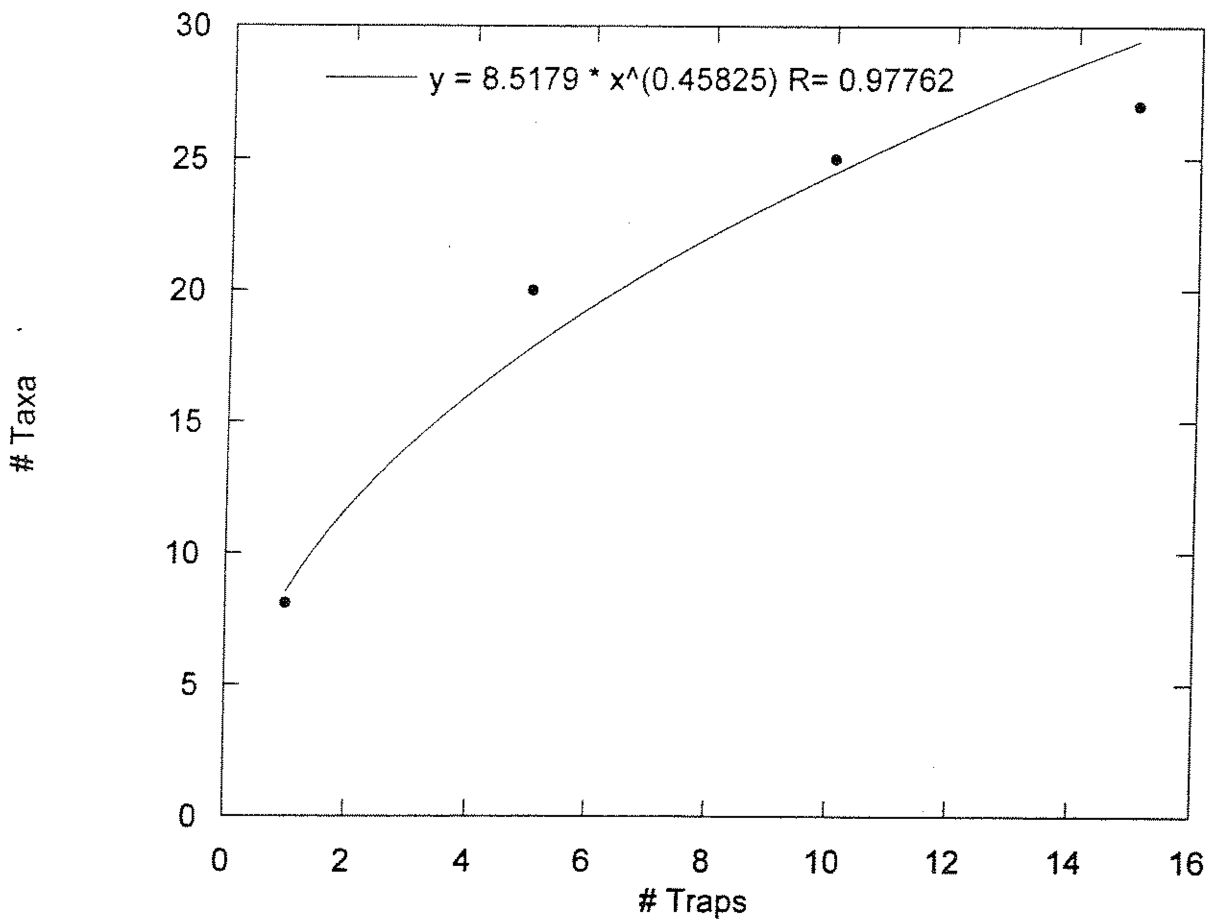


Figure 3-35: Number of Taxa Collected Related to Sampling Effort (Gahanna-May)

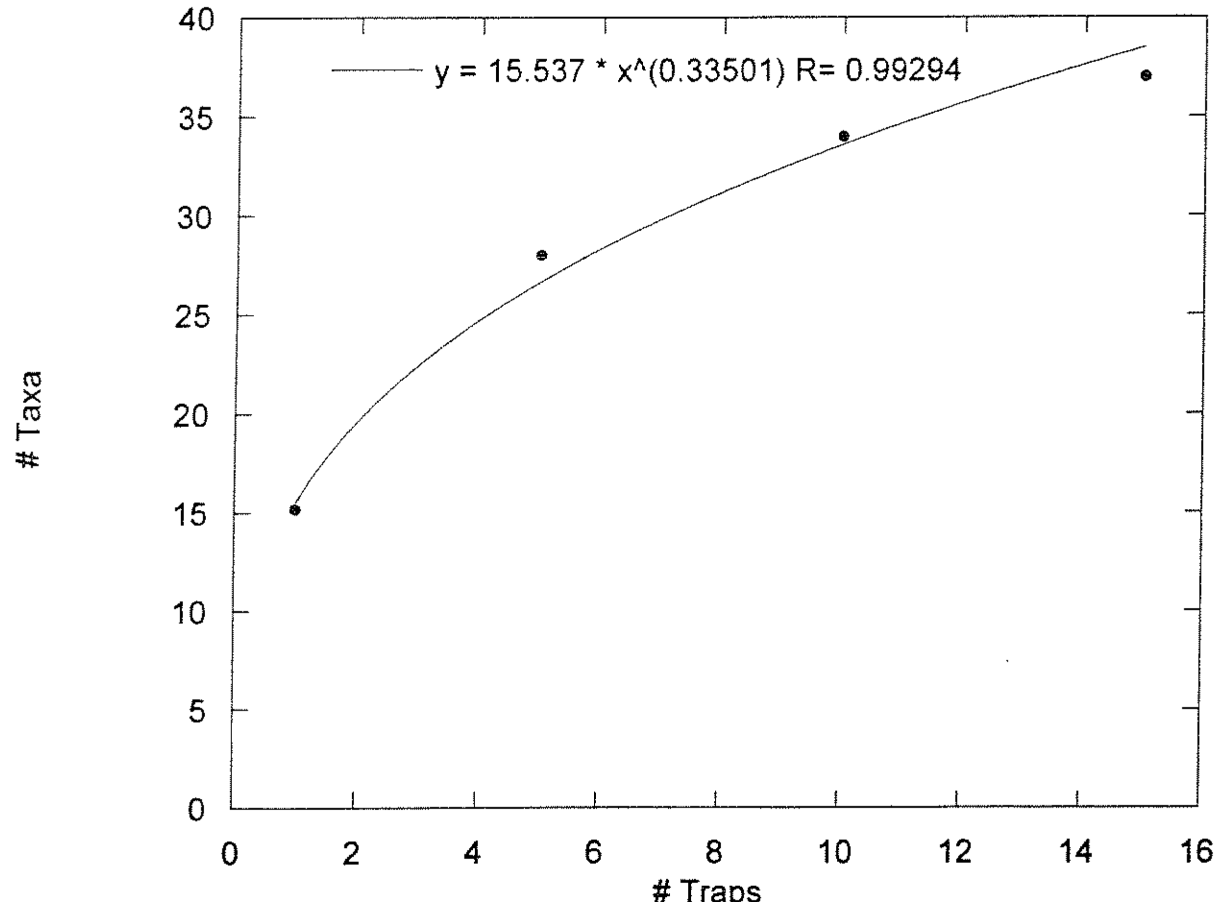


Figure 3-36: Number of Taxa Collected Related to Sampling Effort (Co. Rd. 200-August)

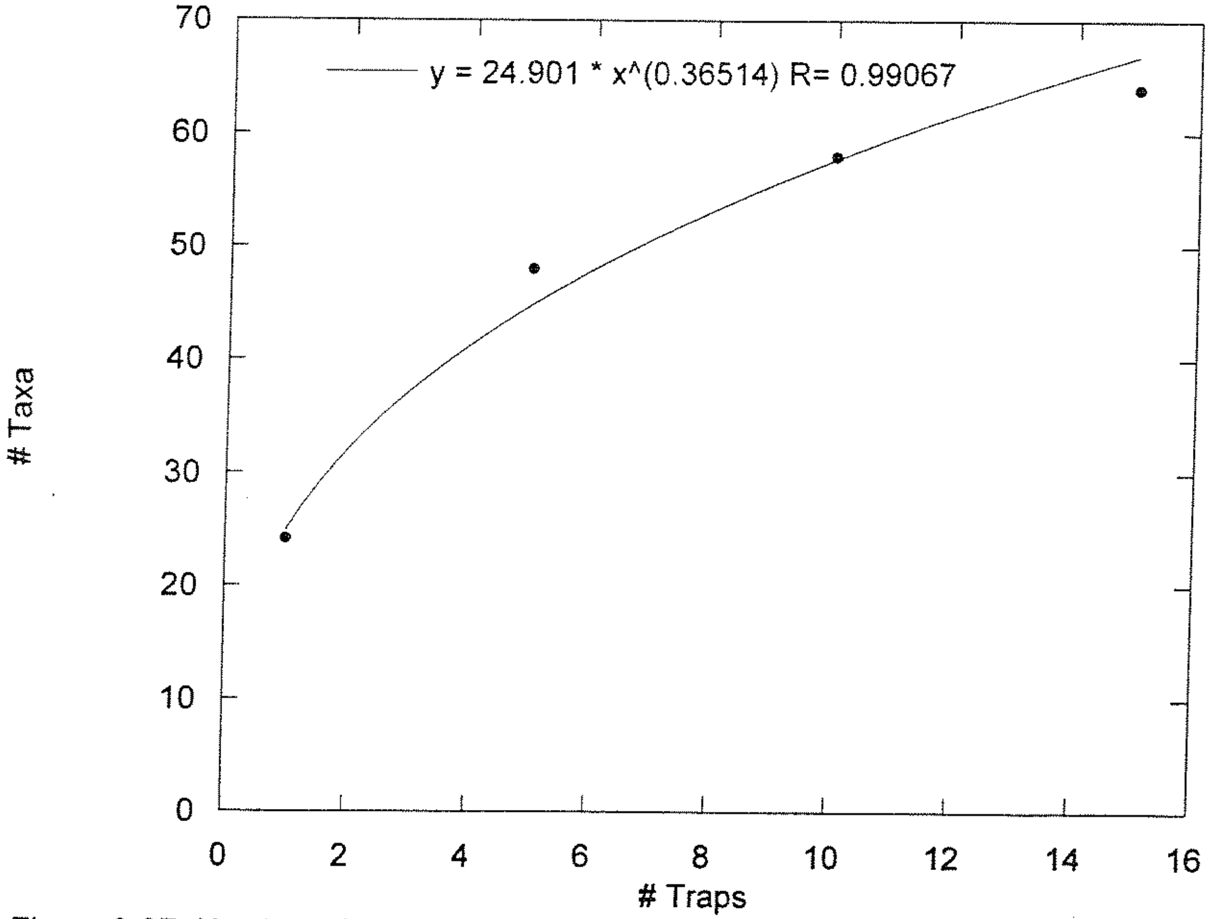


Figure 3-37: Number of Taxa Collected Related to Sampling Effort (Co. Rd. 200-July)

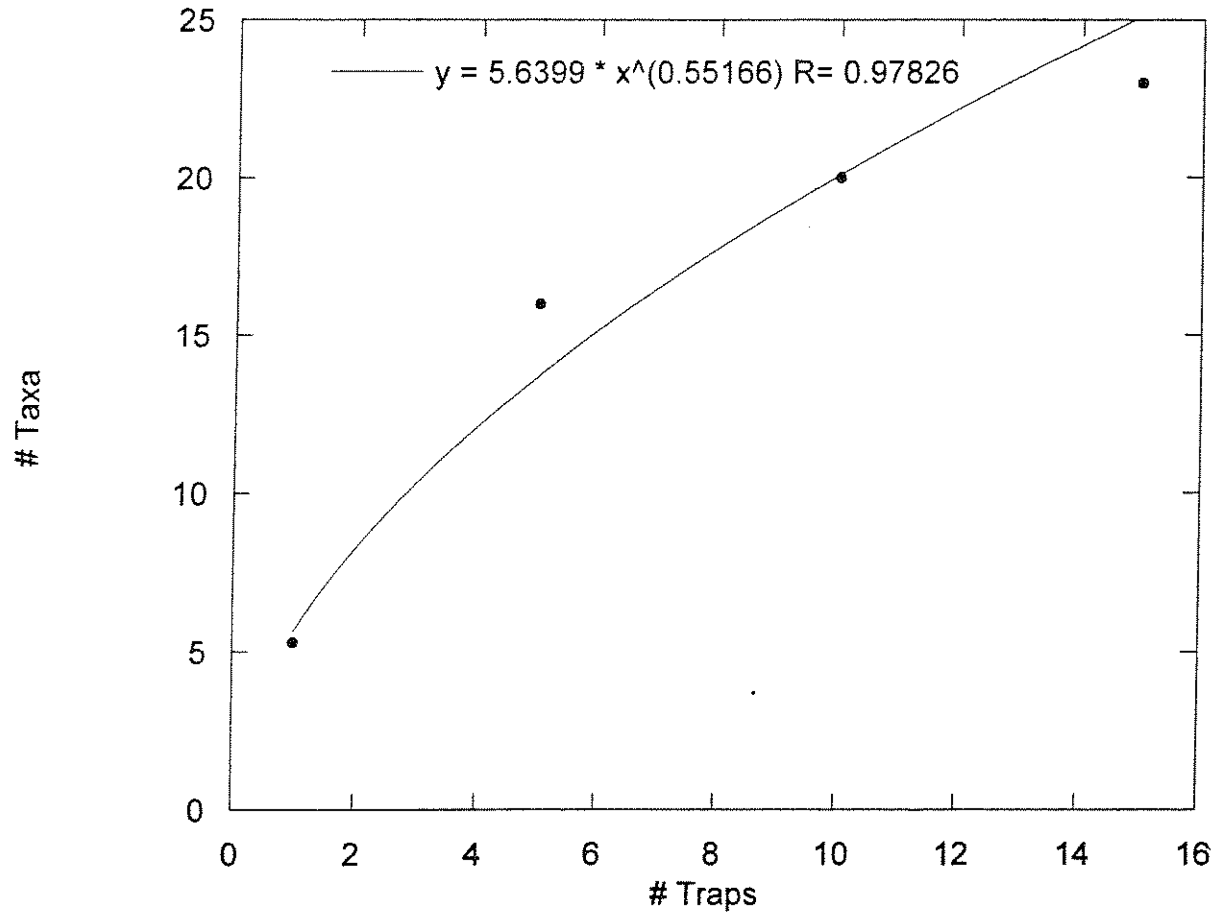


Figure 3-38: Number of Taxa Collected Related to Sampling Effort (Co. Rd. 200-May)

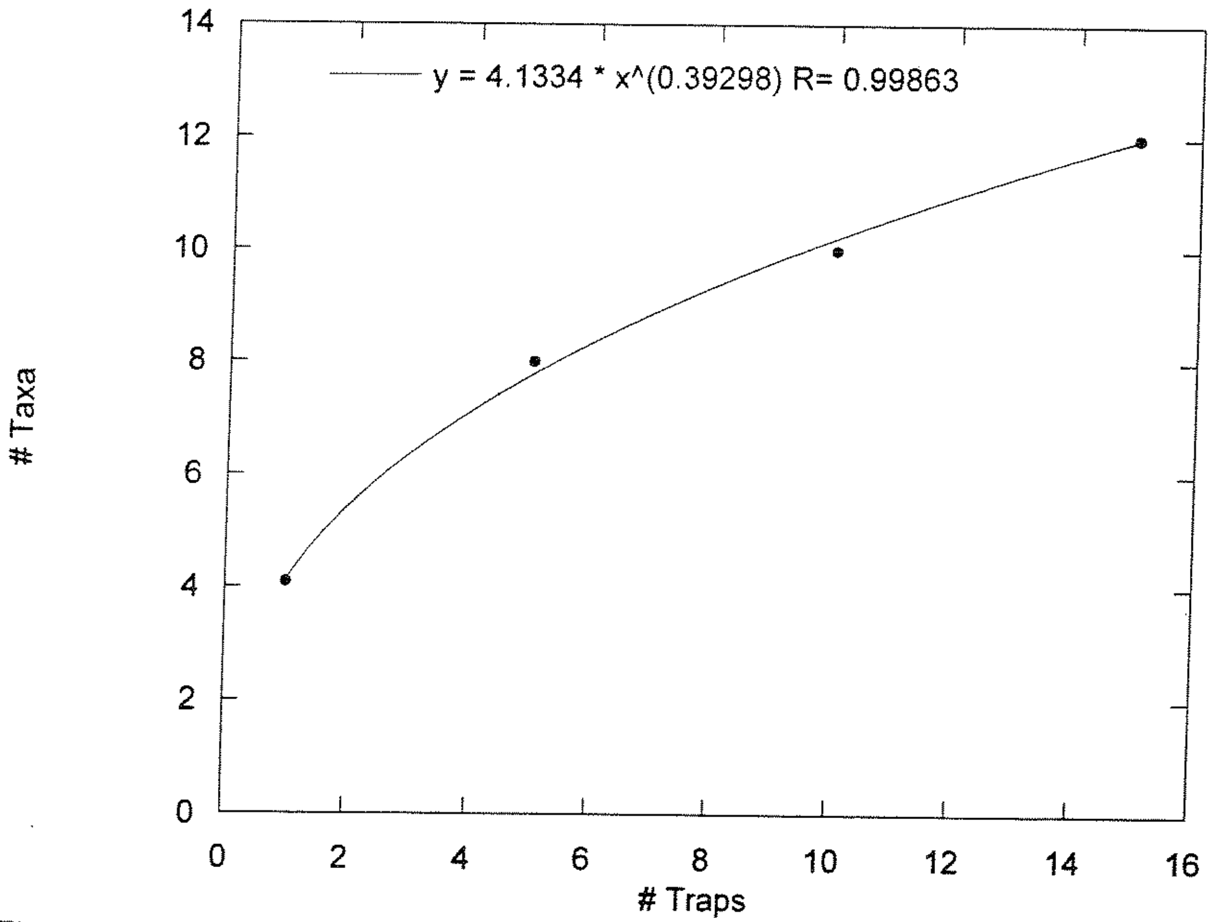


Figure 3-39: Number of Taxa Collected Related to Sampling Effort (Co Rd. 200-March)

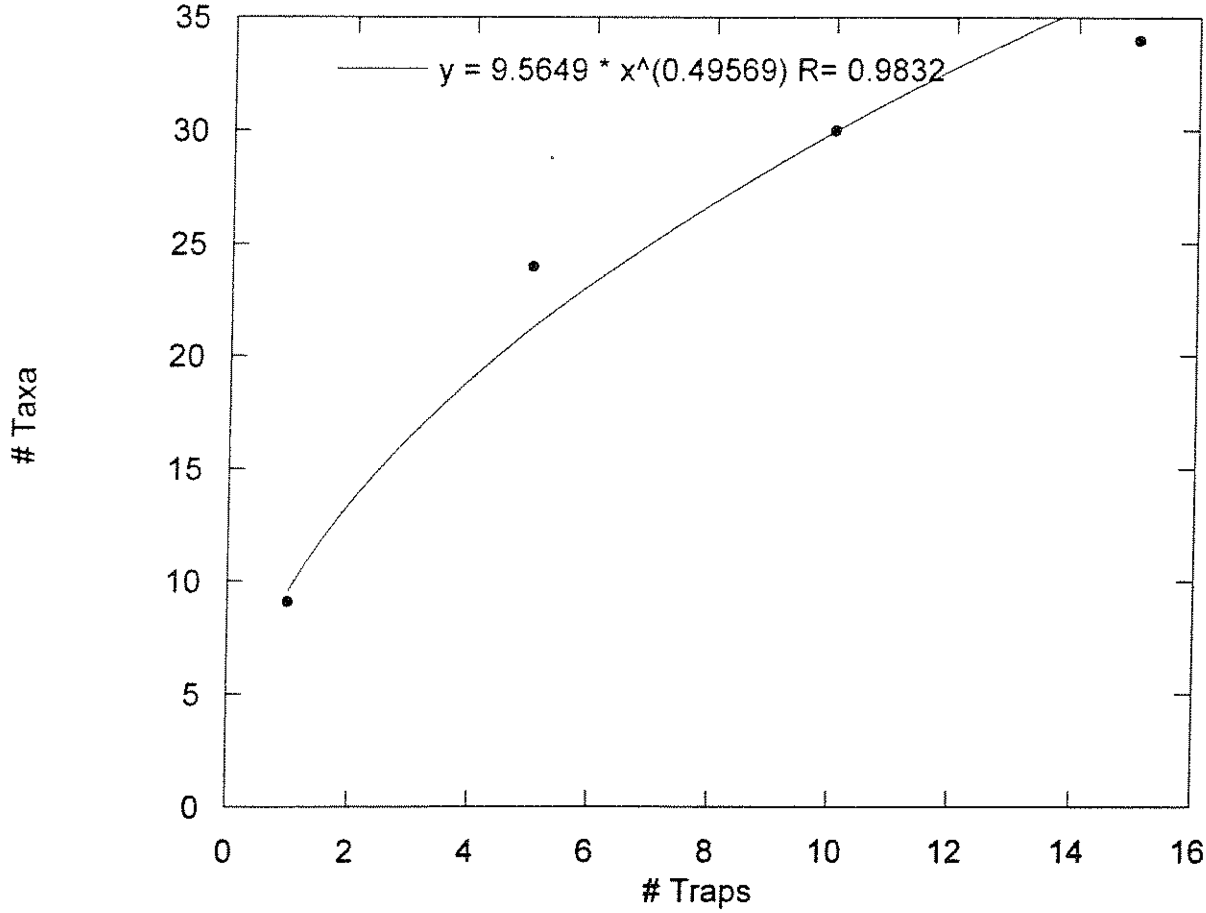


Figure 3-40: Number of Taxa Collected Related to Sampling Effort (Sawmill-May)

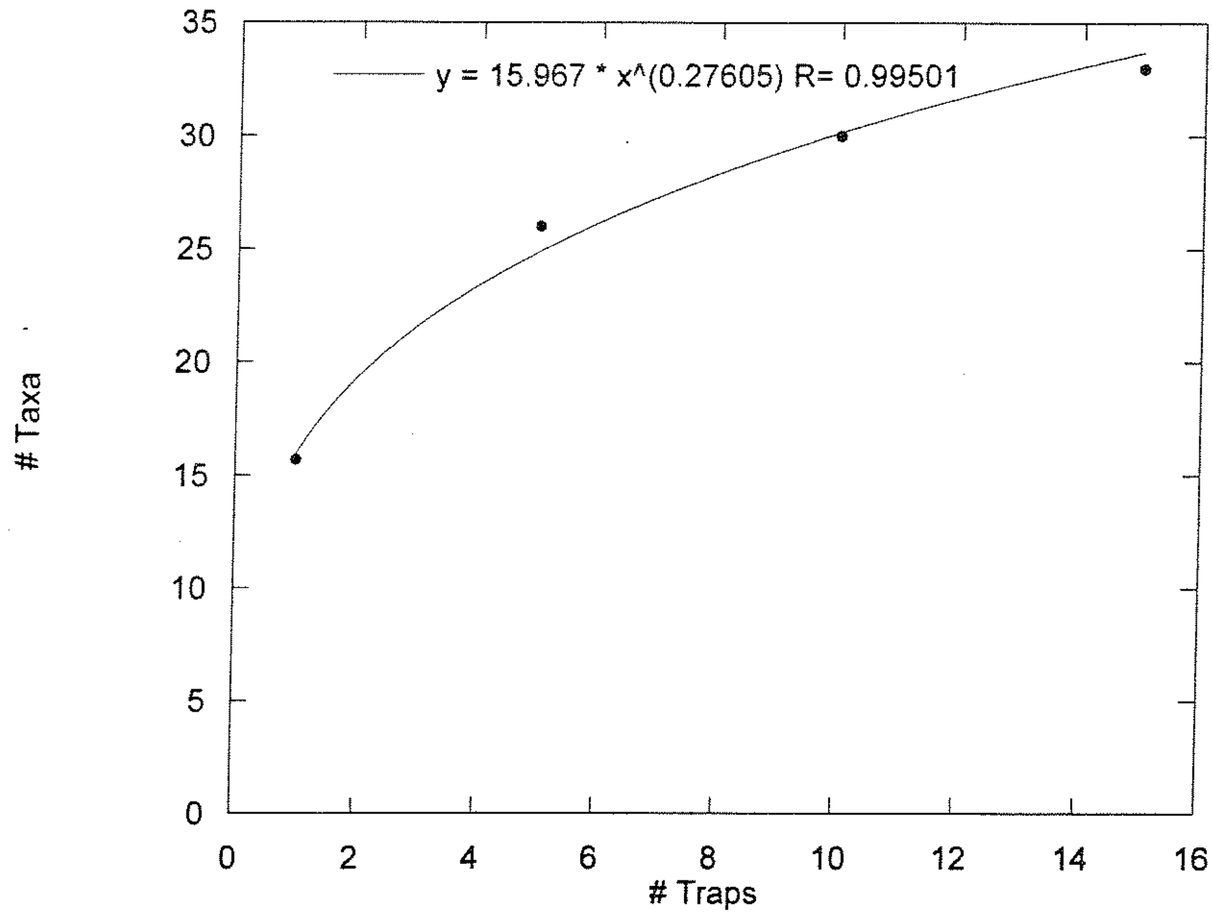


Figure 3-41: Number of Taxa Collected Related to Sampling Effort (Mishne-May)

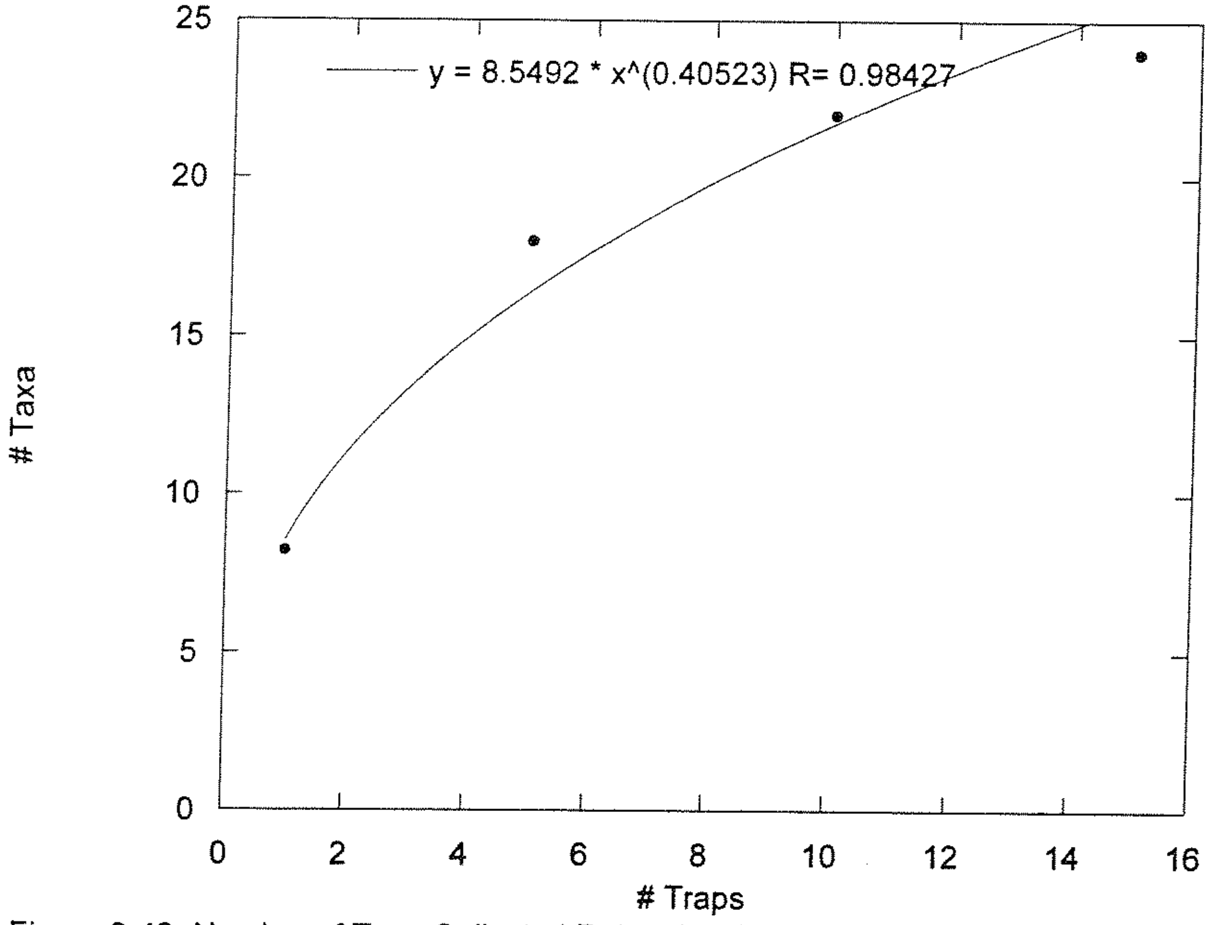


Figure 3-42: Number of Taxa Collected Related to Sampling Effort (Mishne-April)

funnel traps needed to sample a wetland was evaluated. We used up to 15 traps per wetland. There is little increase in field effort when the number of traps set in the wetland is increased, but laboratory processing time increases significantly. In 1997, I averaged 1.1 hours per trap to count and identify the trap contents. We looked at the number of additional taxa added with increased sampling effort. We calculated the number of taxa collected at a site when 1, 5, 10, and 15 traps were used. The number of taxa collected with 1 trap is the average number collected per trap for the 15 traps. The average number of taxa collected with 5 and 10 traps was calculated from randomly selected groups of 5 and 10 traps. The number of taxa collected with 15 traps is the total number of taxa collected from the 15 traps. Plots of the number of taxa collected relative to sampling effort for different wetlands and collection dates are shown in Figures 3-20 to 3-42. All figures show a similar rapid increase in # of taxa collected when trapping effort increases from 1 to 5 traps. The addition of new taxa rapidly declines beyond 10 traps. The results are similar for all wetland types, size of wetland, and season. The average increase in taxa for all sites was 153% in going from 1 to 5 traps. Taxa increased 27% when 10 traps were used. An additional 12% increase in total taxa collected results from using 15 traps. Based on these results we used 10 traps per wetland in our sampling.

<u>Summary of Macroinvertebrate and Amphibian Sampling Techniques</u> - We evaluated three sampling methods in wetlands. Funnel trapping is more effective than qualitative sampling for collecting a variety of macroinvertebrates and amphibians, and it is also advantageous in that it generates relative abundance data. Artificial substrate samplers (HD) were not effective in sampling many wetland taxa. Several other methods can be used to collect abundance data. Benthic corers or dredges (fixed area sampling devices) can be used to sample a fixed area/volume for calculating #/unit area. These devices are not effective in sampling amphibians and motile macroinvertebrates. Active organisms flee at the approach of field crews and avoid being captured in the relatively small corer or dredge. For fixed area sampling methods to be quantitative, all the organisms must be collected from the device. They collect large amounts of mud, plant material and debris which make sample processing difficult. Funnel traps contain little debris so samples are easy to process. Corers and dredges are difficult to use in dense plant

growth and woody debris. Seines can be used to collect quantitative samples but they are difficult to use in wetlands where woody plants and debris obstruct sampling. Seines collect large amounts of debris and quantitative sampling results are no better than the field crew's ability to sample consistently in the appropriate habitat types. Dipnets can be used quantitatively by sweeping the net for a specified distance, but debris and sampling consistency are still a problem. Sampling with dipnets is not effective for all taxa, especially amphibians and Coleoptera, as shown in the comparison of qualitative dipnet sampling and funnel trapping.

Calling frog surveys can be used to determine the presence and relative abundance of adult frogs in a wetland (Heyer et al. 1994). Frog calls are species specific. An approximation of the number of each calling species can be determined in the field. The time of year that each species calls depends upon when they initiate breeding activity. Calling begins in February or March for some early breeding species. Summer breeders may call in June and July. The duration of calling is weather specific and conditions may be appropriate for a week or less. It is difficult to collect data within such a short sampling window. The absence of a frog species from a wetland could be due to sampling error if we didn't sample the wetland at the proper time. Funnel trapping collects both adult frogs and tadpoles. The sampling window for most tadpoles is much longer than the calling adults. Bufo sp. tadpoles complete their development within a few weeks but most frog tadpoles are in the wetland for several months. Bullfrog tadpoles require two years to complete their development. All but the smallest tadpoles can be identified to species. The longer sampling window led us to use funnel traps to sample wetland frog populations.

Salamander populations can be sampled by a variety of methods (Heyer et al. 1994). Drift fences are an effective way to sample adult salamander populations as they approach wetlands in the early spring to breed. A fence of metal flashing is placed around the entire edge of the wetland. At various intervals on the outside of the wetland, buckets are buried in the ground next to the fence. Salamanders approach the wetland and are unable to enter when they encounter the fence. The salamanders travel along the edge of the fence trying to find a way into the wetland and fall into the buckets. The species and numbers of salamanders utilizing the wetland can be

determined. This method is excellent for Ambystoma sp. salamanders but setting up the fence is very labor intensive. The buckets must be checked daily throughout the breeding season to prevent mortality and predation. Resource requirements to set up, maintain, and monitor drift fences made it impractical for our purposes. Funnel traps can be set out and checked the following day in four or five wetlands by a crew of two field workers.

Adult salamanders are in the wetland for only a short period in the spring to breed. Warm, rainy nights in February- April stimulate movement of Ambystoma sp. salamanders from woodlands into wetlands. The salamander species don't all breed at the same time so it is extremely difficult to sample frequently enough to ensure that we have collected every species that utilizes the wetland. Funnel traps did collect adults of all the salamander species that we expected to encounter in wooded wetlands. Failure to collect a particular salamander species from a wetland should not be interpreted to mean absence from the wetland, merely that it wasn't collected. Funnel traps did collect salamander larvae but identification is difficult. Tiger and smallmouth salamander larvae are readily identified but spotted, Jefferson and hybrid larvae are difficult to identify to species.

Enclosure sampling devices are another method of sampling amphibians as well as macroinvertebrates. Enclosure devices are usually a metal box open on the top and the bottom. The box is placed on the bottom at various locations in the wetland. All the organisms within the box are collected. Density of specific organisms can be calculated as #/area of the box. Problems with enclosure devices include avoidance by the more active organisms, separating organisms from large amounts of plant material and debris, and selecting sites to place the trap that are free of obstructions so that the trap can be seated on the bottom. Funnel traps can be located close to habitat features that preclude the use of enclosure devices. Wetlands had to contain water at least 13 cm deep to use funnel traps. For most of the sampling season, water depth was adequate to use funnel traps. There are designs for traps that can be used at almost any depth though these are more expensive to construct (Mushet et al. 1997). Dense macrophyte and algae growth prevented us from sampling one wetland late in the year. We were unable to submerge the traps in the

vegetation but we were also unable to collect a qualitative sample with a dipnet.

The primary purpose of this project was to evaluate methods of sampling wetland macroinvertebrate and amphibian populations. We evaluated three sampling methods and found funnel traps were effective in sampling both macroinvertebrates and amphibians. Hester-Dendy artificial substrate samplers were not colonized by many taxa which were collected by other methods. Qualitative sampling did not collect as many taxa as funnel trapping. In addition, qualitative sampling does not provide relative abundance data. Other sampling methods described in the literature were considered, but not used based on limitations discussed above. The ultimate goal of the wetland sampling program is to collect data that can be used to develop indicators of wetland quality. At this point we do not know what taxonomic group(s) of organisms may be reliable biological indicators of wetland quality, so it is important that our sampling include as many taxa as possible. Once we know what taxa are good indicators, we can use more specific sampling methods as appropriate. Sampling does not have to collect everything found in the wetland, but it must be consistent from one wetland to the next for those organisms that serve as indicators. Sampling results should be quantitative and any observed differences should reflect real differences in wetland quality. We have used the macroinvertebrate and amphibian data in preliminary development of biological indicators of wetland quality. The results are discussed in the following section.

Section 3.2: Biological Indicator Development Using Macroinvertebrates and Amphibian Communities

We have utilized funnel trap data in preliminary biological indicator development. The first phase is to identify a component of the biological community that can be measured. This is called an attribute (Karr and Chu 1997). If the attribute changes in a predictable and measurable way along a gradient of human disturbance it is a metric. Human disturbance for the purposes of this analysis will be quantified by the Rapid Assessment Method (RAM) score. In 1996 the RAM score was based on the Washington State Method and in 1997 it was based on the Ohio Wetland

Assessment Method as discussed in Section 2.2. The relationship to the Floristic Quality Assessment Index (FQAI) was also investigated, though this may be a metric responding to human disturbance. Before we examined the response of attributes to RAM we had to stratify the data based on wetland type. It is important that gradient of human disturbance is the only feature that separates the wetlands. We selected forested and emergent vegetation as two distinct wetland types. Of the 21 wetlands we sampled, 14 were classified as forested and 7 were emergent. The wetlands also differed in hydroperiod. Some wetlands were permanent while others were flooded for only a few months. Seasonal and annual variability in rainfall provides a natural basis to hydroperiod variability. Human alteration to landscape features can provide a human induced alteration to hydroperiod. Our data base is not large enough to stratify by hydroperiod. Most wetland fauna have life history strategies that are well adapted to fluctuating water levels and variable hydro eriods. Permanent wetlands do have some taxa, such as bullfrogs, that are not found in temporary wetlands. Recognition of fauna differences across hydroperiod gradient will be important in assessing disturbance gradient impacts.

Wetland size may also be an important variable. Larger habitats tend to support more species. Ohio EPA uses different metrics for three different classes of stream size. In wetlands, large size may increase available habitat types for amphibian and macroinvertebrate colonization. Large wetlands are a bigger target and may be colonized more readily by flying macroinvertebrates. The wetlands we sampled in 1996 and 1997 ranged in size from 5.4 to 0.02 hectares. As we gather data from more wetlands we will evaluate the impact of wetland size.

Seasonal changes in macroinvertebrate and amphibian distribution and abundance are important in wetlands. Anostraca are the predominant macroinvertebrate group from wetlands in March. By late April, Anostraca have laid eggs and are absent from our samples. Culicidae larvae are very abundant in April, but nearly absent in May and June. Coleoptera and Chironomidae taxa richness and abundance increases in May to July sampling. Metric development was done for data from similar time seasons. Early spring, spring and summer were used. A metric developed from early spring fauna should not be expected to work for the same wetlands in summer. Calendar

dates for sampling intervals may not be accurate due to annual variations in weather. The presence of key indicator species, such as Anostraca, may mark appropriate sampling periods.

Within the forested class of wetlands we looked at a number of potential macroinvertebrate and amphibian indicators. The number of salamander species collected from a wetland is plotted in relation to FQAI and RAM score (Figures 3-43 and 3-44). The number of salamander species appears to be positively related to increasing RAM score while sites with fish have fewer than expected salamander species. The number of frog species appears to have no relationship with FQAI or RAM score (Figure 3-45 and 3-46).

Macroinvertebrate taxa richness is a common biological indicator. In forested wetlands early spring taxa richness is not related to FQAI and RAM score (Figure 3-47 and 3-48). Dominance of the fauna by a few taxa is usually associated with degraded sites. A plot of the percentage of organisms comprising the three most abundant species is plotted in relation to FQAI and RAM score (Figures 3-49 and 3-50). There is a weak association between decreasing dominance and increasing RAM score. From the spring and summer samples we have not found any biological attributes of forested wetlands that are strongly related to RAM score. We have looked at number of taxa, number of taxa by various taxonomic groups, percent of organisms by taxonomic groups, percent of predators, percent dominance by a few taxa, and number of unique taxa in relation to RAM and FQAI score. We have not looked tolerant and intolerant taxa in relation to RAM or FQAI since we don't know which taxa are tolerant or intolerant. Wiggins et al.,1980, presents a grouping of life history strategies for animals in annual temporary pools. Wetland animals are classified as overwintering residents, overwintering spring recruits, overwintering summer recruits and non-overwintering spring migrants. Classification of our wetland fauna based on these life history strategies may reveal potential metrics.

We selected forested wetland sites which we believed represented a range of disturbance gradients from relatively unimpacted to impacted. A preliminary review of our data has produced few biological attributes that respond to disturbance gradient as measured by RAM score. The

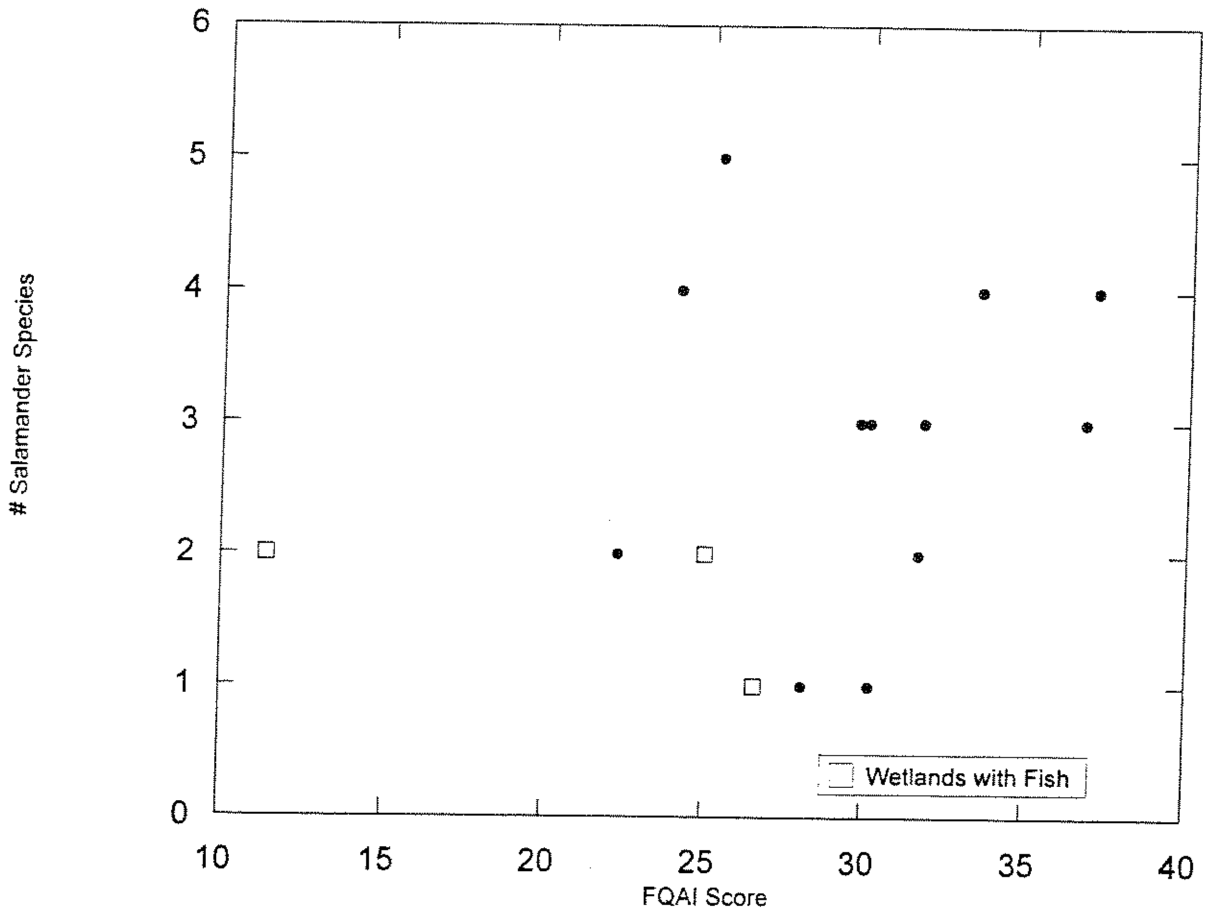


Figure 3-43: Number Salamander Species in Relation to FQAI for Forested Wetlands

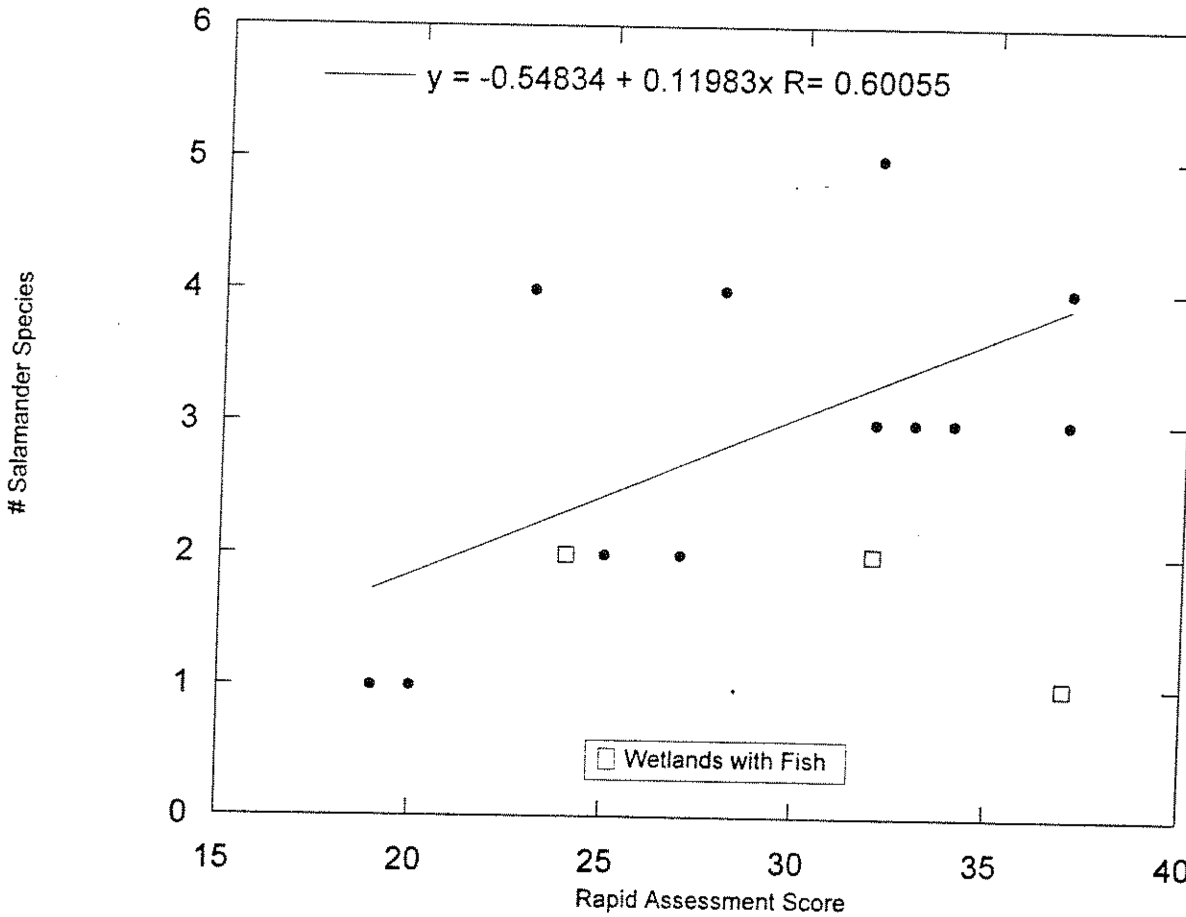


Figure 3-44: Number Salamander Species in Relation to RAM for Forested Wetlands

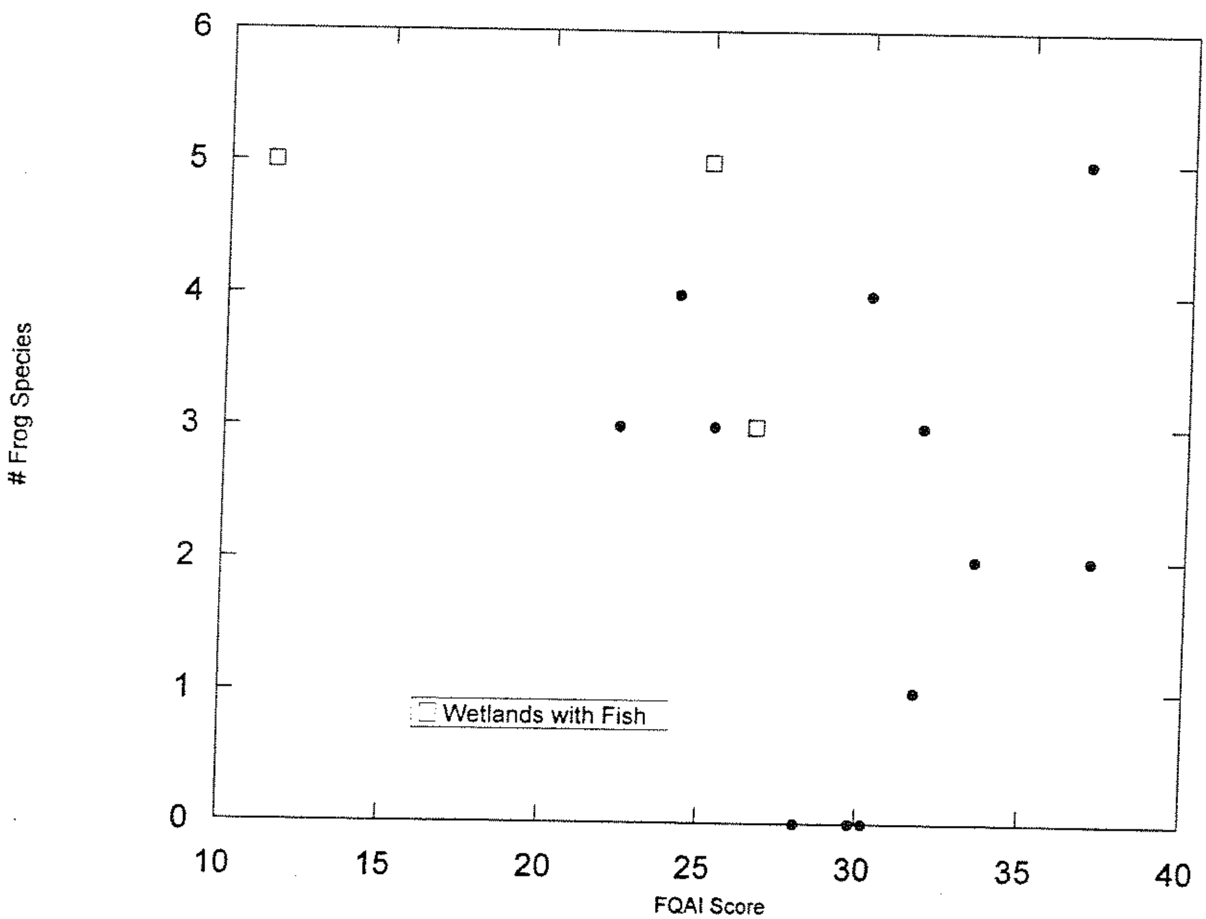


Figure 3-45: Number Frog Species in Relation to FQAI for Forested Wetlands

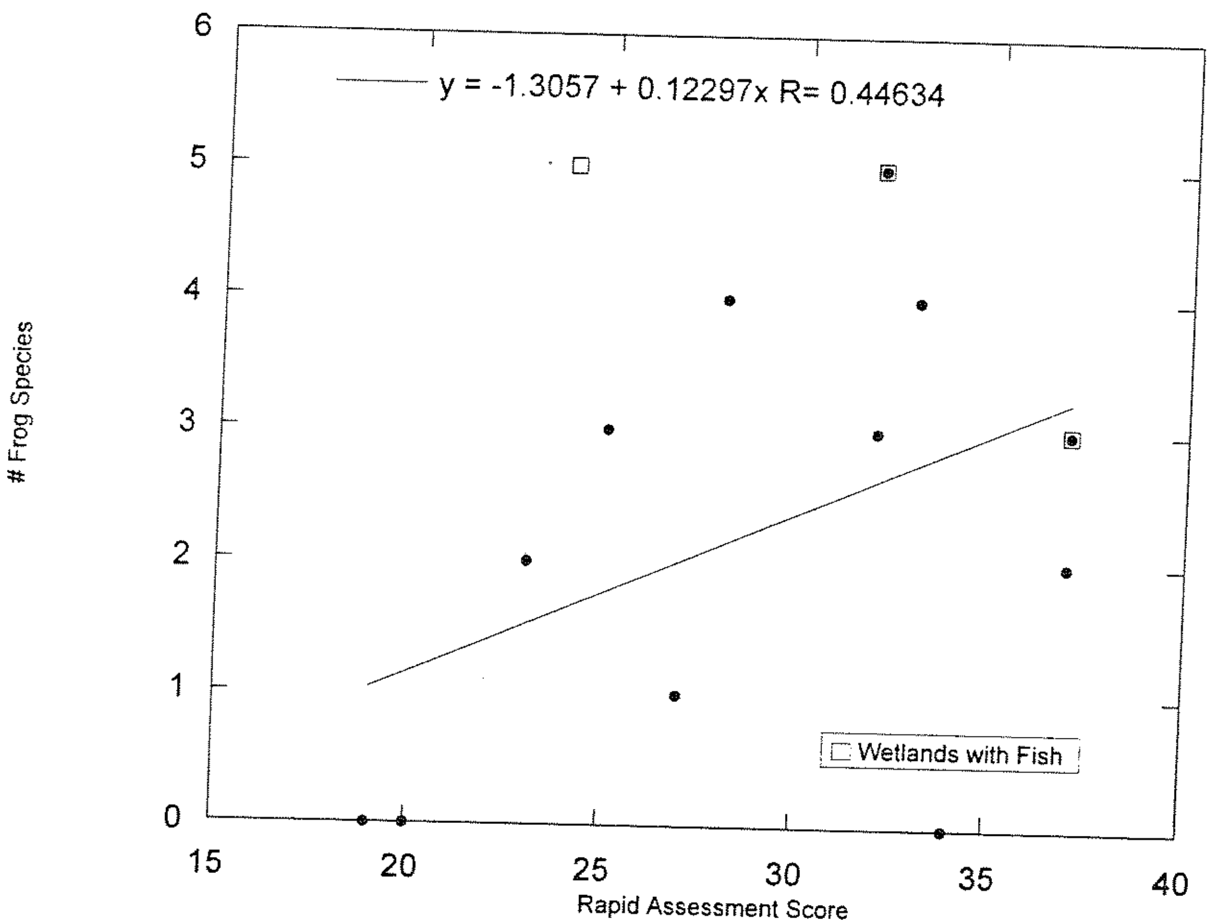


Figure3-46: Number Frog Species in Relation to RAM for Forested Wetlands

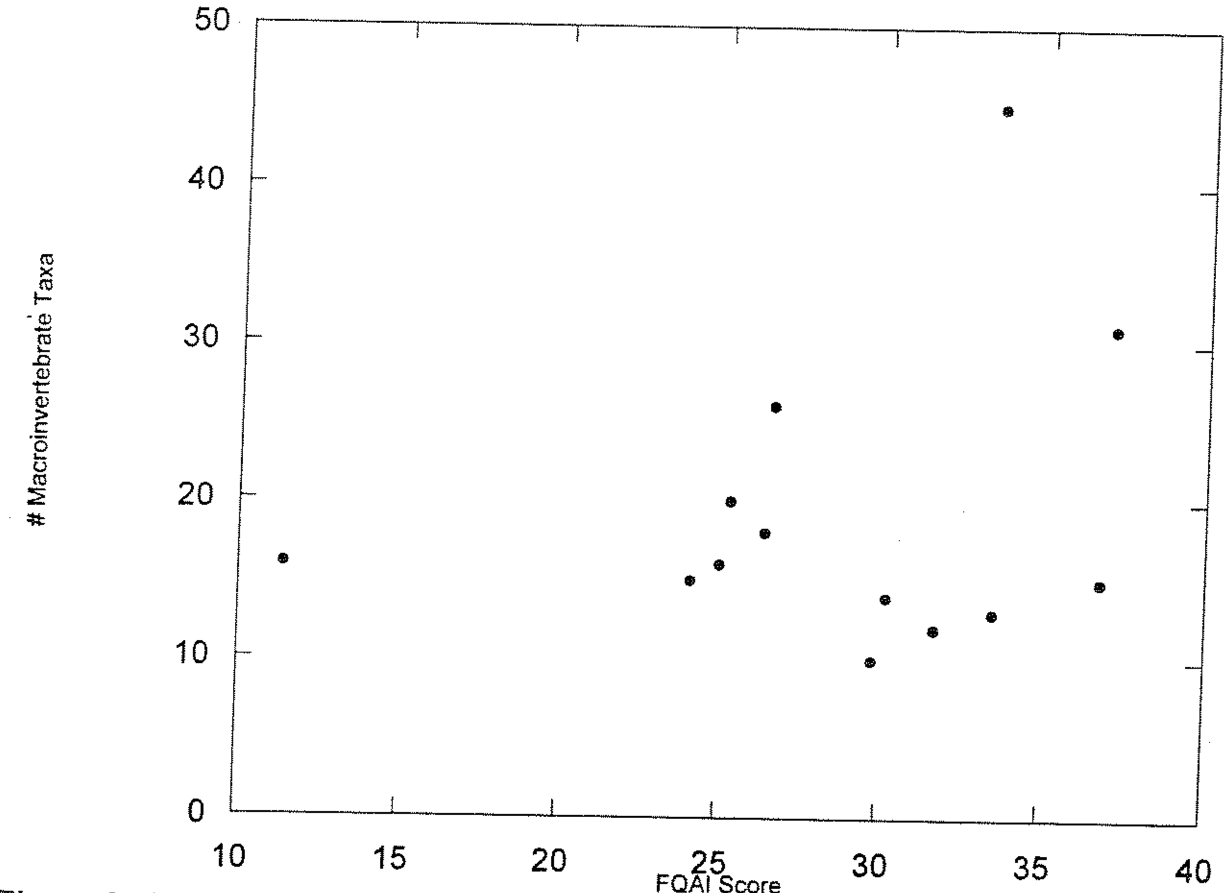


Figure 3-47: # Macroinvertebrate Taxa in Relation to FQAI for Forested Wetlands) (Early Spring)

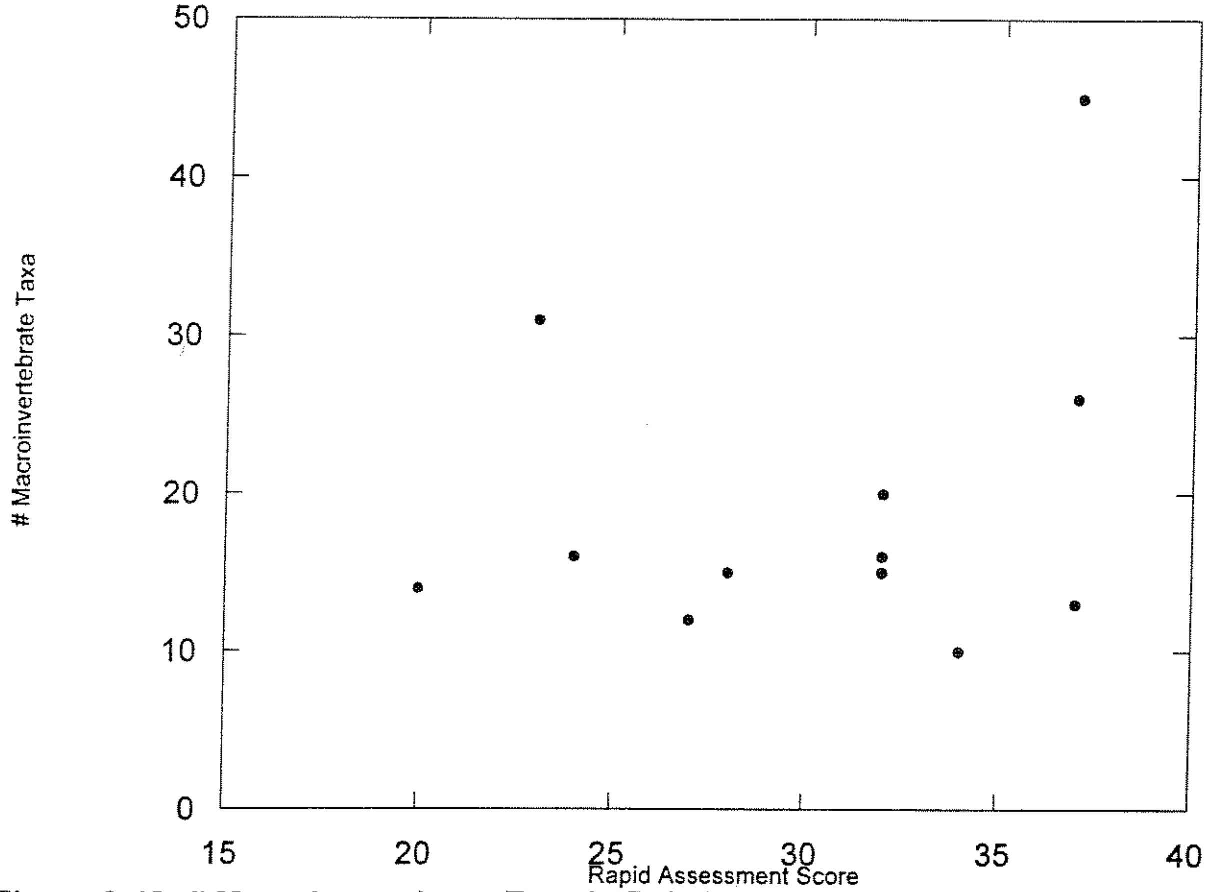


Figure 3-48: # Macroinvertebrate Taxa in Relation to RAM for Forested Wetlands (Early Spring)

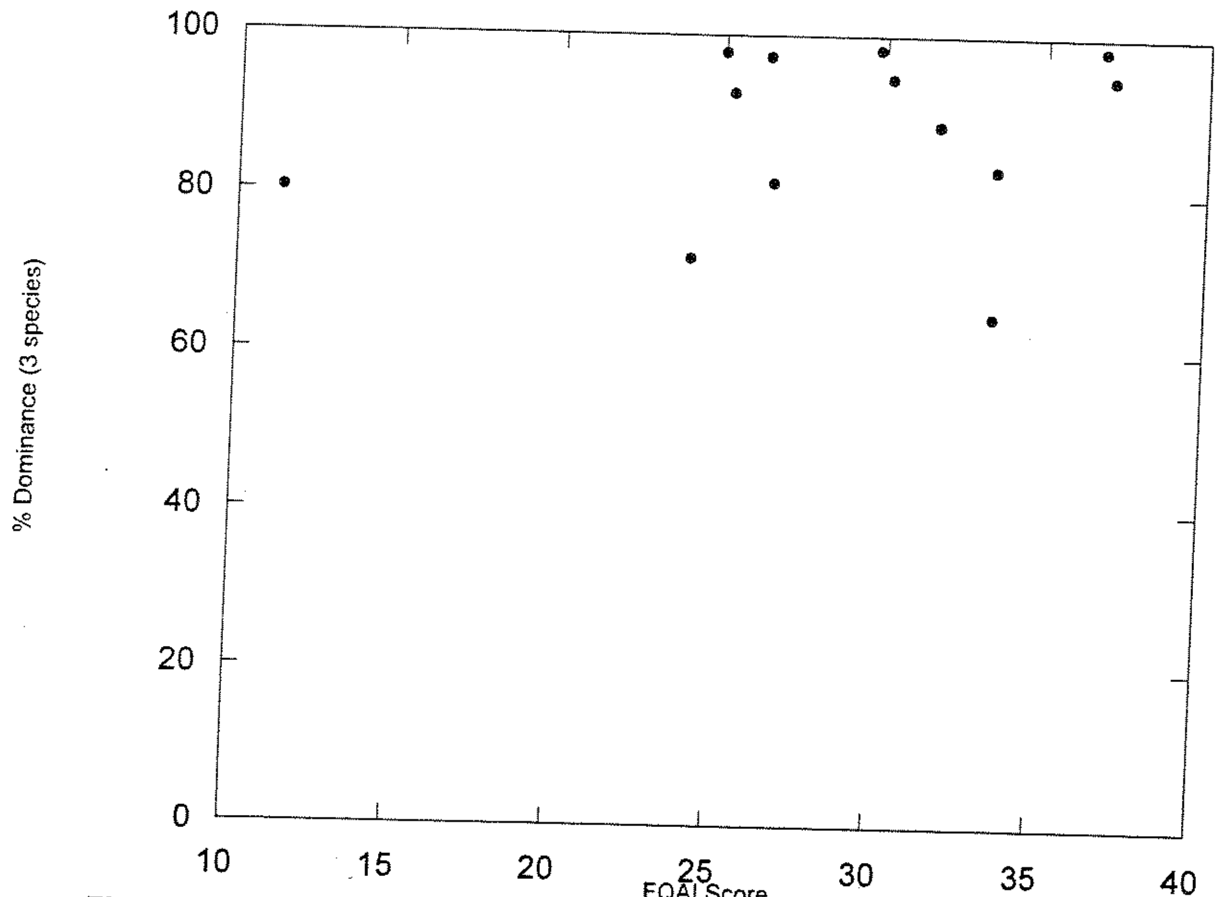


Figure 3-49: % Dominance in Relation to FQAI in Forested Wetlands (Early Spring)

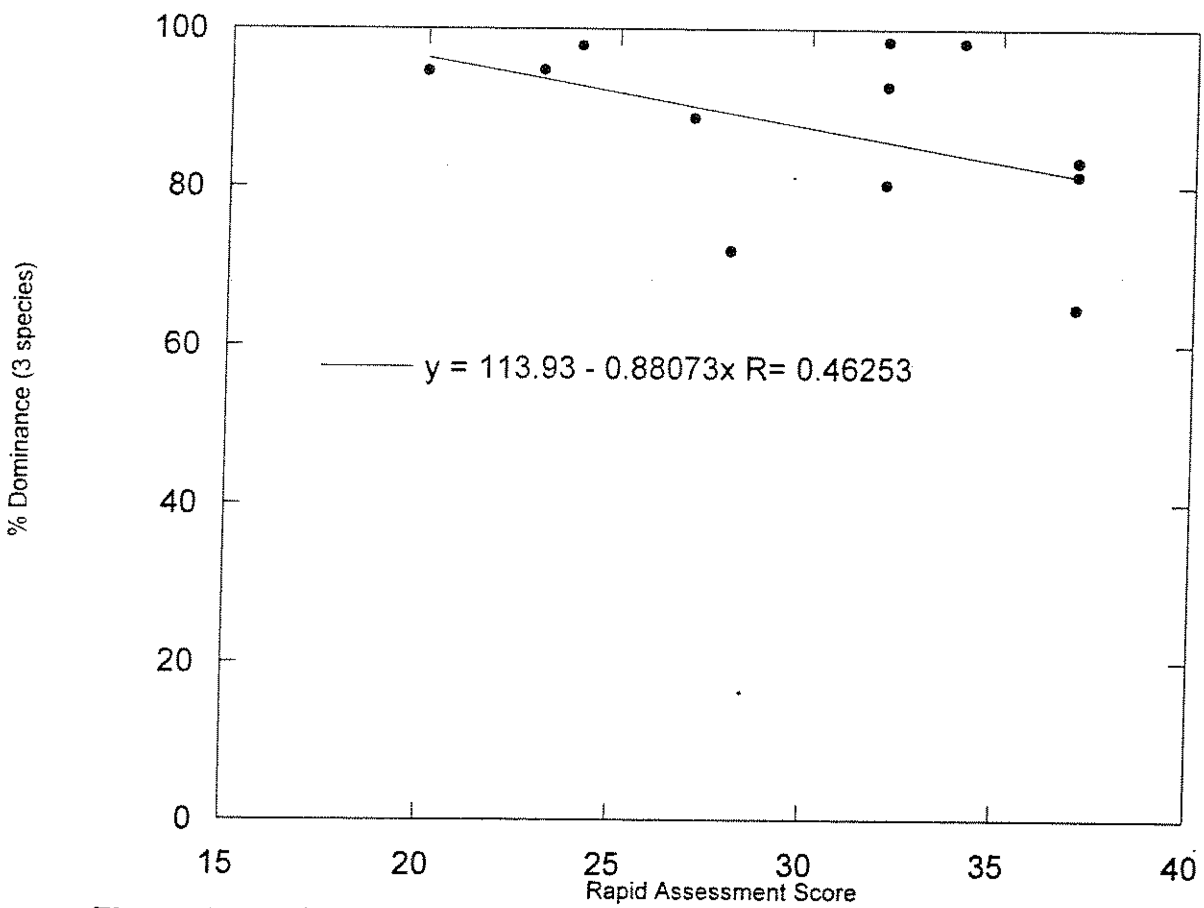


Figure 3-50: % Dominance in Relation to RAM in Forested Wetlands (Early Spring)

lack of response may indicate that the range of disturbance were not as great as we believed. Wetlands that have retained forest cover may have kept functions necessary to maintain biological integrity and resist perturbations from disturbance (i.e., have a long response time). The plot of FQAI in relation to RAM score for forested wetlands indicates that the plant community also did not respond to disturbance gradient (Section 2.2).

In contrast to the forested wetlands, the macroinvertebrate community in emergent wetlands did responde to the disturbance gradient. In early spring, the number of macroinvertebrate taxa, number of mollusca taxa, number of coleoptera taxa, and number of diptera taxa are positively related to increasing RAM score (Figures 3-51 to 3-54). Data from spring samples produced similar results. The number of macroinvertebrate taxa, number of mollusca taxa, and number of diptera taxa all increased with RAM score (Figures 3-55 to 3-57). The percent of total organisms in the family Chironomidae increased with RAM score (Figure 3-58). Summer sampling results were similar to the spring samples.

Amphibian species richness was not related to RAM score in emergent wetlands. Adult Ambystoma sp. salamanders live in woodlands. Only emergent wetlands that have forested areas nearby can support Ambystoma sp. salamanders. Salamander species richness was not related to RAM score (Figure 3-59). The number of frog species in emergent wetlands was also not related to RAM score (Figure 3-60).

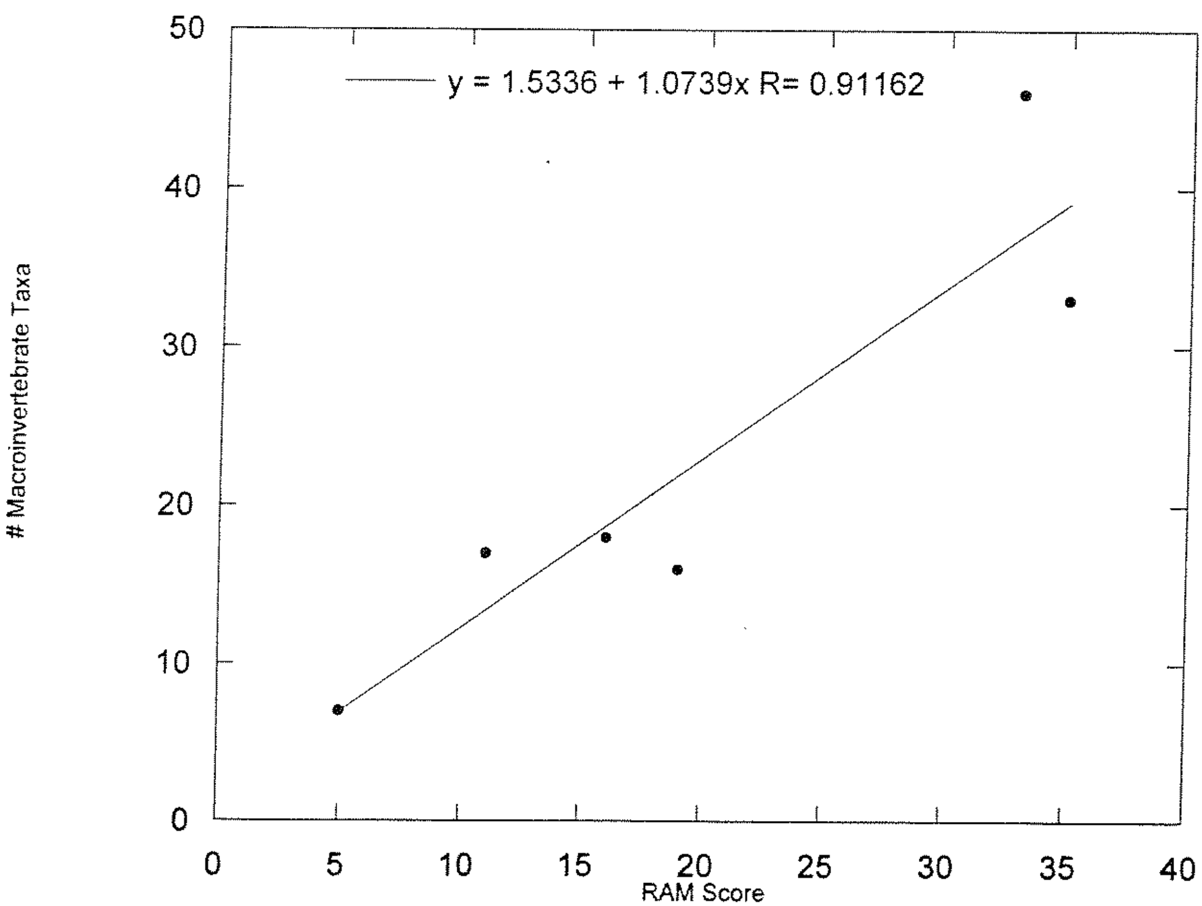


Figure 3-51: # Macroinvertebrate Taxa in Relation to RAM in Emergent Wetlands (Early Spring)

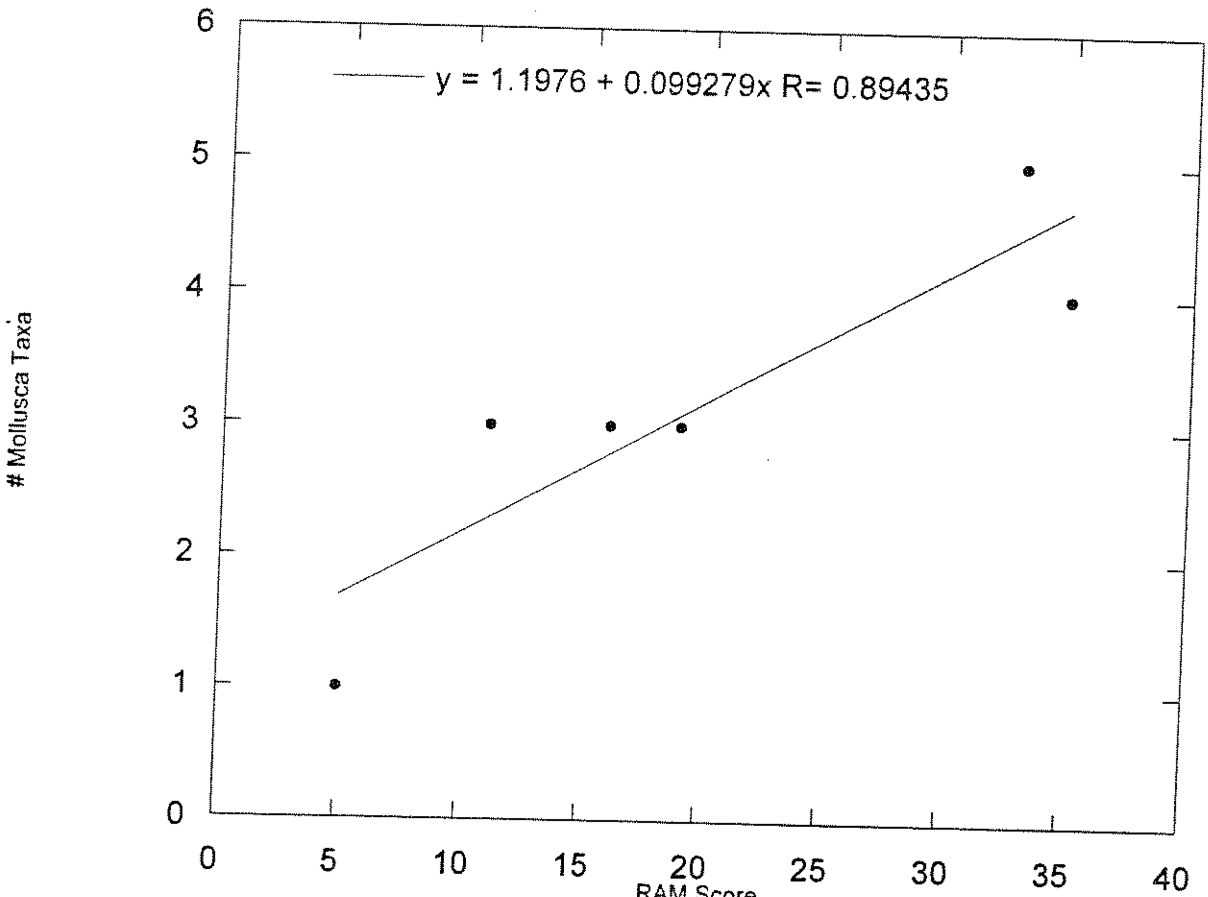


Figure 3-52: # Mollusca Taxa in Relation to RAM in Emergent Wetlands (Early Spring)

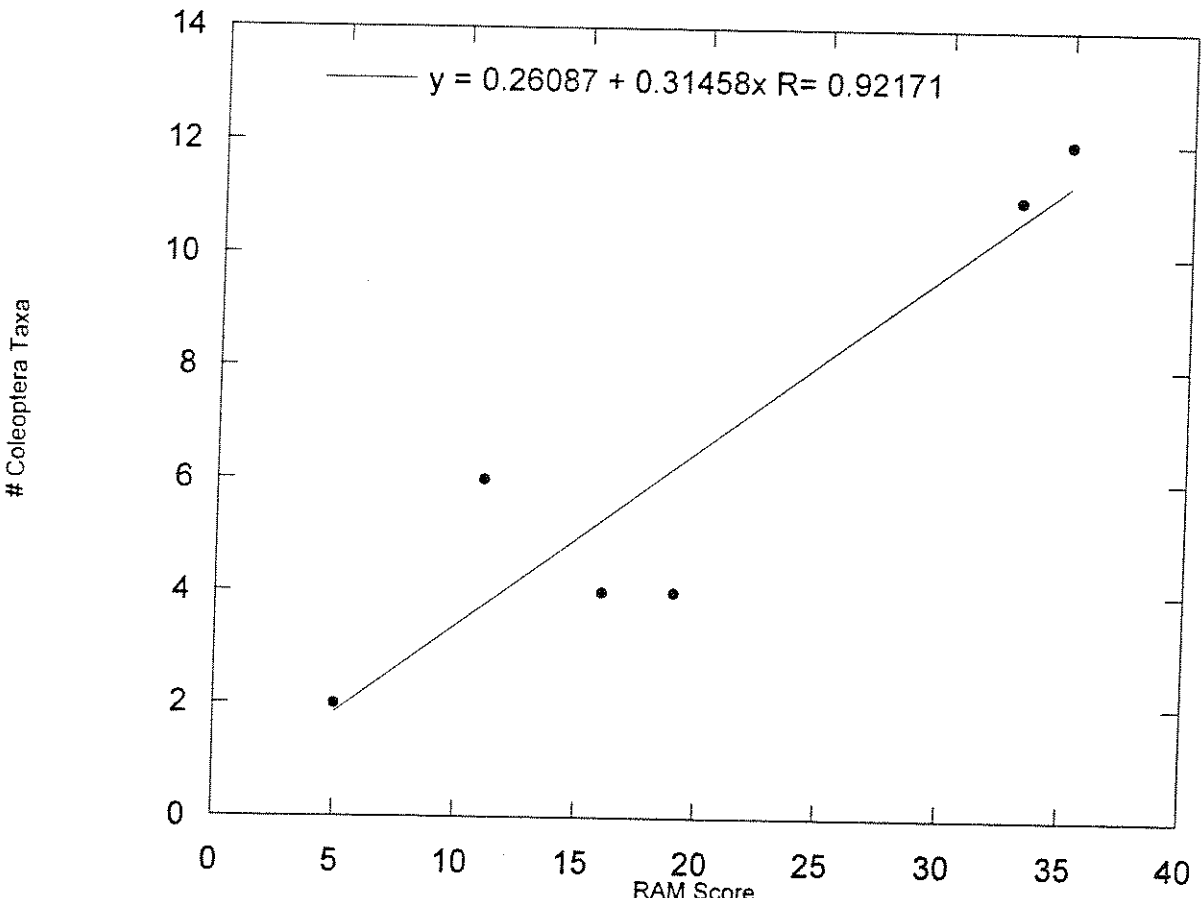


Figure 3-53: # Coleoptera Taxa in Relation to RAM in Emergent Wetlands (Early Spring)

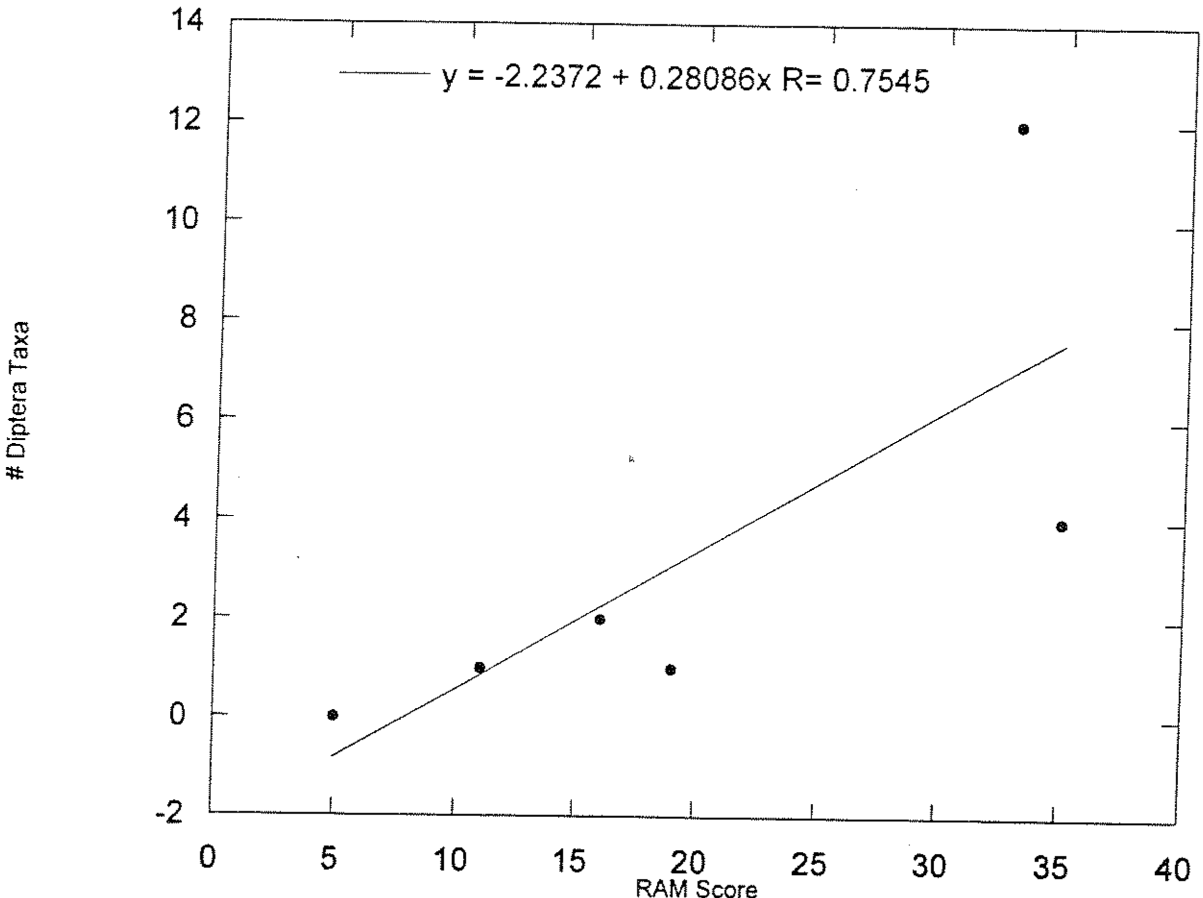


Figure 3-54: # Diptera Taxa in Relation to RAM in Emergent Wetlands (Early Spring)

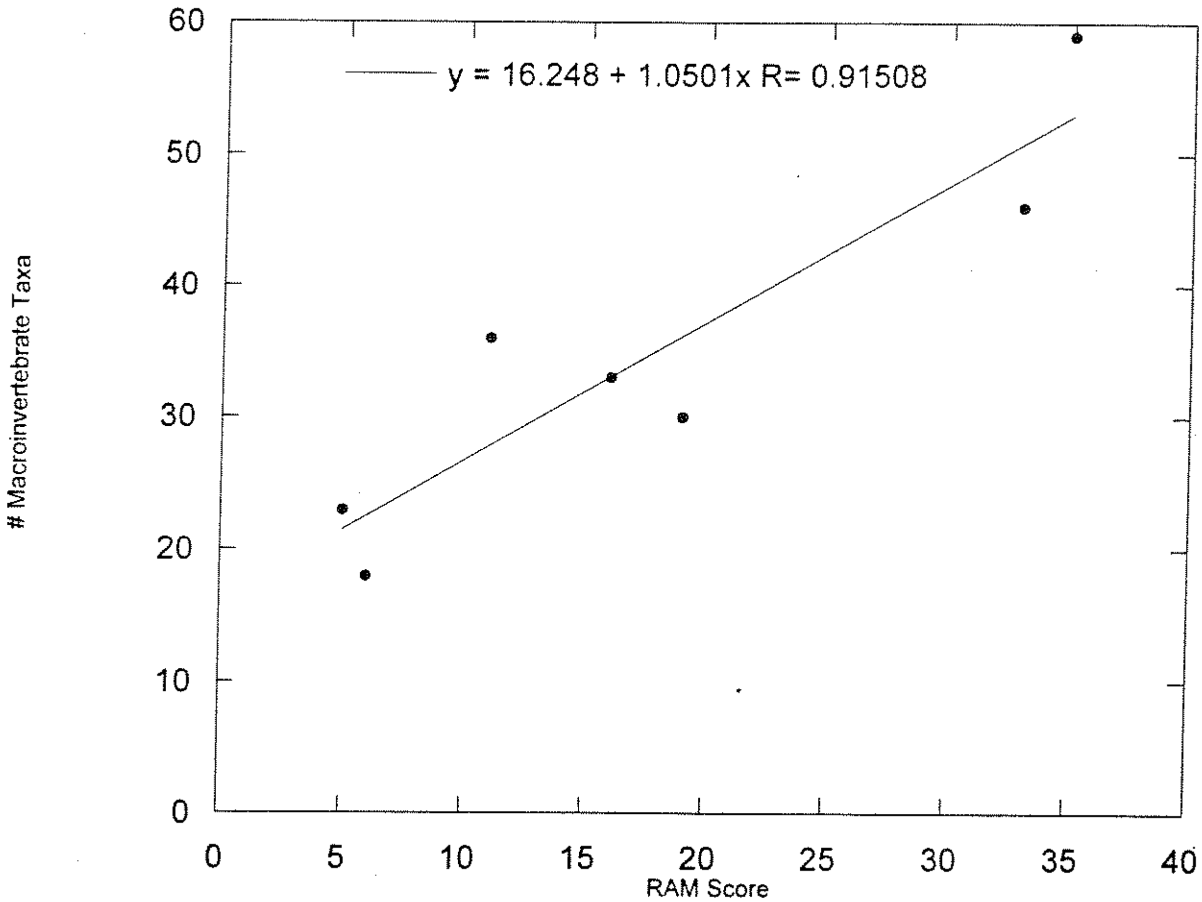


Figure 3-55: # Macroinvertebrate Taxa in Relation to RAM in Emergent Wetlands (Spring)

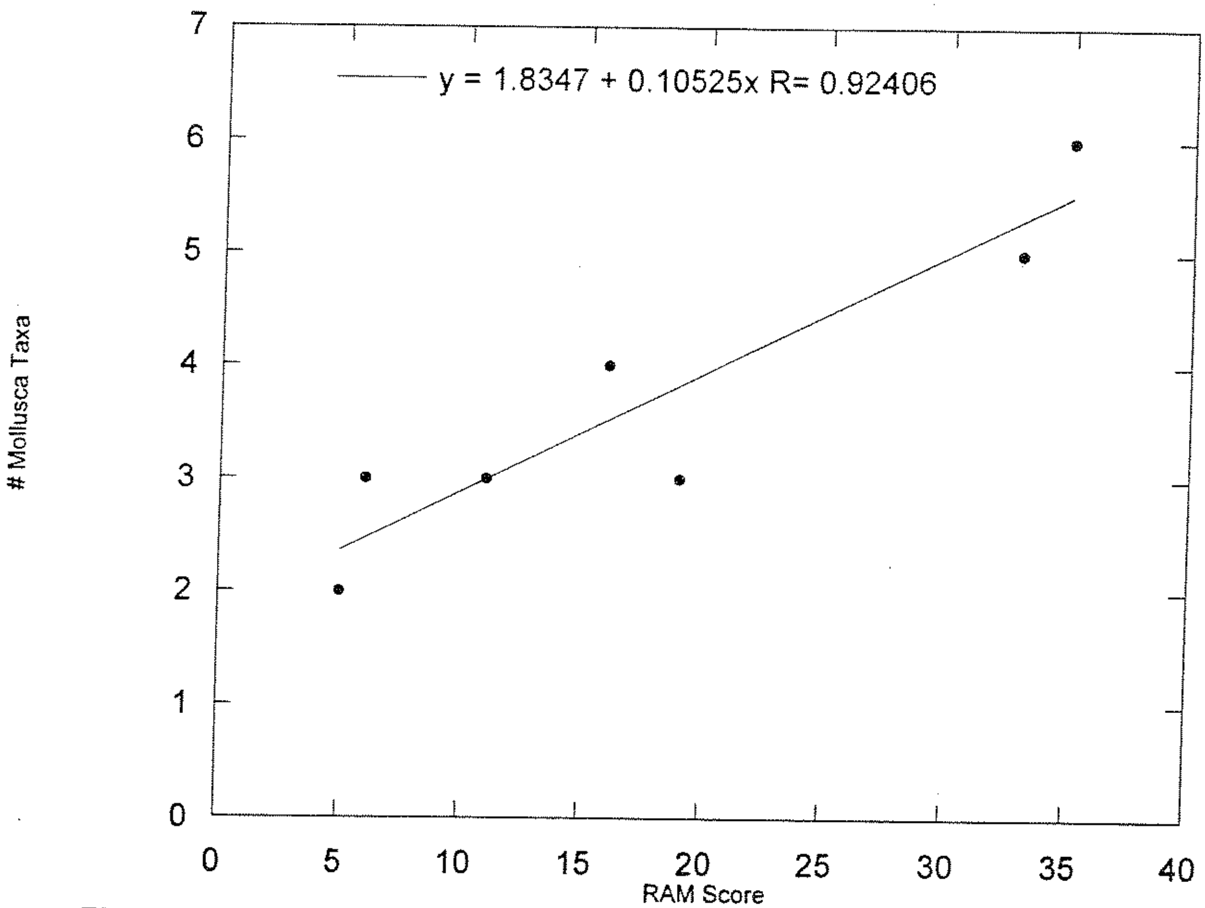


Figure 3-56: # Mollusca Taxa in Relation to RAM in Emergent Wetlands (Spring)

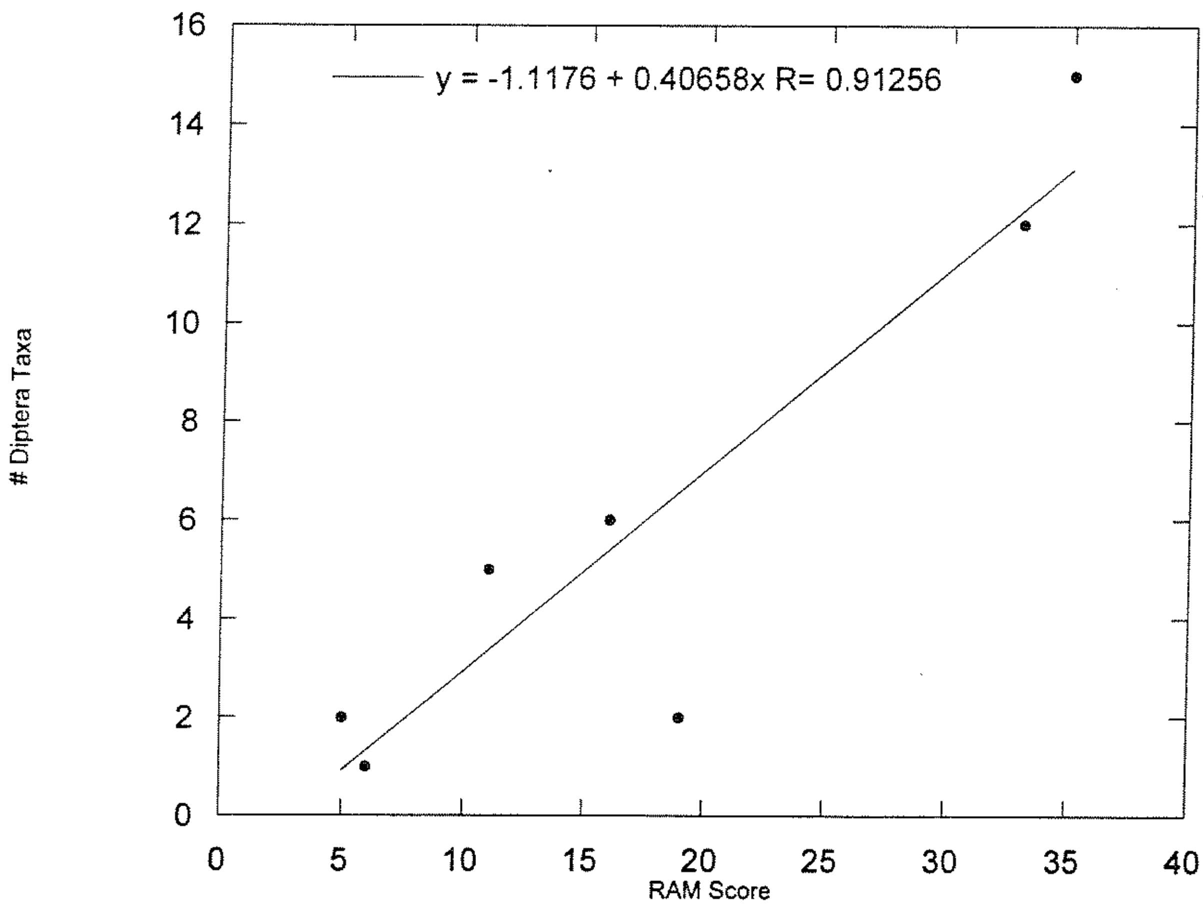


Figure 3-57: # Diptera Taxa in Relation to RAM in Emergent Wetlands (Spring)

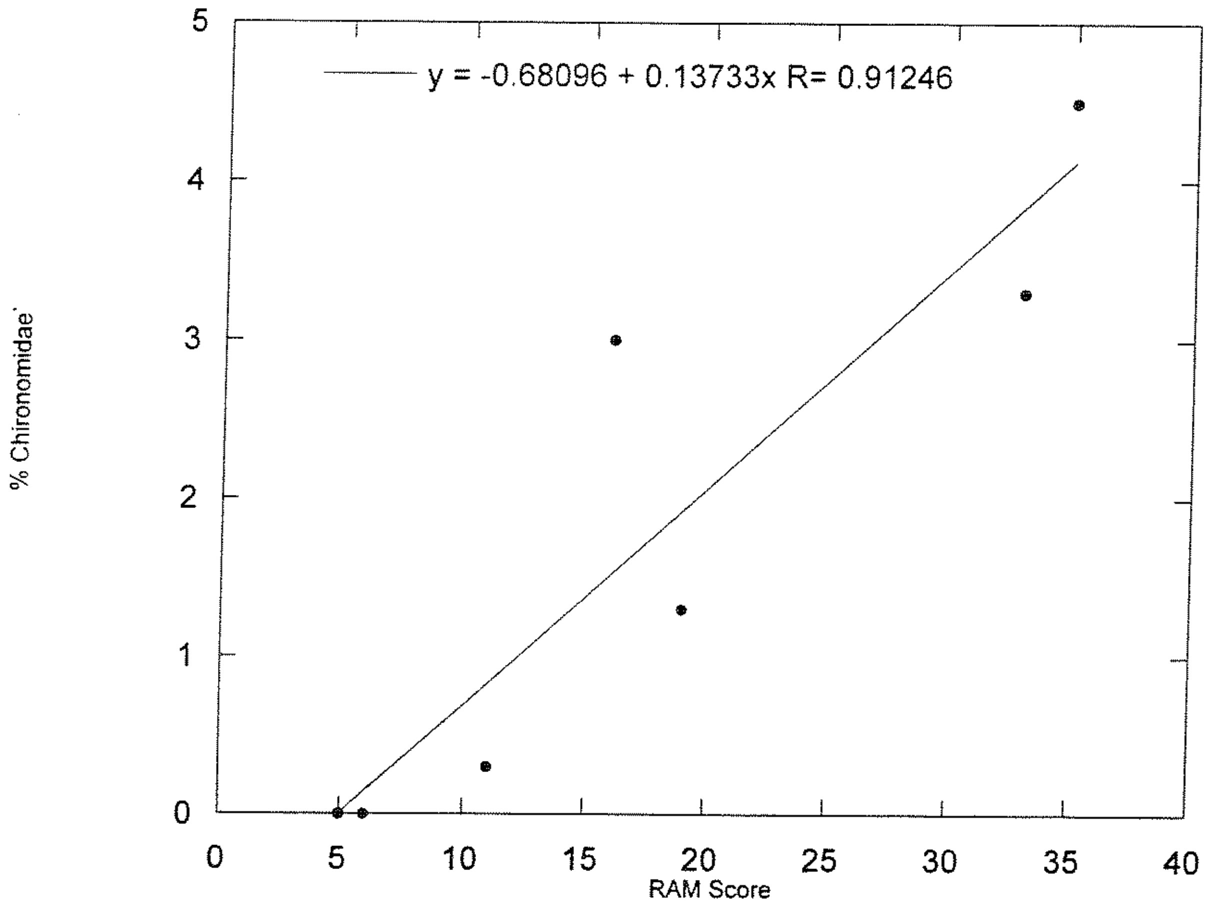


Figure 3-58: % Chironomidae in Relation to RAM in Emergent Wetlands (Spring)

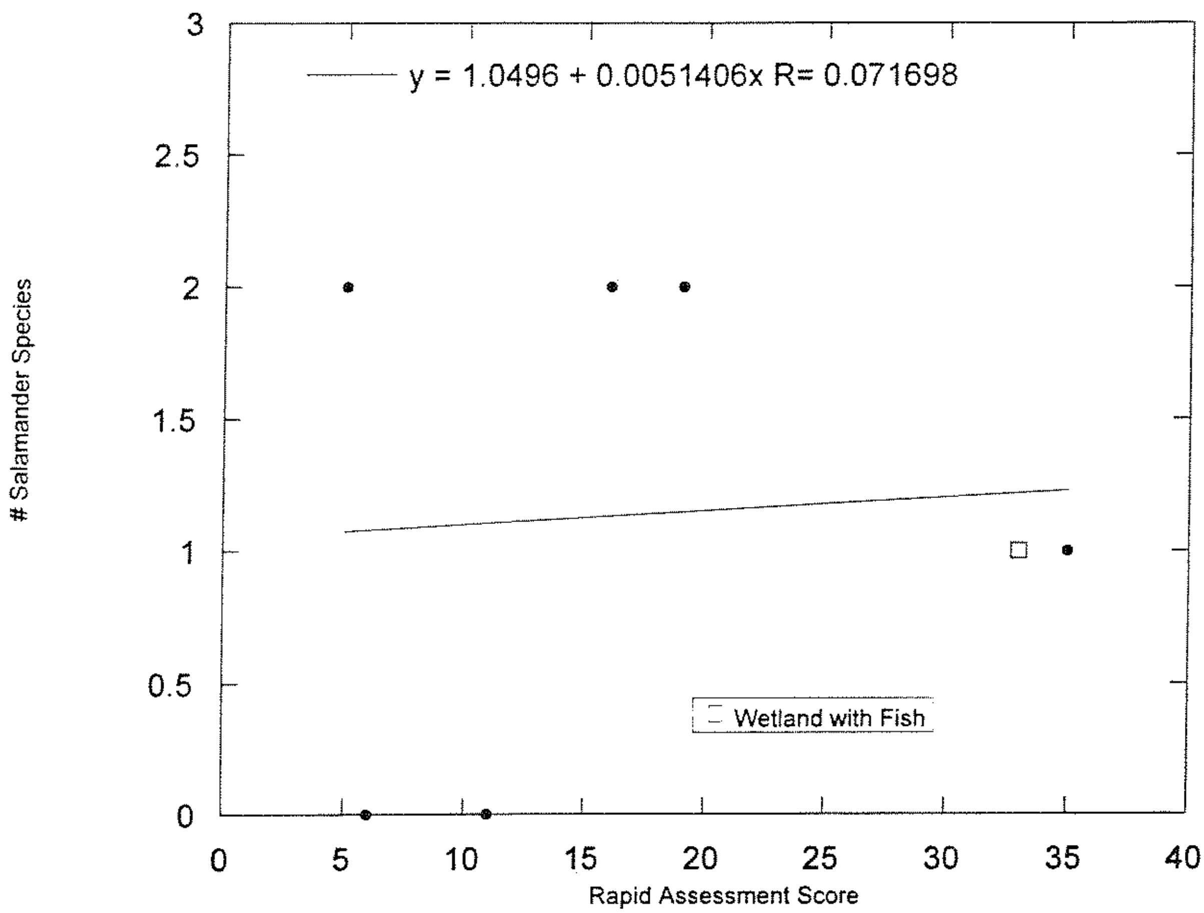


Figure 3-59: # Salamander Species in Relation to RAM in Emergent Wetlands

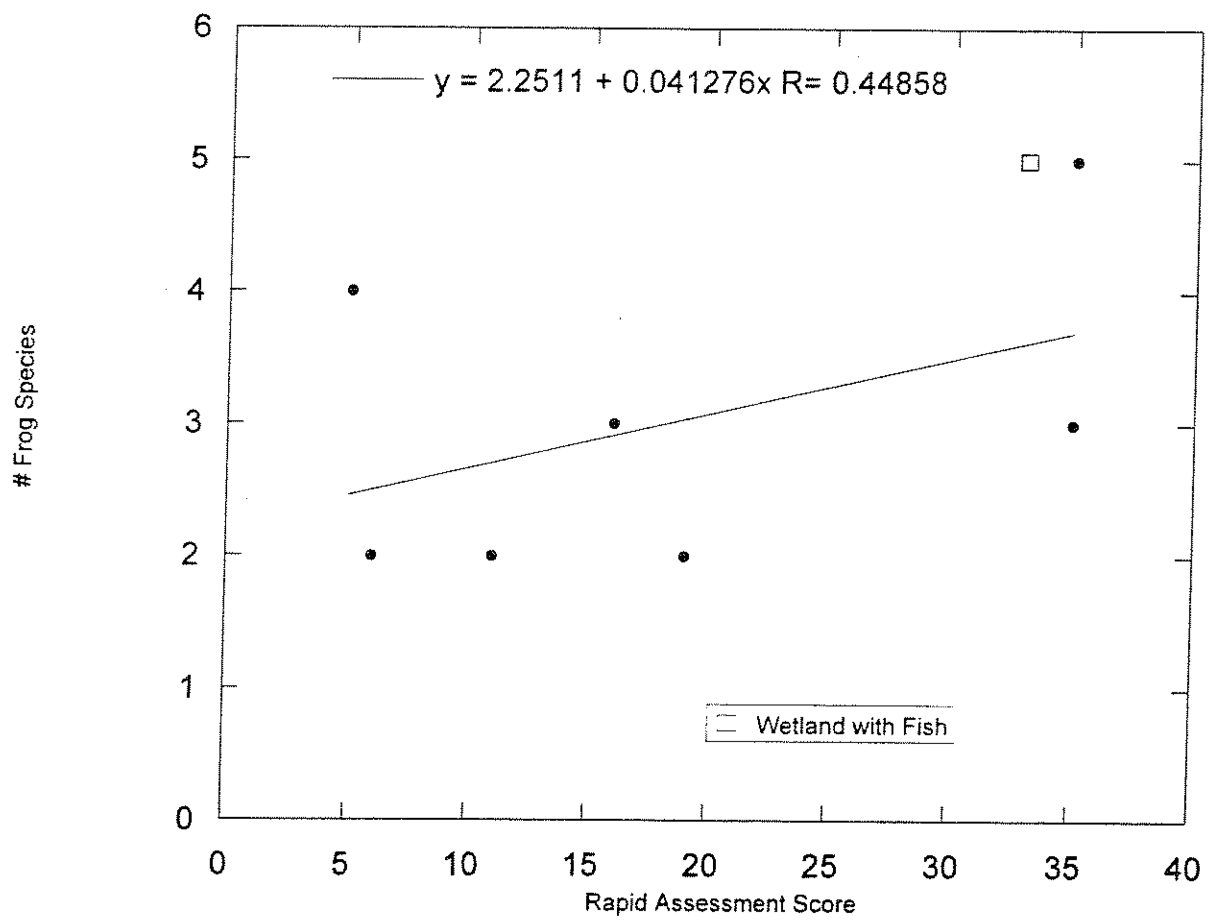


Figure 3-60: # Frog Species in Relation to RAM for Emergent Wetlands

CONCLUSIONS

The goal of this project was to begin development of a wetland biological monitoring and assessment program for the state of Ohio. A total of twenty one wetland reference sites were selected that varied considerably in their level of human impact. We performed a series of rapid functional assessment techniques as well as quantitative biological assessments at each of the wetland reference sites. Specific conclusions based on the results of this study include the following:

- Characteristics that lend themselves to the use of a rapid assessment method for differentiating wetland condition (and assigning antidegradation categories under the Ohio WWQS) include results expressed as a numerical score that can be compared directly to scores at other sites, as opposed to a set of "high", "medium" and "low" ratings for a list of wetland functions. Interpretation of a list of relative ranks for a set of functions would be difficult in a regulatory framework. For this reason, a rapid assessment method (The Ohio Wetland Assessment Method) was developed based on the Washington Wetland Rating System which assigns a numerical score to each wetland assessed.

- An *a priori* classification system was developed to rank wetlands according to the intensity of human impact (Karr and Chu 1997). Sites were assigned to one of 24 categories (relative levels of disturbance) based on the surrounding land use, buffer characteristics, and the extent of human modification to the hydrology of the site.

- FQAI scores were highly correlated with the relative level of wetland disturbance. FQAI scores increase as disturbance levels decrease providing an indication that the FQAI is providing a biological signal of the relative level of wetland degradation. This supports the use of the FQAI in a wetland biological monitoring and assessment program. Karr and Chu (1997) state that successful biological monitoring depends on demonstrating that an attribute changes consistently across a gradient of human impact. The FQAI shows this response.

- Repeat sampling in the summer and fall seasons revealed that, although FQAI scores did increases as visits to a site increased, there appeared to be no advantage to repeat sampling in terms of differentiating between sites. The relative ranking of sites did not change substantially with repeat site visits. Therefore, the FQAI sampling index period was set for between June 15 and August 31. This sampling window may be narrowed further with future investigations.

-In a landscape context, FQAI scores and species richness at the wetland reference sites tended to increase as the mean distance to nearest neighbor wetlands (of the same class) decreased. Thus, as the wetland becomes more isolated by human dominated land use, and as the distance to a source of propagules increases, both FQAI scores and the number of species at a given site decreases. A similar pattern was found relative to wetland density (number of wetlands per 1 km radius) in the area surrounding forested wetlands, i.e., as wetland density increases, FQAI scores increase. This relationship did not hold true for the emergent wetlands, in part due to the small sample size of emergent sites.

- FQAI scores also varied as a function of the type of buffer area surrounding the wetland. An unpaired t-test show that mean FQAI scores were significantly higher ($p = 0.001$) at sites with a forested/old field buffer area. Mean FQAI scores for sites with no buffer zone (agricultural use up to the wetland boundary) were nearly 50 percent lower. This has potentially important implications for land use management. If the provision of a small area of wetland buffer has such a pronounced effect on the quality of the wetland (as measured by the FQAI), then landscape level planning must take this into account.

- Funnel traps were the most effective way to sample the macroinvertebrate and amphibian community in wetlands. Funnel traps collected more taxa than other sampling methods and generated relative abundance data.

- Ten funnel traps spaced proportionally around the perimeter of the wetland for 24 hours were adequate to characterize the fauna. Using fifteen traps per wetland increased the number of taxa

collected by 12% while increasing laboratory processing time by 50%.

- The presence of potential predators such as fish and salamanders in the funnel traps did not appear to reduce the number of taxa or number of organisms collected by the traps. Large numbers of mature crayfish in the traps do reduce the number of taxa collected.

- The composition and abundance of the macroinvertebrate and amphibian community changes with sampling season. In metric development, samples from similar time periods must be used. The presence of specific seasonally distributed taxa may be a better indicator of sampling season than actual calendar date.

- The biological attributes we have examined respond to changes in Rapid Assessment Method score in emergent wetlands but not as consistently in forested wetlands. Forested wetland sites believed to represent a range of disturbance were selected. The lack of response may indicate that the range of disturbance were not as great as we believed in our population of forested wetlands. Difficulty was encountered during the site selection process to find forested wetland sites which fully spanned the range of disturbance from least-impacted to impaired. Forested depressional wetlands in Ohio tend to remain on the landscape because they were too wet to drain effectively for agricultural production. And although these sites have been impacted to some degree by human activities, most were left relatively undisturbed. Thus the range of condition of the forested sites was relatively narrow. This has implications for reference site selection in future studies.

Finally, this study elucidated some strengths and weaknesses of using vegetation community characteristics as indicators of wetland ecological integrity. These are summarized below (with thanks to input from the Biological Assessment of Wetlands Workgroup Plant Focus Group):

Advantages:

- Plants occur in most wetlands whether open water is present or not

- Most plants are immobile (exceptions include duckweeds and some submerged aquatics) and therefore are indicative of long-term, chronic stresses to a system
- Vegetation is a common focus of wetland evaluation techniques which provide a wealth of experience to draw upon
- Plant response to changing hydrology is reasonably predictable
- Many standardized sampling techniques exist
- Voucher specimens are easy to collect and store; many voucher specimens available in herbaria and can aid in identification
- Good floras/manuals are available for most parts of country
- Wetland vegetation autecology is being compiled for many species
- Different vegetation strata may have differential response to stressors

Disadvantages:

- Plant identification to species level often laborious and difficult, or restricted to narrow periods during the field seasons for some species; results may vary with personnel
- Woody species have long response time (i.e., resist change due to human-induced alterations)
- Plant communities highly variable in time and space; care must be taken to differentiate natural versus anthropogenic variability
- Some types of vegetation data, such as productivity and stem density, can be labor intensive to collect in the field
- Vegetation communities in some wetland classes (i.e. depressional) are in constant flux in response to long-term hydrologic cycles, which can make both classification and assessing response to impacts difficult
- Research/literature on plant species tolerances to disturbance (or changing environmental conditions) not well developed
- Different vegetation strata may have differential response to stressors

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