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AQUATIC MACROINVERTEBRATE COMMUNITIES OF CONSTRUCTED AND NATURAL FRESHWATER MARSHES IN CENTRAL FLORIDA

By

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A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
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AQUATIC MACROINVERTEBRATE COMMUNITIES OF CONSTRUCTED AND NATURAL FRESHWATER MARSHES IN CENTRAL FLORIDA

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David L. Evans

December, 1996

Chairperson: Dr. Thomas L. Crisman
Major Department: Environmental Engineering Sciences

Macroinvertebrate communities of 8 natural wetlands and 11 constructed wetlands of varying ages were sampled quarterly for 1 year. Shifts in macroinvertebrate assemblages occurring during constructed wetland development were estimated using data from constructed wetlands of varying ages. Macroinvertebrate assemblages of natural and constructed wetlands were compared and the efficacy of using macroinvertebrates as indicators of constructed and natural wetland structure and function was evaluated.

Natural wetlands were more similar to older constructed wetlands (>3 years old) than to newly constructed wetlands, providing evidence of directional changes over time. Parameters showing this pattern included macroinvertebrate community structure (Morisita's Similarity Index), structure of feeding guild, community macroindicators (total organism abundance, taxa richness, and diversity), degree of

siltation, and vegetation density. Based on a confidence interval analysis, macroinvertebrate abundance, species richness, and diversity constructed wetlands did not attain stability relative to natural wetlands within the age range studied (8 years).

Natural wetlands supported a higher number of semi-terrestrial invertebrate species than constructed wetlands probably because some of the natural wetlands studied went through a dry down phase during the dry season. I conclude that macroinvertebrates may provide a useful indication of hydrological function.

Sediments in constructed wetlands with gently sloping banks (<1.5 percent) were lower in silt content than constructed wetlands with steeper slopes. Sediments of older constructed wetlands tended to be lower in silt content than sediments of newly constructed wetlands, but results were not significant ($p=0.0601$, $R\text{-square}=0.76$).

Siltation may be reduced over time as constructed wetland banks are vegetated and become more stabilized. In spite of constraints imposed by high variability of macroinvertebrate populations, I conclude that a reduced sampling effort directed toward the collection of key subsets of the macroinvertebrate community can be sufficient to detect the effects of major influential factors (hydrology, vegetation, water quality). Even when the sampling effort is limited, semi-terrestrial dipteran species and gastropods may be particularly useful indicators of wetland function (hydrology and energy flow, respectively).

CHAPTER 1
INTRODUCTION

General Background

The social, aesthetic, and ecological benefits of wetlands have been described by numerous wetland scientists (Hook et al. 1988; Sharitz and Gibbons 1989; Kusler and Kentula 1990; Hammer 1992). In Florida, the phosphate industry has mined 5,400 hectares of wetlands, and approximately 2,700 hectares of wetlands have been constructed in an effort to replace lost resources (Armstrong 1991). There is general agreement among wetland scientists and the public that wetlands lost to mining activities must be replaced, but methods of wetland resource replacement, evaluation, and management are controversial due to differing opinion on goals for wetland function (Kentula et al. 1993).

A commonly used method of evaluation of mitigation efforts employs the comparison of constructed wetlands with natural "reference" wetlands. Easily measured parameters are often highly variable among reference wetlands, and selection of appropriate evaluation criteria is often controversial due to differing opinion regarding desired wetland function. Furthermore, it is generally recognized that there is difficulty in constructing wetlands that are identical in structure (static measurements, i.e., abundance, biomass) and function (nonstatic measurements, I.e., energy flow) to the wetlands they are intended to replace, and many investigators question the ability of constructed wetlands to consistently exhibit ecological functions characteristic of natural wetlands (Zedler 1990). Despite these difficulties, reference wetland comparisons provide a relative standard for measuring development of ecological function of constructed wetlands over time (Kentula et al. 1993).

Aquatic invertebrates traditionally have been used as indicators of water quality, particularly in streams and rivers (Gaufin and Tarzwell 1952). Their limited mobility, relatively long life span, and sensitivity to various types of environmental stresses place aquatic macroinvertebrates among the most useful biological indicators of long-term environmental conditions in aquatic systems (Weber 1973). Aquatic biologists have constructed indices that can be used to assess environmental conditions (e.g., trophic level, dissolved oxygen availability) in lakes (Thienemann 1913; Deevey 1941; Brundin 1949, 1956; Wiederholm 1976, Saether 1979; Crisman et al. 1986; Crisman and Crisman 1988) and lotic systems (Beck 1954; Wihlm 1970; Hilsenhoff 1988).

Values and functions of wetland systems have been addressed by many investigators (Leitch 1981; Gore 1983; Ewel and Odum 1984; Mitsch and Gosselink 1986; Hook et al. 1988), but few publications have considered wetland invertebrates in detail (Mitsch and Gosselink 1986; Ogaard et al. 1981). Much of the current knowledge of the distribution, abundance, and function of wetland insects has accumulated during the past 15 years (Connelly and Chesmore 1980; Mason and Standen 1983; Speight and Blackith 1983; Pehrsson 1984; Wrubleski 1984; Rosenberg and Danks 1987). Wetland invertebrate studies in Florida have been associated with wastewater impact studies (Brightman 1976; Haack 1984; Pezeshki 1987) and wetland reclamation by the phosphate industry (Evans and Sullivan 1988; Evans 1989; Erwin 1988; Streever and Crisman 1993; Streever et al. 1995). Macroinvertebrate studies are also being conducted by the Florida Game and Freshwater Fish Commission and by the South Florida Water Management District in wetlands associated with Lake Okeechobee (G. Warren, personal communication, 1994). Most of these studies suggest that macroinvertebrate models developed for lakes should not be applied to Florida wetlands because prevalent environmental conditions in wetlands are not typical in lakes.

Invertebrate-based models or other biotic indices that could be useful for the assessment of environmental conditions in wetland systems are lacking. There is a particular need for biotic indices that are designed for use in evaluating design criteria for constructed wetlands. Models and indices designed for streams, rivers, and lakes are inappropriate for use in wetlands because, due to differences in ecosystem structure, invertebrate species composition in wetlands differs from that in open water habitats (Brightman 1976; Haack 1984; Crisman and Meier 1986; Pezeshki 1987). Unique fauna are known to occur in vegetated littoral zones (Wetzel 1983; Hudson et al. 1996). Current models largely ignore species that occur in shallow vegetated habitats.

Most wetland research historically has focused on economically important fauna such as waterfowl, mammals, and fish. Wetland vegetation has been studied extensively as it relates to wetland boundaries, hydroperiod, fish production, and overall wetland function. Although research regarding aquatic invertebrates in natural wetlands is increasing, knowledge of ecological factors that control invertebrate populations in natural wetlands is limited. A few aquatic invertebrate monitoring studies have been conducted in constructed and natural wetlands of central Florida (Evans and Sullivan 1984, 1986a, 1986b, 1987, 1988; Erwin 1983, 1984, 1985, 1986, 1987, 1988), but understanding of factors controlling development of aquatic invertebrate communities in constructed wetlands remains poor.

Successful quantitative analysis of benthic macroinvertebrate populations is limited by their intermittent temporal distribution. For example, populations are known to vary seasonally (Sweeney 1984). However, it has been suggested that due to warmer temperatures in Florida, many macroinvertebrate species exhibit longer growing seasons, as compared to more temperate latitudes (Sweeney 1984). Thus, in Florida, the limitations to quantitative analysis imposed by short-lived pulses in population densities are somewhat alleviated. However, seasonal sampling is desired in order to more fully document the abundance of macroinvertebrate communities.

Spatial distribution represents another constraint for quantitative analysis of macrofauna populations. Spatial distribution of individuals is often clumped (Downing 1984; Streever et al. 1995). This makes it more difficult to estimate population densities accurately since a much larger sample size is required (Elliott 1977). Streever and Portier (1994) analyzed chironomid data from central Florida wetlands and found that 7 core samples from each of 5 stations in 10 natural and 10 created wetlands are required to provide even modest statistical power.

Kentula et al. (1993) suggested that older constructed sites provide a useful reference for evaluating the development of newly constructed sites. There is some evidence that, given sufficient time, constructed wetlands develop structure and function similar to that of natural wetlands. Within 3 years after initial inundation, most constructed wetlands in central Florida develop plant cover approaching densities observed in natural wetlands (Evans and Sullivan 1987; Erwin 1988; Evans 1989).

In a study of some of the same wetlands included in the current study, Kiefer (1991) reported that constructed marshes in central Florida attained water chemistry similar to that of natural marshes within 4 to 6 years after construction. He also concluded that nutrient partitioning among macrophytes, detritus, and the water column reached stability approximately 4 years after construction. However, it is not known whether benthic invertebrate assemblages at that stage of wetland development are similar to those of natural wetlands.

Of the 102 constructed wetlands being tracked by the phosphate industry in Florida, approximately 56 percent include freshwater marsh systems (Armstrong 1991). The general purpose of the current study was to observe the structure and function of natural and constructed freshwater marshes in order to document constructed wetland development and to determine whether their characteristics ever approximate those of natural marshes.

This study was designed to

1. document shifts in macroinvertebrate assemblages during the ecological development of constructed wetlands by simultaneously sampling constructed wetlands of varying age,

2. compare macroinvertebrate assemblages of constructed and natural wetlands, and

3. evaluate the usefulness of various indices associated with benthic macroinvertebrate assemblages in

comparing structure and function of constructed and natural wetlands.

Hypothesis

A major objective in constructing wetlands is to create systems with ecological functions that persist and achieve relative stability. Plant and animal communities may change over time, but wetland functions persist. With this objective in mind, it is appropriate to ask the question: Do aquatic invertebrate communities of newly constructed wetlands eventually become similar to those of natural wetlands with respect to abundance, species richness, and diversity? If so, how long does it take communities and/or individual populations to attain similarity and what paths do these populations take as they approach stability relative to natural wetlands?

This study was designed to investigate these questions using the following criteria:

Colonization Sequence of Macroinvertebrate Communities

Establishment of Macroinvertebrate Feeding Guilds

Wetland Development and Similarity of Macroinvertebrate Community Structure

Relationships between Wetland Design and Macroinvertebrates

Ecological Development and Macroinvertebrate Community Variability

Establishment of Vegetation Communities

The expected behavior of these variables and rationale for related hypotheses are summarized below.

Most scientists now agree that wetlands tend to be pulsed systems controlled by both allogenic (water level fluctuation, fire) and autogenic processes (light competition, soil development). Odum (1971) described the concept of pulsed stability in relation to conditions in the Everglades. Other examples include tidal marshes, pocosins, hardwood swamps, cypress domes, prairie potholes, and other types of freshwater marshes (Mitsch and Gosselink 1986). Lewin (1986) discussed evidence supporting the notion that such fluctuations or changes in environmental conditions can act to stabilize ecological systems, leading to a state of relative equilibrium.

Ulanowicz (1980) described the biological aspects of ecosystem development from a rudimentary state (i.e., bare substrate) as being analogous to a biological island which has been exposed to severe trauma, leaving only a small number of species. The initial response of the biological community is to maximize energy flow through the system (throughput) as opportunistic species make use of the available resources and populations increase rapidly in size. Complexity of the community increases more slowly as new species colonize the system. Competition and mutualism become more prevalent as utilization of available energy sources becomes saturated. As the number of species increases and available energy sources are more finely partitioned, the frequency that rare species become extinct due to environmental perturbations increases until relative equilibrium is reached.

Capacity is defined as the sum of ascendancy, respiration (dissipation), energy export (tribute), and redundancy (residual). Ulanowicz uses the term "ascendancy" to describe ecosystem growth and development during ecosystem development. Throughput being constant, ascendancy increases with positive feedback loops and decreases with internalization, specialization, and the number of system compartments. Ascendancy can be empirically defined as system capacity, less export, respiration, and redundancy. Given sufficient time, a self-organizing system behaves so as to optimize its ascendancy, subject to hierarchical, thermodynamic, and environmental constraints. Overhead is defined as the summation of the latter three terms (export, respiration, and redundancy). Overhead is relatively unrestricted in recently disturbed systems as opportunistic species expand rapidly to make use of available energy resources (Ulanowicz 1980).

The disturbed biological island described by Ulanowicz is not unlike conditions existing in a newly created wetland. Although many of the measures used in the current study are not directly applicable to thermodynamics theory, Ulanowicz's hypothesis regarding the development of natural communities after a disturbance provides a holistic theoretical framework for the current hypotheses which emphasize macroinvertebrate community development in newly constructed marshes.

Sequence of Colonization of Macroinvertebrate Communities

One of the objectives of the current study was to document the sequence of macrofaunal colonization of newly created wetland habitat and to determine which major taxonomic groups tend to dominate the fauna during early wetland development. The following factors have a major influence on success of aquatic invertebrate colonization:

Vagility (ability to migrate)
Reproductive strategy
Habitat and food resources
Degree of competition
Degree of predation

Particularly vagile organisms such as winged aquatic insects are able to colonize new aquatic habitats rapidly (Sheldon 1984). The following aquatic insect groups are reported to undergo dispersal flights:

Chironomids (Johnson 1969; Cheng and Birch 1977)
Trichopterans (Svensson 1974)
Ephemeroptera (Burks 1953)
Odonates (Corbet 1980)
Hemipterans (Popham 1964)
Coleopterans (Zalom et al. 1979, 1980)

These insects may be the first organisms to enter a new wetland due to their ability to fly (Mackay 1984; Wiggins et al. 1980; Corbet 1980). Other organisms such as crustaceans and gastropods depend on passive dispersal mechanisms to colonize a new wetland (Wiggins et al. 1980). Their introduction is related to conditions of the dispersal vector (e.g., waterfowl, wading birds). Organisms relying on passive dispersal may be introduced to newly created wetlands more slowly than those capable of dispersal flights (Danell and Sjoberg 1982).

Organisms with very short life cycles such as oligochaetes (Brinkhurst and Jamieson 1971) and chironomids (Oliver 1971) may dominate during early stages of succession because of their ability to reproduce rapidly. Organisms exhibiting longer life cycles are hypothesized to take longer to attain equilibrium. For example, *Chaoborus*, naidid oligochaetes, and chironomids were the first lentic organisms to colonize a new reservoir during the first year after impoundment (Bass 1992). Trichopterans and amphipods were not collected until the second year after impoundment.

Groups that collect and feed on fine particulate organic matter have an immediate food resource, whereas active predators may be food limited during initial wetland development. This suggests that chironomids and oligochaetes should dominate benthic communities during early succession due to their vagility, abundant food resources and their ability to reproduce rapidly. Mayfly, caddisfly, and odonate populations may take longer to reach stability because they have longer life cycles. In addition, hemipterans and coleopterans could exhibit relatively low population levels during early wetland development due to food limitation during early succession in spite of their ability to rapidly colonize new wetlands.

Development of Vegetation Communities

Autotrophic communities are included in the overall hypothesis because they can have a large influence on macroinvertebrate community development in that they provide food resources and habitat. Algal blooms often develop shortly after initial inundation of previously unflooded soils due to the release of inorganic nutrients (Ponnamperuma 1972; Hossner and Baker 1988). Newly constructed wetlands can support relatively thick algal growth and high inorganic nutrient levels (Evans and Sullivan 1984). Early algal blooms are hypothesized to provide an abundant food supply for macroinvertebrate species colonizing newly constructed wetlands, leading to a rapid peak in macroinvertebrate abundance.

As newly constructed wetlands age, environmental conditions may shift from those similar to a shallow eutrophic lake to conditions more typical of a freshwater emergent marsh. During this process, nutrients in the water column decrease as they are taken up by plants and sequestered in the sediments (Kiefer 1991). The autotrophic community shifts from one dominated by algae to a community dominated by rooted macrophytes because after macrophytes are introduced, they can outcompete algae for light.

Although living macrophytes generally are not an available macroinvertebrate food resource, decaying plant material and the bacteria colonizing the material can be important energy sources for macroinvertebrates (Wetzel 1983). Direct and indirect relationships between vascular plants and macroinvertebrates encompass factors such as physical surface area for attachment (Krecker 1939; Gerrish and Bristow 1979; Brown and Lodge 1993), provision of epiphytic and detrital food resources (Cattaneo 1983; Smock and Stoneburner 1980), and protection from predation (Thorp 1988; Suthers and Gee 1986). Macrophytes can also affect physical and chemical aspects of water column and sediments (Beckett et al. 1992; Murkin et al. 1983; Chen and Barko 1988). Based on the above-mentioned studies, macrophyte development in constructed wetlands is expected to have a significant influence on aquatic macroinvertebrate community structure. Constructed wetlands supporting dense macrophyte cover are hypothesized to support greater macroinvertebrate abundance and species richness than newly constructed wetlands that are sparsely vegetated.

Development of Aquatic Macroinvertebrate Feeding Guilds

Aquatic insects have been assigned to the following trophic functional groups by Merritt and Cummins (1983):

Collectors-gatherers
Collector-filterers
Shredders
Scrapers
Predator-piercers
Predator-engulfers

Food resources are hypothesized to have an influence on the abundance of macroinvertebrate feeding guilds. As previously discussed, the quantity of various types of foods may change as a created wetland develops. Initially, fine particulate organic matter may be the only abundant resource. Coarse organic material may be present in created wetlands that are lined with mulch. Within weeks or months after initial inundation, phytoplankton and periphyton populations may become another important food resource, but as nutrients are bound up in macrophytes and sediments, algal populations may decline and detritus becomes increasingly available in the sediments. After invertebrate populations have become established, predators may also have an abundant food supply.

Based on the scenario outlined above, consumers of fine particulate organic matter (collector-gatherers) have an immediate food resource and are expected to dominate initially. Shredders may also have an immediate food resource in wetlands that are mulched. Within weeks to months, collector-filterers could proliferate as phytoplankton populations become established. Scrapers may take longer to become established as rooted vascular plant communities develop and epiphytic and epilithic algal populations are established. Vascular plants provide important substrates for periphyton growth, a primary food source of scrapers (Cattaneo and Kalff 1980; Cattaneo 1983). Eventually scrapers and collector-filterers could decline as algal nutrients become limited. Predator populations are expected to be the last trophic group to reach peak population levels due to initial food limitation and relatively long life cycles (odonates, beetles, hemipterans, decapods). Therefore, the benthic community trophic structure is hypothesized to be strongly dominated by deposit-feeding organisms and filtering organisms during early stages of succession, whereas predators are expected to become more prevalent as created wetlands age. Shredders are hypothesized to be relatively depauperate during early wetland development and to increase in abundance as a dense cover of rooted macrophytes develops.

Development and Similarity of Macroinvertebrate Community Structure

Benthic invertebrate communities of natural wetlands should be more similar to those of older constructed wetlands than to those of newly constructed wetlands, if constructed wetlands go through predictable stages of succession similar to "old field" succession. Hypothetically, as constructed wetlands age, their macroinvertebrate communities become increasingly similar to those of natural wetlands.

This hypothesis is based on the assumption that shifts in the macroinvertbrate communities will follow autogenically driven shifts in environmental conditions. As a rooted macrophyte community is established, peat accumulation accelerates (Mitsch and Gosselink 1986). The living plants and the peat provide new and increasingly complex invertebrate habitat and a food base for detritivores (including shredders). Peat accumulation ultimately brings shallower water depths, more characteristic of the natural marshes studied. This directional shift in vegetation communities (the shift from algae to macrophytes) is hypothesized to cause macroinvertebrate communities to become increasingly similar to natural communities. In many of the constructed wetlands studied, mulching and macrophyte planting were used to enhance the rate of succession.

Relationships between Wetland Design and Macroinvertebrates

The design of constructed wetland morphometry can influence the rate of ecological development. Historically, emphasis has been placed on wetland bank elevations (slope) and water depth because these characteristics influence bank stabilization and vegetation zonation (Hammer 1992). Banks of wetlands that are contoured with gentle slopes and shallow water depths are less likely to erode and can stabilize relatively quickly (Kruczynski 1990; Broome 1990). All other factors being equal, the rate of siltation due to surface water runoff is enhanced with increasing bank slope because steep banks are less stable. A high rate of siltation can have a negative influence on macroinvertebrate communities by interfering with feeding and respiratory mechanisms (Minshall 1984); therefore, constructed wetlands with relatively steep slopes are hypothesized to support smaller macroinvertebrate populations and a lower number of species than wetlands with gently sloping banks.

Development and Macroinvertebrate Community Variability

Abiotic and biotic parameters can change rapidly in newly constructed wetlands (Evans and Sullivan 1988; Hammer 1992). Considering the rapidly changing environmental conditions characteristic of newly constructed marshes and the stochastic nature of chance colonization, benthic invertebrate populations are hypothesized to respond in a similar manner, resulting in greater variability in communities of constructed wetlands than might occur in natural wetlands.

Potential Application of this Work

Invertebrate communities are known to respond either directly or indirectly to a broad spectrum of environmental factors, including sediment quality (de March 1976), hydrology (Cranston, Oliver, and Saether 1983), algae as an energy source (Porter 1977), rooted plant communities (Beckett et al. 1992), inorganic nutrients, and dissolved oxygen (Wetzel 1983). On the other hand, a majority of macroinvertebrate species tend to be opportunistic, in that they are able to disperse rapidly, are adapted to rapid population growth, and can tolerate a wide range of environmental conditions. Part of the focus of this study is to provide evidence of influential factors and the resulting patterns of organism distribution. If macroinvertebrate communities exhibit measurable, predictable patterns as constructed wetlands age, they may provide an integral tool for monitoring the ecological development of constructed wetlands. Conversely, if evidence suggests that distribution of macroinvertebrates is primarily stochastic in nature, or if our ability to measure distribution patterns is precluded by other constraints, such as the lack of sufficient time or financial support to make adequate measurements, they may be of little use in the evaluation of constructed wetlands.

CHAPTER 2
METHODS

Site Selection

Benthic macroinvertebrates were sampled quarterly for a 1-year period in 8 natural and 11 constructed wetlands located in south central Florida. All marshes sampled in this study were palustrine emergent marshes occurring in or near the Central-Pebble Phosphate District. The wetlands selected for this study were classified as follows:

1. Natural marshes,

2. Constructed marshes--deep (>40 cm) with steep sloping banks (>1.5 percent), and

3. Constructed marshes--shallow (<40 cm) with gently sloping banks (<1.5 percent).

Table 1 summarizes information regarding the construction time for the 11 constructed wetlands. Although constructed wetlands become inundated shortly after contouring, planting often takes place one or 2 years after grading. As recommended by the Florida Department of Environmental Protection, the date planting began was considered to be time zero. Wetland ages were assigned according to the amount of time elapsed between the planting date and the initial date of sample collection.

Table 1. Constructed Marshes Selected for Study

Wetland Name	Mine Name	Age* (Years)	Grading Date	Planting Date	Constr. Type***
P90**	Phosphoria	0.2	4/89	3/90	S
HP90**	Hookers Prairie	0.5	1989	1/90	D
G90	Gardinier	1.5	1989	1989	S
CS88	Clear Springs	2.0	1988	1988	D
CS86	Clear Springs	4.0	1985	1986	D
FG86	Fort Green	4.5	1986	1986	S
CS85	Clear Springs	6.0	1984	1984	D
CS84	Clear Springs	6.2	1983	1984	S
CS83	Clear Springs	7.0	1981	1984	D
FG82	Fort Green	8.0	1982	1982	D
G81	Gardinier	8.0	1981	1981?	D

* Wetland age as of the initial benthic sampling event.
** Sampled for approximately 2 years.
*** D--Deep, steep slope. S--Shallow, gradual slope.

In the present study constructed wetlands were classified according to age to allow comparisons between newly established sites and older sites. The following wetland classes were based on the ancillary data discussed above (Evans and Sullivan 1988; Erwin 1988; Kiefer 1991).

1. Newly constructed wetlands (< 4 years old).
2. Older constructed wetlands ($\geq$ 4 years old).

Newly constructed and older constructed wetlands, as defined above, will be referenced in this document as "NC" and "OC" wetlands, respectively. Natural wetlands are referenced as "N." The term "constructed wetland" refers to a reclaimed wetland of any age.

Field Sampling Procedures

Core Samples

Macrobenthos were sampled quarterly for a 1-year period at two sampling locations in each wetland. Each sampling location was approximately 16 square meters in size. Five core samples were collected at random locations within each sampling area with a 2-inch ID PVC core sampler. This sampling method was selective in that only organisms associated with the sediment-water interface were collected. Organisms associated with aquatic vegetation were eliminated. Upon collection, each core sample was rinsed in a U.S. Standard No. 30 mesh bucket sieve (0.595 mm mesh) to remove fine silt and sand before being placed in labeled sample containers. Each core was placed in a separate container and analyzed separately. The samples were stained with Rose Bengal dye and preserved in 80 percent ethanol.

Sweep Net Samples

Two sweep net samples were collected randomly within each sampling area (two areas per wetland). Each sample consisted of five sweeps using a U.S. Standard No. 30 mesh dip net (0.595 mm mesh). Each sweep was taken by pulling the sweep net through approximately 1.5 meters of vegetation. An effort was made to include sediments within each sweep, since the purpose of using this sampling method was to cover a broad range of habitats. Each 5-sweep sample was placed in a separate container and analyzed separately. Samples were stained with Rose Bengal dye and preserved in 80 percent ethanol.

Laboratory Procedures

Macroinvertebrate Sample Analysis

All samples were rinsed in a U.S. Standard No. 30 mesh sieve (0.595 mm mesh) and placed in a white enamel pan partially filled with water. Organisms were sorted from detritus and coarse sediments and placed in vials filled with 80 percent ethanol. Vials were labeled internally using high rag content paper. Label information included sample location, replicate number, and date of collection.

Samples containing more than 400 organisms were subsampled by splitting the sample into quarters. All organisms were counted and identified in samples containing less than 400 organisms.

Organisms were identified by using either a stereoscopic dissecting scope (7x to 80x) or a binocular compound light microscope (40x to 1000x). Chironomidae, Oligochaeta, and other taxonomic groups that were difficult to identify accurately under low power were mounted on slides for more complete identification. The CMC-10 mounting medium, which contains a clearing agent, was used for slide mounts. Taxonomic references are listed in Table 2.

Sediment Analysis

Sediments were analyzed for silt, clay, sand, and organic content as reported by Kiefer (1991). Sediments were dried at 100 degrees Centigrade for 24 hours. Percent organic content was determined by incinerating dry sediments at 550 degrees Centigrade in a muffle furnace. Percent sand, silt and clay were calculated using ASTM method D 422-63 (ASTM 1985).

Statistical Analyses

Indices

Statistical analyses included organism abundance, species richness (number of taxa), equitability (Pielou 1966), Shannon-Weiner species diversity index (Shannon and Weaver 1949), and Morisita's Similarity Index (Morisita 1959). The latter three statistics warrant further explanation. Means for NC, OC, and N wetlands were compared

Table 2. Taxonomic References Used for the Identification of Aquatic Macroinvertebrates

Reference	Taxonomic Group
Berner (1950)	Ephemeroptera
Herring (1950a, 1950b, 1951a, 1951b	Hemiptera
Young (1954)	Coleoptera
Needham and Westfall (1955)	Odonata (Anisoptera)
Usinger (1956)	Aquatic Insects
Beck (1962, 1976)	Chironomidae
Roback (1977, 1978, 1980, 1981, 1982, and 1985)	Chironomidae
Saether (1975, 1977)	Chironomidae
Brinkhurst and Jamieson (1971)	Oligochaeta
Brown (1972)	Coleoptera
Holsinger (1972)	Amphipoda
Edmunds et al. (1976)	Ephemeroptera
Williams (1976)	Isopoda
Wiggins (1977)	Trichoptera
Pennak (1978, 1989)	Freshwater Invertebrates
Hiltunen and Klemm (1980)	Oligochaeta (Naididae)
Brigham, Brigham, and Gnilka (1982)	Insecta and Oligochaeta
Fittkau and Roback (1983)	Diptera (Tanypodinae)
Cranston, Oliver, and Saether (1983)	Diptera Orthocladiinae)
Pinder and Reiss (1983)	Diptera (Chironominae)
Klemm (1985)	Oligochaeta and Hirudinea
Brinkhurst (1986)	Oligochaeta
Epler (1992)	Diptera (Chironomidae)
Berner and Pescador (1988)	Ephemeroptera

using the nonparametric Kruskal-Wallis test and a pair-wise Wilcoxon test (SAS 1988).

Equitability. The equation for equitability (Pielou 1966) is as follows:

$$e = \frac{\overline{H}}{\log_2 S}$$

where $\overline{H}$ is the Shannon-Weiner index value and

S is the total number of taxa.

Equitability is a measure of the evenness of distribution (abundance) among the various species sampled. Highest equitability values are achieved when each species contains the same number of individuals. Lower values occur when species abundances vary widely.

Shannon-Weiner diversity. Shannon-Weiner species diversity index (Shannon and Weaver 1949) is influenced by both species richness and equitability. The equation is as follows:

$$\overline{H} = -\sum \left(\frac{n_i}{N}\right) \log_2 \left(\frac{n_i}{N}\right)$$

where n_i is the abundance of each species and

N is total number of organisms.

Thus, it increases with the number of species present and the degree of evenness in abundance among the species. This index was used as a means of comparing constructed wetlands to natural wetlands.

Morisita's similarity index. Morisita's (1959) similarity index measures the similarity between two sets of species-abundance data. The more species in common between the two sets, the higher the index value. Likewise, increasing similarity in the abundance of overlapping species has a positive influence on the index value. The equation is as follows:

$$S_{ik} = \frac{2 \sum_{j=1}^{s} [x_{ij} \; x_{kj}]}{X_i \; X_k \; (A_i + A_k)}$$

$$A_i = \sum_{j=1}^{s} [x_{ij}(x_{ij-1})] \; / \; X_i(X_i - 1)$$

$$A_k = \sum_{j=1}^{s} [x_{kj}(x_{kj} - 1)] \; / \; X_k(X_k - 1)$$

$$X_i = \sum_{j=1}^{s} x_{ij} \qquad \text{and} \qquad X_k = \sum_{j=1}^{s} x_{kj}$$

where x_{ij} is the number of individuals in the jth taxon within sample i and

x_{kj} is the number of individuals in the jth taxon within sample k.

Morisita's similarity index was used to determine the degree of similarity between benthic communities of natural wetlands and constructed wetlands. The P90 and HP90 wetlands were monitored for a 2-year period. Second-year values were analyzed, while first-year data were omitted to avoid the effect of wetland self-comparisons. Omissions were made because the purpose of the similarity analysis was to compare distinct wetlands of varying age, not changes within a single wetland over time (i.e., from one year to the next). Morisita's values were based on mean annual abundance values for each species. Mean Morisita's index values were calculated for the following comparisons:

Constructed vs. Constructed wetlands
Natural vs. Constructed wetlands
Natural vs. Natural wetlands

Means were compared using Analysis of Variance (ANOVA), and Wilcoxon ranked sum test was used as a double check, first with the above treatments and then with pair-wise treatments. Duncan's multiple range test was used to detect any differences among means for each treatment.

Mean index values were calculated for a second group of comparisons to determine whether OC wetlands were significantly more similar to N wetlands than NC wetlands. These comparisons included

NC vs. NC wetlands
NC vs. OC wetlands

NC vs. N wetlands

OC vs. OC wetlands

OC vs. N wetlands

Duncan's multiple range test was, again used to detect differences between means.

Coefficient of Variation Analysis

A coefficient of variation (v) referenced by Fairchild (1981) was used to estimate variation in abundance of species in core samples within each wetland type (N, NC, and OC). Coefficient values were calculated using the following equation:

$$v = (s/x)100$$

where s is standard deviation and

x is the pooled mean organism abundance within a given wetland type.

These values were used as a measure of relative variation in organism abundance. A high value indicates relatively high variation in abundance. Only taxa known to be associated with wetland sediments were considered, because these were the only organisms collected quantitatively using the described core sampling technique. The coefficient of variation analysis was not performed on sweep samples.

Coefficients of variation within natural and constructed wetlands were calculated separately for each species. The Wilcoxon signed rank test was used to compare coefficients of natural and constructed wetlands. Coefficient comparisons were made using only the 31 species occurring in both natural and constructed wetlands.

Confidence Interval Analysis

A confidence interval analysis was used to measure the degree to which macroinvertebrate communities of attain equilibrium relative to communities of natural wetlands. Confidence intervals of 95 percent were calculated for abundance, taxa richness, and Shannon-Weiner species diversity using core and sweep net data from natural wetlands. Abundance data were transformed to log(x+1) prior to calculation of intervals. Calculated intervals were then back-transformed to obtain abundance interval endpoints. Mean abundance, taxa richness, and Shannon-Weiner diversity values for the constructed wetlands were then compared to the natural wetland confidence intervals.

Statistical Comparisons of Core and Sweep Net Data

Statistical comparisons of core and sweep net data were based on total organism abundance, total taxa richness, and Shannon-Weiner species diversity. A log transformation (log (x+1)) was used for abundance data to better meet the assumption of variance homogeneity. Based on residual plots, taxa richness and Shannon-Weiner index values met the assumption of constant variance for ANOVA. The following factors were also considered: type of wetland (constructed or natural, constructed wetland age class, construction type), individual wetland site, and season (fall/winter or spring/summer). The fall/winter and spring/summer sampling periods were chosen to represent dry and wet season conditions, respectively.

Total organism abundance, taxa richness, and diversity were compared using a F-test model designed with a split plot in which the whole plot factor was wetland class and subplot factors were collection method and season. The variable class had five values:

1. natural wetlands,
2. constructed wetlands less than 3 years of age with steep slopes (>1.5 percent),
3. constructed wetlands less than 3 years old with gentle slopes (<1.5 percent),
4. constructed wetlands more than 3 years old with steep slopes, and
5. constructed wetlands more than 3 years old with gentle slopes.

These values have the structure of a 2 by 2 factorial plus the natural sites.

Abundance and taxa richness within major taxonomic groups were compared using a similar split plot design in which the whole plot and subplot factors were wetland class and collection method, respectively. The variable class was assigned the same five values described above. Abundance data were transformed to log (x+1) to help meet the assumption of constant variance. Based on residual plots, taxa richness values met the assumption of constant variance for ANOVA. Nemertea, Enchytraeidae, Trombidiformes, and Pelecypoda were excluded from the abundance analysis due to their rarity. In addition to the four taxonomic groups mentioned above, Planariidae, Tubificidae, Isopoda, Amphipoda, Muscidae, Stratiomyidae, and Trichoptera were eliminated from the taxa richness analysis due to the extremely low number of taxa within each group.

A similar split plot analysis was used to analyze differences in the abundance of macroinvertebrate feeding guilds. It was not necessary to screen the data after grouping organisms into feeding guilds. Subplot factors were wetland class and collection method, respectively. The variable class was assigned the same five values described above. Data were transformed to log (x+1) to better meet the assumption of variance homogeneity.

Statistical Analysis of Relationships between Vegetation Cover and Macroinvertebrate Communities

A stepwise regression analysis of log (x+1) transformed total abundance, taxa richness, Shannon-Weiner species diversity, and log (x+1) abundance of individual taxa was performed. Total abundance and individual taxa abundance were transformed to better meet the assumption of constant variance. Stepwise regression is a technique that selects the explanatory (independent) variable that has the strongest linear relationship with the response and includes that variable in the model first. Subsequently, the variable with the next strongest relationship is included. After appending the model, if one of the variables is no longer significant, it is dropped from the model. The significance threshold for a variable to remain in the model was set at $p<0.10$.

The independent variables that were tested were percent cover of plant components (filamentous algae, submergent, floating, and emergent plants) and total percent plant cover. Construction type (slope) and wetland age were also included for constructed sites. The regressions were performed separately for the two wetland types (natural and constructed), two collection methods, and the two seasons. Due to small sample size, there was insufficient power to test for the interaction between independent variables. Individual taxa included in the analysis were collected from more than 50 percent of the wetlands and were represented by at least two distinct nonzero abundance values.

Statistical Analysis of Relationships between Sediment Quality and Macroinvertebrate Communities

Statistical analysis of relationships between sand, silt, clay, and organic content of sediments and macroinvertebrate abundance, species richness, and Shannon-Weiner diversity followed methods used for testing relationships with vegetation presented in the previous section. A stepwise regression analysis of dependent variables including log (x+1) transformed total abundance, taxa richness, Shannon-Weiner species diversity, and log (x+1) abundance of individual taxa was performed. Total abundance and individual taxa abundance were transformed to better meet the assumption of constant variance.

Independent variables included percent sand, clay, silt, and organic content of sediments. Construction type (slope) and wetland age were also included for constructed sites. The regressions were performed separately for the two wetland types (natural and constructed), two collection methods, and the two seasons. Due to small sample size, there was insufficient power to test for the interaction between independent variables. Individual taxa included in the analysis were collected from more than 50 percent of the wetlands and were represented by at least two distinct nonzero abundance values.

CHAPTER 3
RESULTS AND DISCUSSION

Comparison of Natural and Constructed Wetlands--Core Data

The following discussion compares macroinvertebrate community structure and function in natural and constructed wetlands. Some comparisons are also made between newly constructed sites (<4 yrs) and older (≥4 yrs) constructed wetlands (Tables B-3 and B-4). Abundance value ranges and means for constructed (NC and OC) and natural (N) wetlands are summarized for core and sweep net data in Tables 3 and 4, respectively.

Abundance

Within newly constructed wetlands, organism abundance in core samples was highly variable and without apparent trend. These wetlands supported macroinvertebrate population levels slightly lower than levels typical of OC and N wetlands. Mean annual macroinvertebrate abundances in NC, OC, and N wetlands were not significantly different (Figure 1, Table 3).

High variability in newly constructed wetlands was expected due to the rapid changes in environmental conditions that occur in newly constructed wetlands, including water

Figure 1. Total abundance (No./M^2) of macroinvertebrates in constructed and natural wetlands in central Florida--Core data.

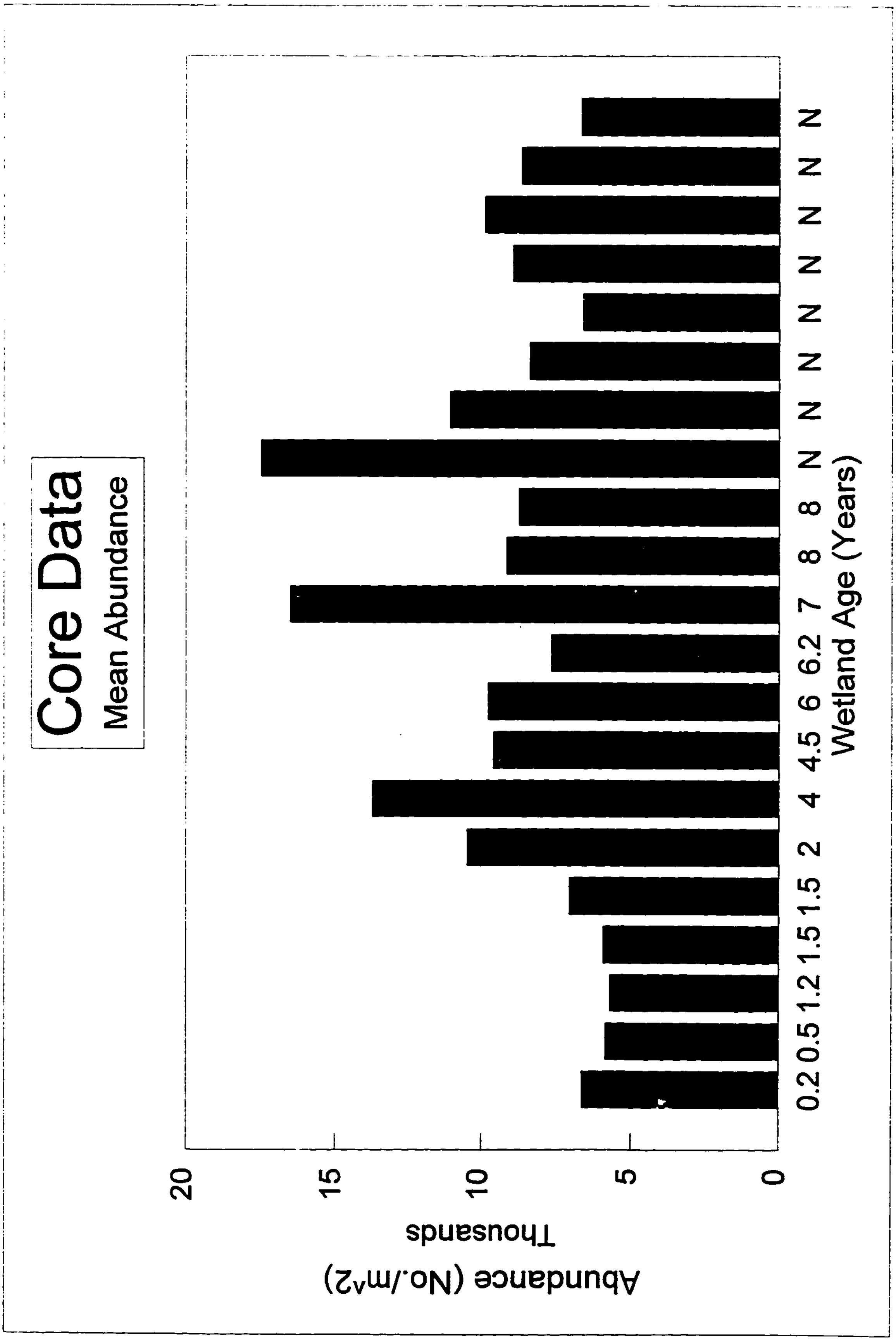

Core Data
Mean Abundance
Abundance (No./m^2)
Thousands
20
15
10
5
0
0.2
0.5
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
N
Wetland Age (Years)

Table 3. Comparison of Natural (N), Newly Constructed (NC), and Old Constructed (OC) Wetlands-Core Data

	Wetland Type		Max	Min	Mean
Abundance (No./m^2)	N	Natural	17472	6639	9721
	All	Constructed	16510	5737	9006
	NC	1st 3 yrs	10500	5738	6982
	OC	> 3 yrs	16510	7675	10741
Number of Taxa	N	Natural	52	30	40
	All	Constructed	48	20	31
	NC	1st 3 yrs	30	20	23
	OC	> 3 yrs	48	29	38
Diversity	N	Natural	4.50	3.94	4.23
	All	Constructed	4.50	2.49	3.43
	NC	1st 3 yrs	4.00	3.30	3.10
	OC	> 3 yrs	4.50	2.49	3.77
Equitability	N	Natural	0.92	0.65	0.79
	All	Constructed	0.93	0.28	0.64
	NC	1st 3 yrs	0.93	0.58	0.66
	OC	> 3 yrs	0.76	0.28	0.62

level fluctuation, nutrient influx, phytoplankton blooms, and newly introduced species. However, organism abundance was hypothesized to be significantly higher in newly constructed wetlands than in older constructed or natural marshes. Expectations were based on the observation that algal blooms often develop shortly after initial inundation of previously unflooded soils due to the release of inorganic nutrients (Ponnamperuma 1972; Evans and Sullivan 1984; Hossner and Baker 1988). These algal blooms were hypothesized to provide an abundant food supply for a wide variety of species colonizing newly constructed wetlands. The expected early peak in organism abundance was not realized. The observed algal blooms were dominated by filamentous blue-green algae which can be a suboptimal food resource for many herbivorous invertebrates because they are unmanageable, unpalatable, or even toxic (Porter 1973, 1977). In the absence of detrital accumulation, food availability in newly constructed wetlands may be more limited than once thought. This new hypothesis is untested.

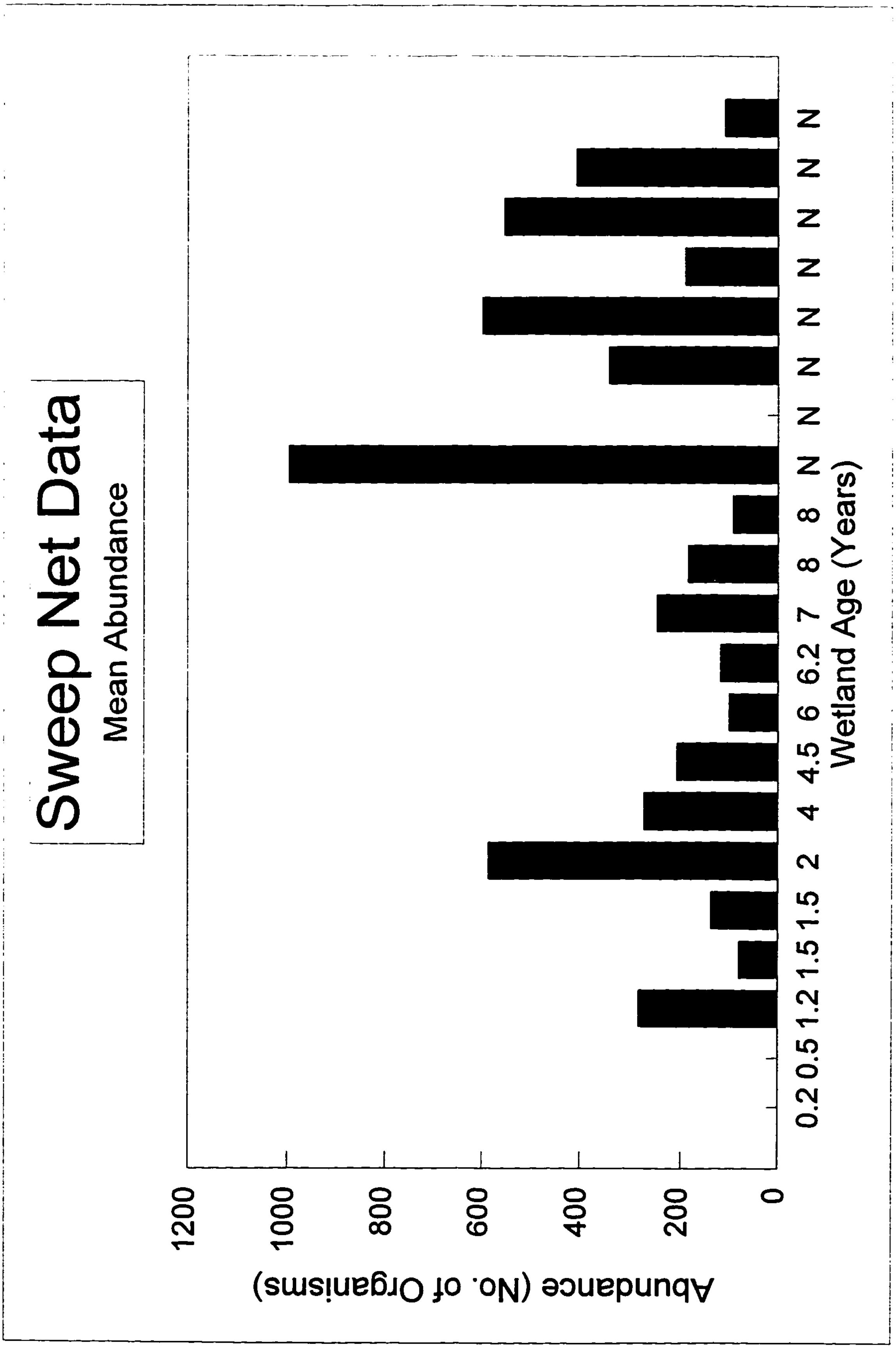
Predation pressure might also explain the absence of the expected peak in abundance. The trophic model of Carpenter (1988) predicts that changes in production of intermediate trophic levels may be undetectable when parallel shifts occur in food availability and predation pressure. For example, while detritivores may be most productive in OC wetlands, a difference in production cannot be observed due to relatively high invertebrate predation pressure applied by abundant odonate populations. Invertebrate production in constructed marshes was similar to that of natural marshes (core data), despite higher chlorophyll a production in constructed marshes less than 6 years old (Kiefer 1991). Invertebrate predation is perhaps, partially responsible. The only evidence of this is that predators that feed by piercing prey (primarily Hemiptera and Coleoptera) were more abundant in newly constructed wetlands than in older constructed wetlands (sweep data, p=0.0079).

Abundance in sweep net samples was significantly higher in natural wetlands than in constructed wetlands, particularly following the dry season (winter) (p=0.0106) (Table 4, Figure 2). This difference in abundance is most likely attributed to differences in hydroperiod between natural and constructed wetlands. Many of the natural wetlands studied were observed to dry in the winter, whereas constructed marshes were continually flooded. During drydown the flooded portion of a marsh is reduced in size, effectively concentrating aquatic macroinvertebrate populations. The fact that there were no significant differences in organism abundance at other times of the year further supports the hypothesis that this is a seasonal effect caused in part by low water level in the natural wetlands. These findings also support the more general

Table 4. Comparison of Natural (N), Newly Constructed (NC), and Old Constructed (OC) Wetlands-Sweep Net Data

	Wetland Type		Max	Min	Mean
Abundance	N	Natural	966	111	457
	All	Constructed	586	81	194
	NC	1st 3 yrs	586	81	219
	OC	> 3 yrs	274	95	176
Number of Taxa	N	Natural	55	26	43
	All	Constructed	39	20	28
	NC	1st 3 yrs	38	20	22
	OC	> 3 yrs	39	24	33
Diversity	N	Natural	4.40	3.76	4.10
	All	Constructed	4.14	2.67	3.62
	NC	1st 3 yrs	4.01	2.67	3.28
	OC	> 3 yrs	4.14	3.07	3.81
Equitability	N	Natural	0.89	0.61	0.70
	All	Constructed	1.03	0.44	0.67
	NC	1st 3 yrs	1.03	0.44	0.55
	OC	> 3 yrs	0.91	0.49	0.75

Figure 2. Total abundance (No./M^2) of macroinvertebrates in constructed and natural wetlands in central Florida--Sweep net data.


Sweep Net Data
Mean Abundance
Abundance (No. of Organisms)
0
200
400
600
800
1000
1200
Wetland Age (Years)
0.2
0.5
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
N

hypothesis that hydrological function is an important driving force in wetland biological communities.

Differences in macrophyte cover (habitat structure) and the amount of detritus in sediments (food availability) may also partially explain the differences in macroinvertebrate abundance between NC and OC wetlands. In a study of some of the same wetlands included in the current study, Kiefer (1991) found evidence for the occurrence of a "trophic surge" in above ground macrophyte biomass approximately 3 years after construction, presumably brought on by high nutrient availability in newly flooded soils. The increase in living plant biomass was followed by marked accumulations of plant litter and detritus. The observed peaks in benthic macroinvertebrate abundance in wetlands 2 to 4 years of age may be largely influenced by this "trophic surge" (Figures 1 and 2). This observation supports the hypothesis that plant production is perhaps one of the most important factors influencing invertebrate productivity via the detrital food web (Murkin and Wrubleski 1988).

Numerous studies have demonstrated higher benthic invertebrate abundance in vegetated habitats than in non-vegetated habitats (Minckley 1963; Lindegaard et al. 1975; Gregg 1981). This observation has been attributed to greater surface area for attachment, more abundant detrital food resources, and enhanced availability of refugia allowing successful avoidance of predation in vegetated areas. All of these influencing factors may play a role in determining benthic macroinvertebrate abundance in newly constructed wetlands, but the greater surface area provided by aquatic macrophytes is perhaps the major reason for higher abundance observed in vegetated areas (Minshall 1984).

Kiefer (1991) provided evidence suggesting that detrital food resources do not peak until the fourth or fifth year after construction. The increase in core sample abundance with wetland age coincides with the accumulation of detritus. These findings support the notion that plant communities are keystone in determining the ecological function of constructed wetlands either directly or indirectly. However, this study afforded no conclusive evidence that there is a strong direct relationship between living macrophytes and macroinvertebrate populations.

Species Richness (Number of Taxa)

Among core samples, OC wetlands exhibited species richness values similar to those of N wetlands (Table 3, Figure 3). The mean number of taxa collected per sampling event with a coring device was significantly higher in Natural and Older Constructed wetlands than in Newly Constructed wetlands ($p=0.0224$ and $p=0.0384$, respectively).

Within the sweep net data, significantly more taxa were collected in natural wetlands than constructed wetlands ($p=0.0005$) (Table 4, Figure 4). It is possible that the constructed wetlands studied have simply not been in

Figure 3. Number of taxa (taxa richness) of macroinvertebrates in constructed and natural wetlands in central Florida--Core data.

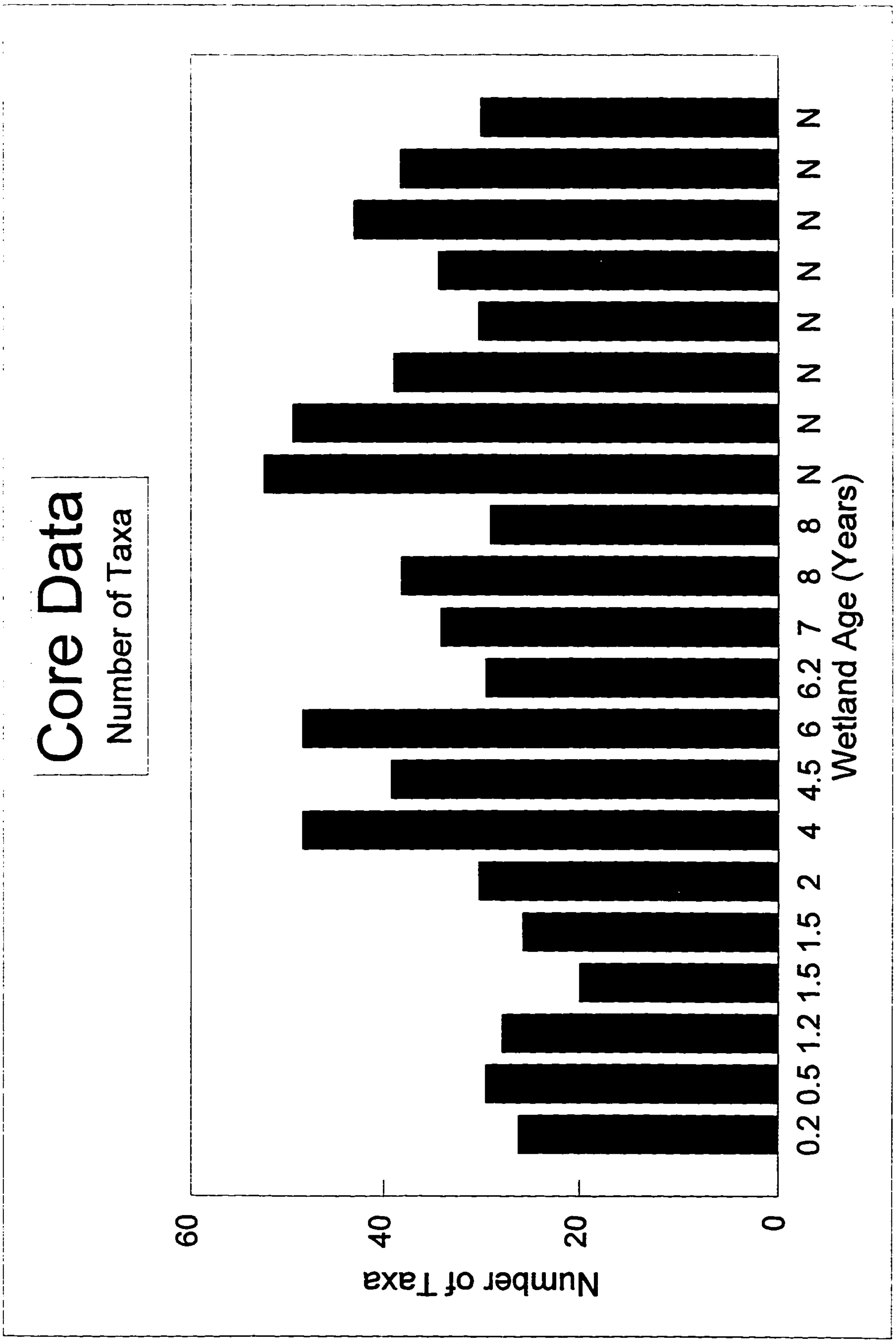
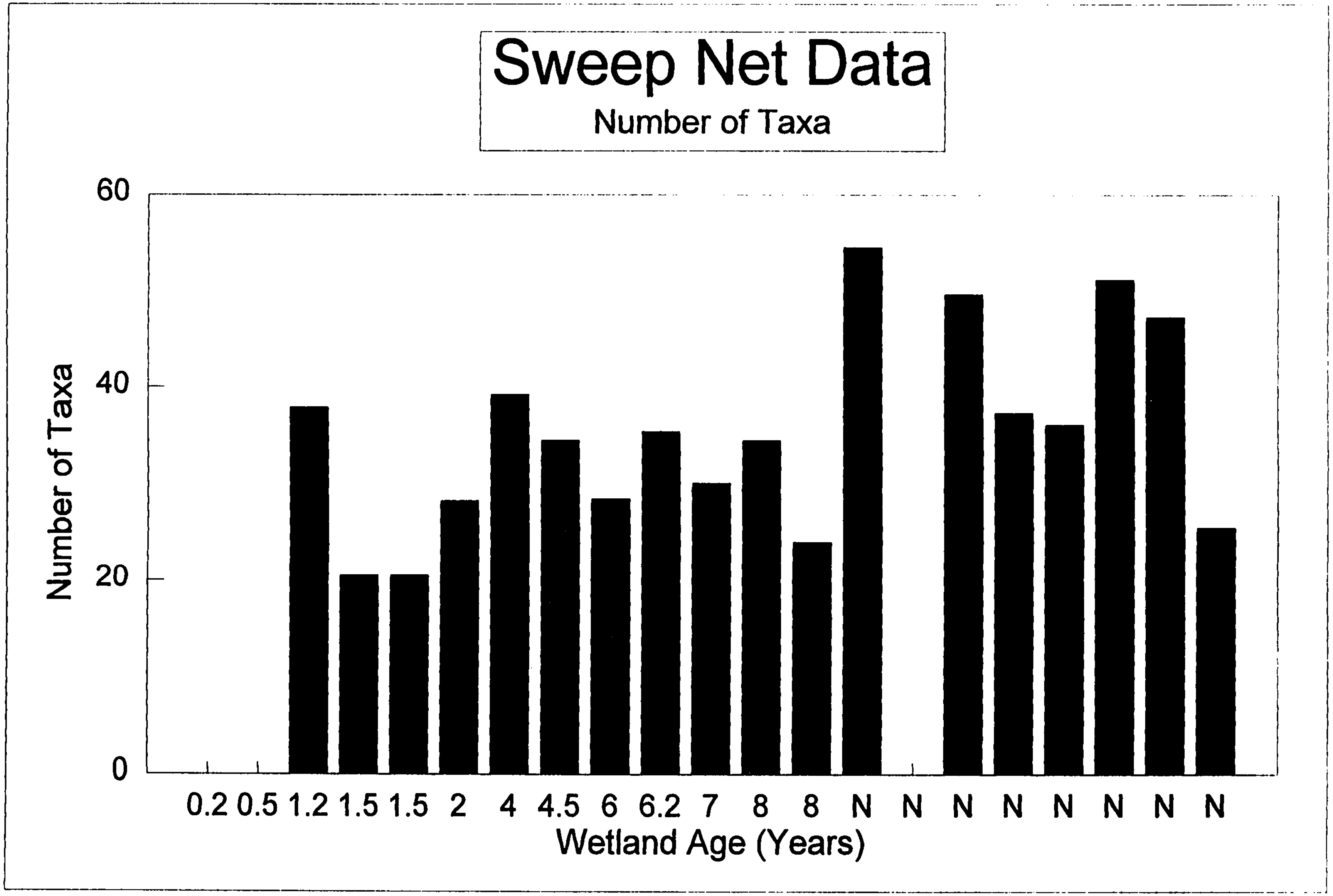

Core Data
Number of Taxa
Number of Taxa
60
40
20
0
0.2
0.5
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
N
N
Wetland Age (Years)

Figure 4. Number of taxa (taxa richness) of macroinvertebrates in constructed and natural wetlands in central Florida--Sweep net data.


Sweep Net Data
Number of Taxa
60
40
20
0
Number of Taxa
0.2
0.5
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
N
Wetland Age (Years)

existence for a sufficient time to allow as many aquatic macroinvertebrate populations to become established. Habitat structure may not be as well developed in newly formed wetlands.

In newly constructed wetlands, species richness (defined here as the number of unique taxa per sampling unit) is expected to increase as new species colonize previously unoccupied habitat. As predation and competition for food and space increase, some species will be eliminated. Therefore, predation, competition, and the absence of specific environmental requirements may ultimately limit growth in species richness (Ulanowicz 1980; Kentula et al. 1993). Although organism abundance reached capacity (relative to natural wetlands) early in the development of the constructed wetlands, taxa richness did not reach the level observed in natural wetlands. This observation is consistent with the hypothesis that energy flow is initially maximized by the proliferation of opportunistic species and complexity of the community increases at a slower rate. Based on taxa richness, macroinvertebrate communities of constructed wetlands did not reach the level of complexity observed in natural wetlands. The data support Ulanowicz's hypothesis.

Shannon-Weiner Diversity

Newly constructed wetlands were significantly lower in diversity than older constructed and natural wetlands (p=0.01

and $p<0.01$, respectively). Core data for constructed wetlands exhibited a wider range of diversity values than natural wetlands (Figure 5). The greatest variability for this variable was within older constructed wetlands. Mean diversity was highest in natural wetlands. Diversity in natural wetlands was significantly higher than in constructed wetlands ($p=0.0039$). Diversity values within older constructed wetlands tended to be slightly lower than values calculated for natural wetlands.

Sweep net data exhibited trends in diversity similar to the core results, but there were no significant differences between the wetland types (Table 4, Figure 6). Mean diversity values for newly constructed, older constructed and natural wetlands were 3.28, 3.81, and 4.10, respectively. Within constructed wetlands, species diversity tended to be higher with increasing wetland age ($p=0.018$, R-square=0.52). Although the regression has considerable scatter, this observation fits the hypothesis that complexity of community structure increases during wetland development (Ulanowicz 1980).

When comparing older constructed and natural wetlands, the evaluation based on the diversity index showed little difference between the wetland types, whereas species richness and equitability measurements suggested that there are differences. Equitability and species richness estimates may provide more useful information about invertebrate

Figure 5. Shannon-Weiner species diversity of macroinvertebrates in constructed and natural wetlands in central Florida--Core data.

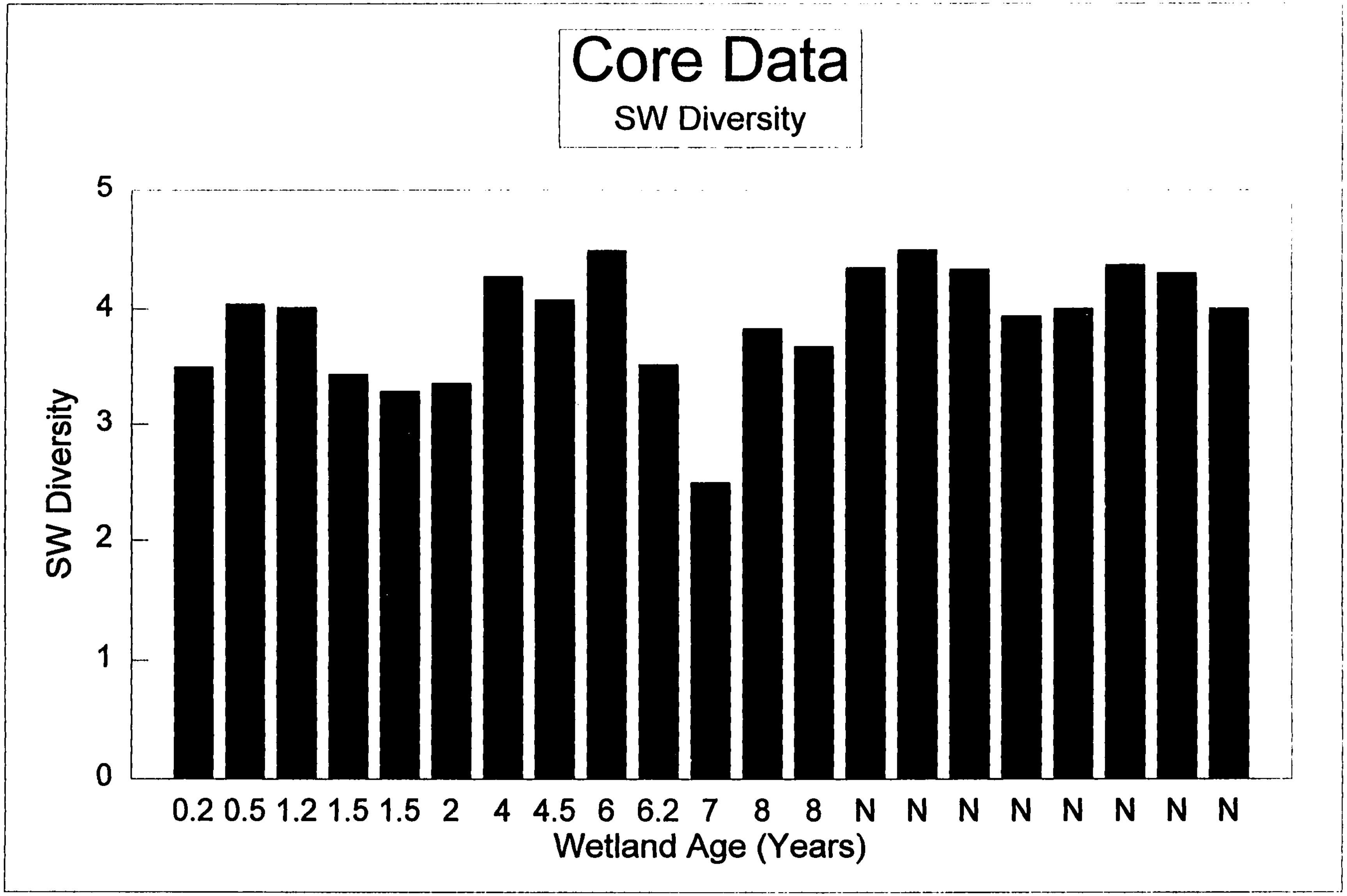
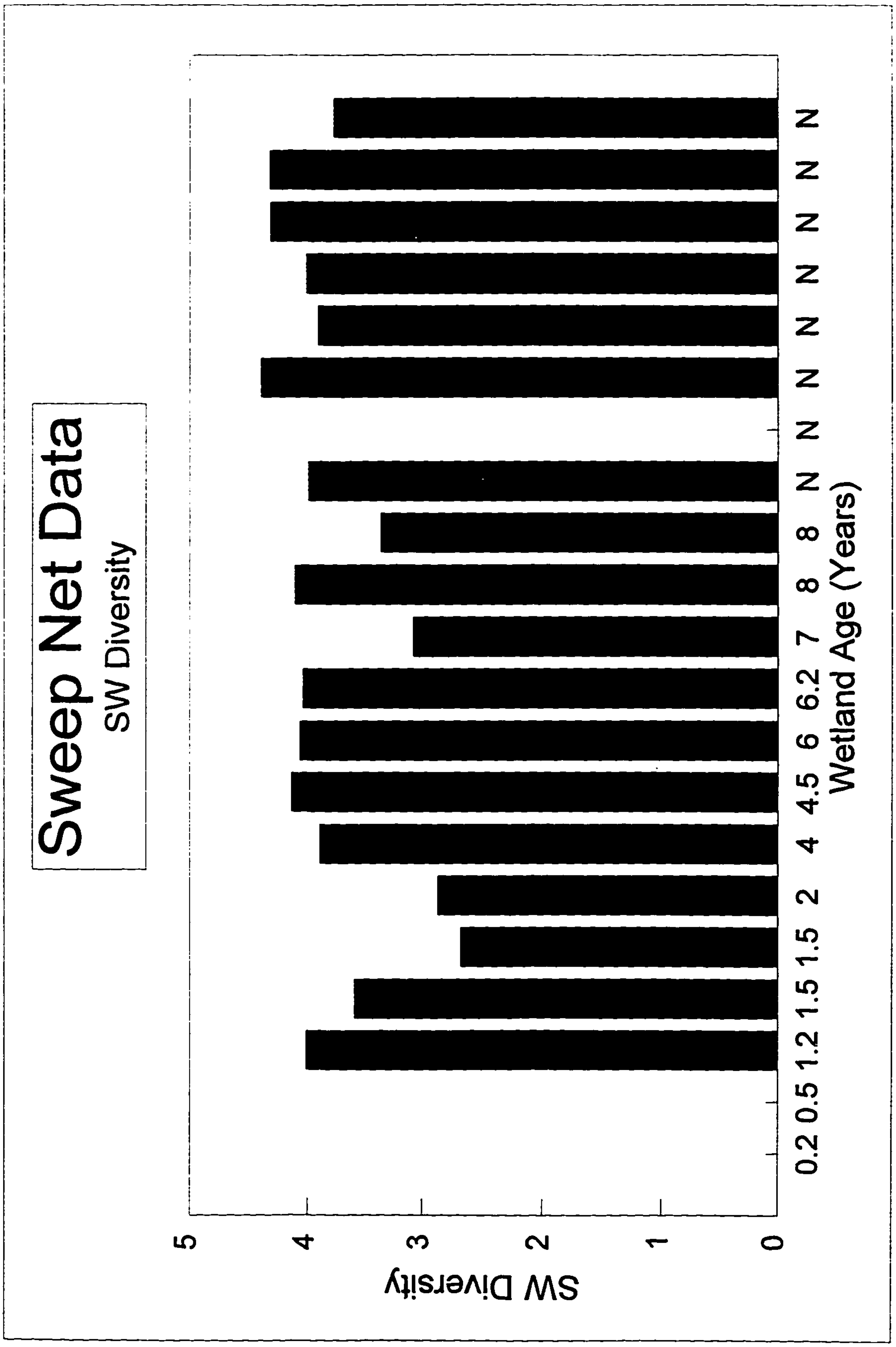

Core Data
SW Diversity
SW Diversity
0
1
2
3
4
5
0.2
0.5
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
N
Wetland Age (Years)

Figure 6. Shannon-Weiner species diversity of macroinvertebrates in constructed and natural wetlands in central Florida--Sweep net data.


Sweep Net Data
SW Diversity
SW Diversity
0
1
2
3
4
5
Wetland Age (Years)
0.2
0.5
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
N

populations than the diversity index alone. These results suggest that although the Shannon-Weiner species diversity index is commonly used in Florida as a measure of biological integrity, the index may be of limited value in evaluating wetland reclamation efforts.

Caldwell (1989) described some of the limitations inherent in the application of the Shannon-Weiner species diversity index to complex biological communities and questioned its usefulness in evaluating the success of wetland reclamation efforts. The index does not take biological function into account. All information bits are treated equally without regard to organism size or ecological function.

Equitability

The widest range of equitability values among core samples were within older constructed wetlands, where extremely abundant species reduced equitability values Table 3, Figure 7). Mean equitability was lowest in older constructed wetlands and highest in natural wetlands. Mean equitability was significantly lower in older constructed wetlands than in natural wetlands ($p < 0.03$). There was no significant difference between mean equitability in newly constructed wetlands and other wetland types.

In contrast, mean equitability values for sweep net samples tended to be lowest in newly constructed wetlands and highest in older constructed wetlands (Table 4, Figure 8).

Figure 7. Equitability macroinvertebrates in constructed and natural wetlands in central Florida--Core data.

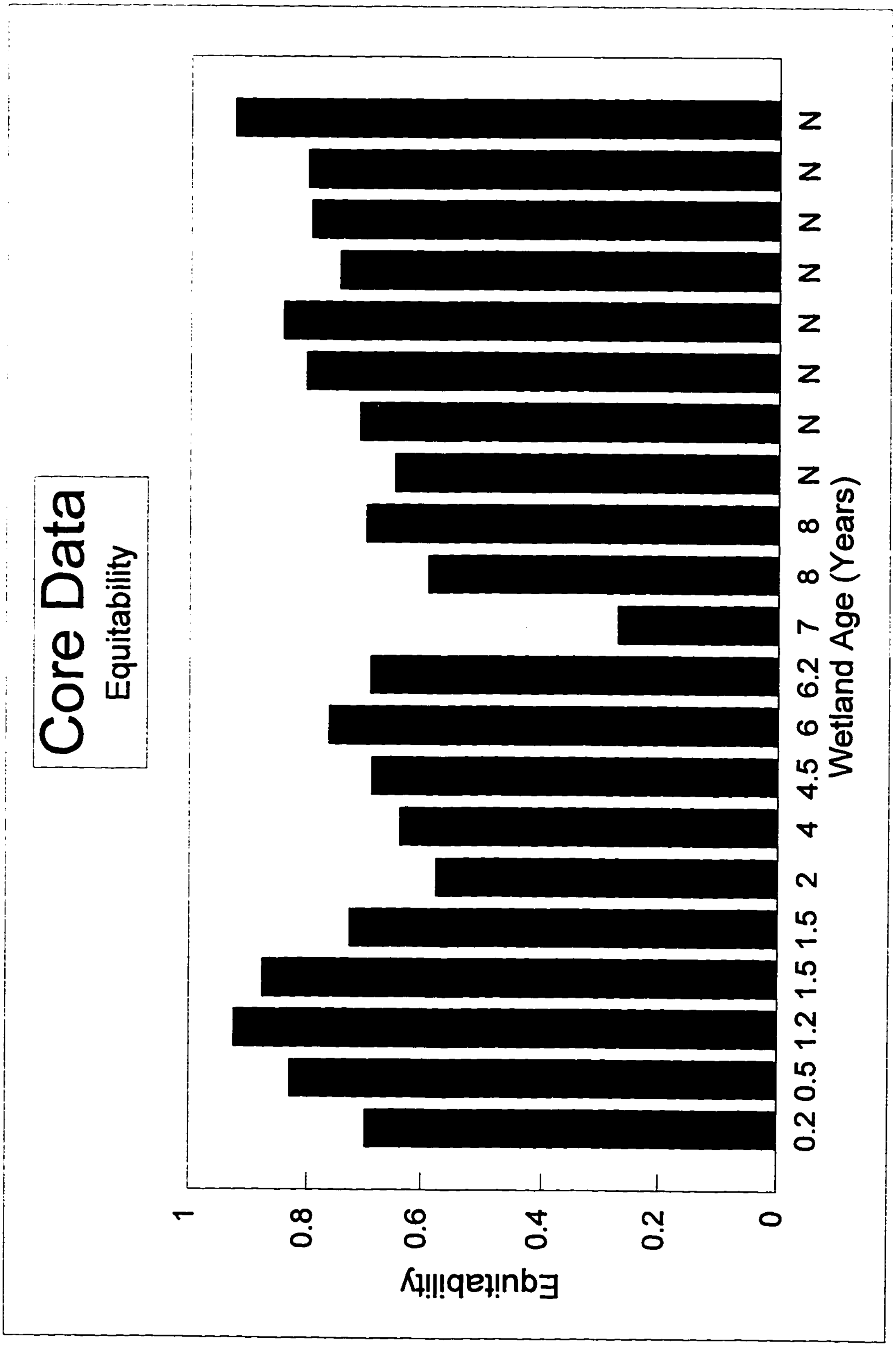
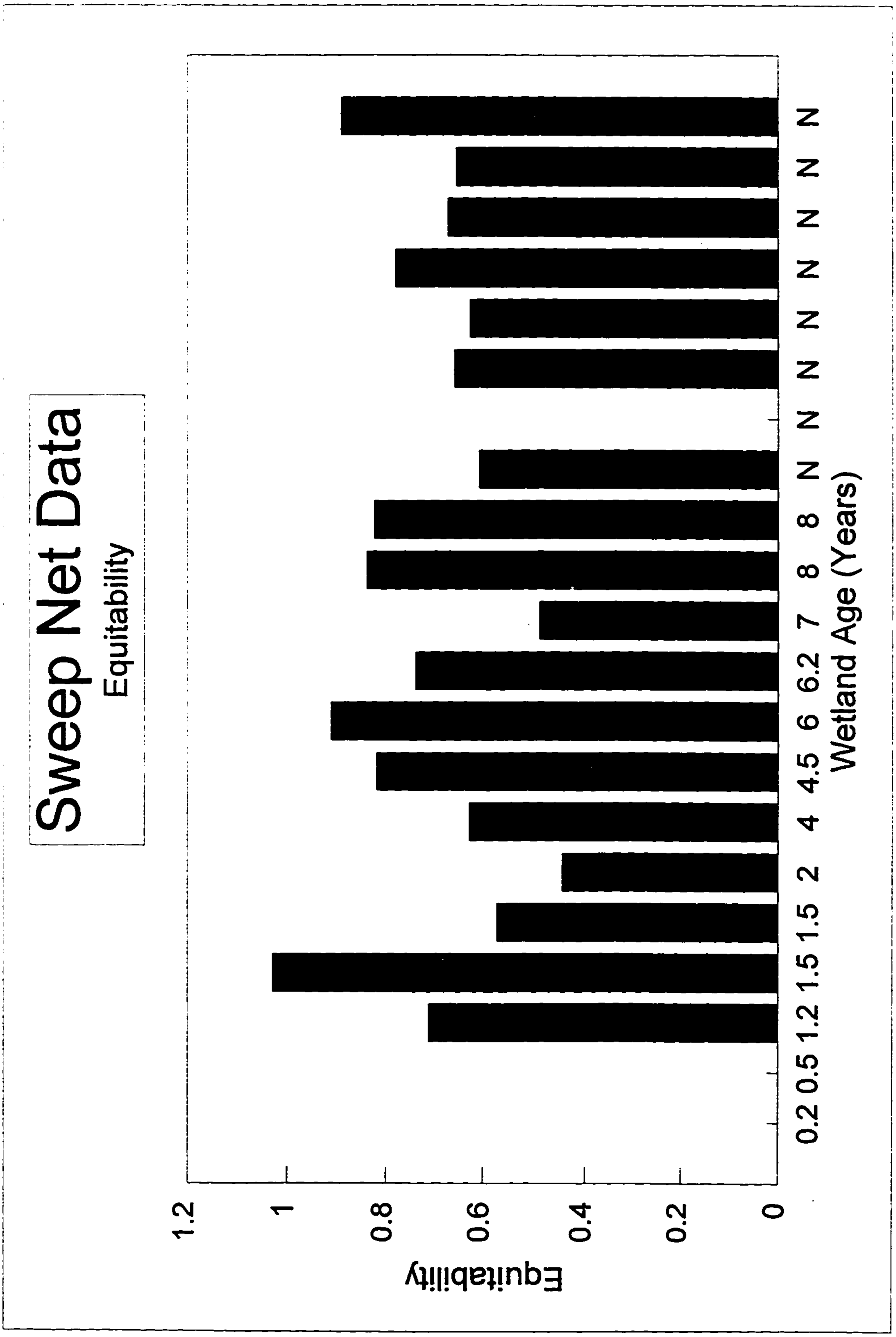

Core Data
Equitability
Equitability
0
0.2
0.4
0.6
0.8
1
0.2
0.5
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
N
Wetland Age (Years)

Figure 8. Equitability of macroinvertebrates in constructed and natural wetlands in central Florida--Sweep net data.


Sweep Net Data
Equitability
Equitability
0
0.2
0.4
0.6
0.8
1
1.2
0.2
0.5
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
N
Wetland Age (Years)

Differences between core and sweep net results emphasize the importance of using a variety of sampling techniques to adequately assess the status of aquatic macroinvertebrate communities.

Benthic community equitability is often low under disturbed or newly established environmental conditions (Weber 1973). During the early stages of marsh development, a small number of species, particularly those with short life cycles and early reproduction, may become extremely abundant as they take advantage of an ample food supply and reduced competition. The presence of a few extremely abundant species would reduce benthic community equitability; therefore, equitability values of newly constructed wetlands were expected to be relatively low.

Morisita's Similarity Index

Mean Morisita's similarity index values (core data) for comparisons between constructed wetlands (C vs. C), between natural and constructed wetlands (N vs. C), and between natural wetlands (N vs. N) were 0.51, 0.28, and 0.44, respectively (Table 5). ANOVA demonstrated a highly significant difference between treatments. Duncan's multiple range test indicated no significant difference between the means for treatments C vs. C (0.51) and N vs. N (0.44). However, the mean for treatment N vs. C (0.28) was significantly different from means for treatments C vs. C and

Table 5. Mean Morisita's Similarity Index Values for Comparisons Between Newly Constructed (NC), Older Constructed (OC), and Natural (N) Wetlands

Treatment	Comparison*	Mean Value
A	C vs. C	0.51
B	N vs. C	0.28
C	N vs. N	0.44
D	NC vs. NC	0.39
E	NC vs. OC	0.50
F	NC vs. N	0.21
G	OC vs. OC	0.57
H	OC vs. N	0.32

* C = Constructed; N = Natural; NC = Newly Constructed; OC = Older Constructed

N vs. N ($p < 0.05$). The Wilcoxon ranked sum test yielded the same result ($p < 0.0001$).

Constructed wetland benthic invertebrate communities are more similar to one another than they were to natural wetland assemblages. Likewise, benthic invertebrate communities of natural wetlands were more similar to one another than to those of constructed wetlands. This observation is consistent with the hypothesized differences in macroinvertebrate community structure of constructed and natural marshes.

Streever and Crisman (1993) used Sorensen's similarity index to compare chydorid assemblages in many of the natural and constructed wetlands included in the current study. They found that natural wetland assemblages were less similar to each other than those of constructed wetlands. Their results suggest that meiobenthic assemblages occurring in natural wetlands are more variable than those found in constructed wetlands. Within the confines of the current study, benthic macroinvertebrate assemblages of natural marshes were no more variable than those of constructed marshes. Macro- and meiofaunal assemblages of constructed wetlands appear to be more similar to those of other constructed wetlands than to assemblages found in natural wetlands.

Mean similarity values presented in Table 5 suggest that benthic macroinvertebrate communities of natural wetlands are more similar to those of OC wetlands than to NC wetlands.

ANOVA GLM showed that mean similarity values for N vs. N (0.44), N vs OC (0.32), and N vs. NC (0.21) comparisons were significantly different ($p < 0.0001$). Duncan's Multiple Range Test indicated a significant difference between each of the means ($p < 0.05$).

These observations support the hypothesis that macroinvertebrate communities of constructed wetlands go through directional shifts similar to "old field" succession. As constructed wetlands age, their macroinvertebrate communities become increasingly similar to those of natural wetlands.

Changes in sediment quality over time may be a primary forcing function driving the shift in macroinvertebrate assemblages. As constructed wetlands age, their sediments increase in organic content because plants die off and form detritus (Kiefer 1991). The organic content of the sediments may have an important influence on benthic invertebrate community structure. However, degree of similarity between constructed and natural wetlands did not correlate well with constructed wetland age or organic content of the sediments. Among constructed wetlands, there is not a consistent trend of increasing similarity to natural wetlands with increasing age. A more uniform trend might be observed if all constructed wetlands were designed in a similar manner.

Although sediment characteristics certainly have an influence on benthic invertebrate community composition, wetland morphology, hydrology, and vegetation may determine, in part, the degree of similarity between benthic invertebrate assemblages. For example, although CS83 was among the oldest constructed wetlands and had sediments that were high in organic content relative to other constructed marshes (9 percent organic matter), it exhibited the lowest similarity values when compared to natural wetlands. This wetland was contoured with steep slopes and was narrowly rectangular in shape. Vegetation in CS83 was dominated by floating plants, whereas most natural marshes supported dense stands of rooted emergent vegetation. These differences in wetland design and plant community structure could explain, in part, why the macroinvertebrate community structure of CS83 is so different from the natural wetlands studied.

In contrast, benthic macroinvertebrate assemblages in FG82 and FG86 were most similar to those in natural wetlands. These wetlands were contoured with gradual slopes and relatively shallow water depths, mulched, and planted with rooted emergent vegetation. The relatively close similarity between benthic communities of shallow constructed wetlands with a gradual slope and natural wetlands, which are also shallow with gradual slopes, provides evidence that hydroperiod, as influenced in part by wetland morphology, may play an important role in determining plant community development, sediment development and benthic invertebrate community structure.

Constructed wetland design characteristics such as elevation contours, vegetation, and soil characteristics may also influence the rate at which constructed wetlands achieve natural ecological function. Design and construction techniques, including construction of gentle slopes and shallow water depths (less than 46 cm), mulch application, and planting, may serve to accelerate development of a benthic invertebrate community and, by extension, an ecological system similar to that of natural marshes. These techniques influence hydrology, water/sediment quality, vegetation development, and benthic invertebrate habitat structure.

Kiefer (1991) observed that both mulched and unmulched constructed wetlands functioned similarly to natural wetlands with regard to water and sediment quality, but only after a sufficient detrital base had developed. He further stated that a mean dry season (winter) depth of less than 35 cm and a slope of less than 1.67 cm/m are desirable. The evidence presented here supports Kiefer's conclusion to the extent that Morisita's Similarity Index (an index based on community structure) represents the ecological function of macroinvertebrate communities.

Temporal Variation in Benthic Macroinvertebrate Abundance in Constructed and Natural Wetlands

For the 31 species occurring in core samples from both natural and constructed wetlands (Table 6), the coefficient of variation was higher in constructed wetlands than natural

Table 6. Coefficients of Variation of Select Species by Wetland Type

Species	Cons.	Nat.	0-3 yr	>3 yrs
Tubificidae sp. B (immature)	205	155	102	158
Tubificidae sp. A (immature)	133	114	144	85
Hyalella azteca	109	116	87	99
Caenis diminuta	95	180	113	81
Callibaetis floridanus	148	56	84	136
Celina sp.	118	60	152	71
Polypedilum illinoense group	172	161	171	158
Chironomus (Lobochironomus)	113	109	91	87
Polypedilum tritum	190	79	94	132
Polypedilum trigonus	96	49	104	88
Larsia decolorata	101	85	85	77
Monopelopia boliekae	100	91	97	89
Larsia indistincta	204	94	134	245
Ablabesmyia peleensis typeII	148	109	64	100
Tanytarsus sp. 4-Rutter	130	166	120	136
Tanytarsini Genus A-Roback	112	138	100	54
Bezzia sp.	85	161	107	61
Dasyhelea sp.	105	102	160	71
Dero digitata	113	107	155	72
Crangonyx floridanus	0	89	0	0
Libellulidae	93	88	115	64
Erythemis simplicicollis	94	132	62	75
Laccophilus sp.	0	59	0	0
Goeldichironomus holoprasinus	170	173	110	87
Parachironomus hirtalatus	70	65	73	40
Dicrotendipes leucoscelis	235	88	0	158
Kiefferulus dux	99	70	163	62
Limnophyes sp.	0	93	0	0
Pseudosmittia sp.	0	117	0	0
Ablabesmyia rhamphe gr.	0	113	0	0
Labrundinia neopilosella	136	96	166	87
Larsia berneri	303	143	224	245
Fittkaumyia prob. serta	0	103	0	0
Atrichopogon sp. A	126	46	0	63
Chaoborus albatus	297	86	224	245
Chaoborus punctipennis	101	265	99	76
Coquillettidia perturbans	256	85	0	175

wetlands (p=0.0114). Perhaps population sizes vary more among constructed than natural marshes. This evidence supports the notion that rapidly changing environmental conditions characteristic of newly constructed marshes and the stochastic nature of chance colonization may enhance population variability in constructed wetlands.

The wide, often erratic, fluctuations of biological, physical, and chemical parameters in newly constructed wetlands (Evans and Sullivan 1988; Kiefer 1991; Hammer 1992) have implications for the timing and frequency of constructed wetland monitoring efforts. Highly variable conditions make it impractical to collect an adequate sample size at a sufficient frequency to acquire meaningful results. These constraints impose limitations on assumptions that can be made regarding macroinvertebrate population sizes. For these reasons, efforts to monitor aquatic invertebrate populations of constructed sites for success evaluation prior to the third year after inundation may be unnecessary.

Development of Wetland Macroinvertebrate Communities in Constructed Wetlands

Colonization of constructed wetlands occurred very rapidly and quarterly sampling was not an adequate sampling interval to document rapidly changing macroinvertebrate communities in newly inundated wetlands. Furthermore, monthly sampling conducted in P90 and HP90 was inadequate to monitor the rapid invertebrate community development.

The amphipod, *Hyalella azteca*, is widespread in distribution and tolerates a wide range of environmental conditions. Its early dominance may be a function of rapid reproduction and an abundant food supply.

A relatively abundant gastropod fauna was present in newly constructed wetlands. They are perhaps able to colonize rapidly, even though they are not active colonizers (e.g. attachment to wading birds). Based on qualitative observations during the current study, elevated epiphytic and epipelic algal growth in newly constructed wetlands may provide an ample food source for gastropods. A layer of algae was observed overlying the sediments during most sampling events at P90 (less than 1 year old).

As expected, chironomids, particularly the Chironominae and Tanypodinae, were early colonizers, dominating the macroinvertebrate communities of newly constructed wetlands almost immediately. Gastropod populations were hypothesized to increase more slowly partly because they are not active colonizers. However, they were observed in highest densities in the youngest constructed wetlands. Gastropods were perhaps introduced at the outset of marsh development during the application of mulch from a donor marsh and/or by attaching to wading birds, which feed frequently in newly constructed marshes.

Bataille and Baldassarre (1993) reported that a seasonal prairie pothole supported significantly lower densities of chironomids than a nearby permanent system. Gastropods demonstrated a slower recovery from drought than chironomids. The natural wetlands studied may have low gastropod populations because of seasonal drying. Although the constructed wetlands of the current study were relatively young (less than 10 years old), they were continually inundated.

Culicids were present immediately after initial inundation but were never collected in large numbers. Culicids are among the earliest colonizers (Wiggins et al. 1980; Laird 1988). Bataille and Baldassarre (1993) reported emergent trap densities of 28-100 M^2 in shallow and deep marsh zones of a semipermanemt prairie pothole wetland, whereas sampling in a seasonally flooded wetland yielded less than 1 M^2.

Achievement of Equilibrium Relative to Natural Wetlands

Stream ecologists have measured equilibrium in lotic invertebrate communities using the MacArthur-Wilson (1967) island biogeographic model (Townsend and Hildrew 1976; Lake and Doeg 1985; Williams and Hynes 1977). The model states that equilibrium is achieved when the rate of species extinction is the same as the rate of species immigration, thus rendering a relatively constant total number of species at any given time. Equilibrium has also been measured using diversity indices and organism densities (Mackay 1992). The time required to meet equilibrium can depend on the way the term is defined and measured. For purposes of the current analysis, relative equilibrium can be defined for a given measure (e.g., abundance) as a state of being consistently within the bounds (confidence interval) of conditions observed in natural wetlands.

Abundance--The confidence interval for organism abundance in core samples collected from natural wetlands was (132, 245). P90, HP90, CS86, and CS85 had abundance values that fell outside the confidence interval. The confidence interval for sweep sample abundance in natural wetlands was (185, 720). Abundance values for five of the constructed sites were below the confidence interval for natural wetlands (HP90, G90, CS85, CS84, and G81).

Taxa Richness--Within core samples, eight of the eleven constructed wetlands fell outside the taxa richness confidence interval for natural marshes (31, 45). HP90, G90, CS88, CS85, CS83, and G81 had mean taxa richness values outside the confidence interval for sweep samples collected from natural wetlands (34, 53).

Shannon-Weiner Diversity--HP90, G90, CS88, CS85, CS84, CS83, FG82, and G81 had mean species diversity values outside the confidence interval for core samples collected in natural wetlands (4.01, 4.37). Within sweep samples, HP90, G90, CS88, CS83, and G81 had mean diversity values outside the natural wetland confidence interval (3.87, 4.33)

The confidence interval analysis was designed to measure the degree to which macroinvertebrate communities attain equilibrium relative to communities of natural wetlands. There is insufficient evidence to conclude that macroinvertebrate communities of the constructed wetlands studied have attained stability relative to natural wetlands. The constructed wetlands falling outside the natural wetland confidence intervals included a broad range of ages. The data do not support the hypothesis that constructed wetland macroinvertebrate communities approach stability relative to natural wetlands during the time interval studied (8 years).

Comparisons with Other Studies

Danell and Sjoberg (1982) tracked the postimpoundment development of aquatic invertebrate populations in a shallow (<0.5 m) boreal man-made lake that freezes annually. Organisms with a relatively high degree of mobility were first to colonize the lake. Coleopteran, hemipteran, and chironomid populations were established within 1 to 3 years of initial inundation. Isopods were first collected during the fourth year. Trichopterans and gastropods were first observed 6 years after initial inundation. Leeches were collected after 7 years, whereas ephemeropterans and odonates were collected after 8 years of flooding.

Colonization rates observed by Danell and Sjoberg (1982) were much slower than exhibited by aquatic invertebrates of subtropical constructed wetlands during the current study, where most major groups were observed to colonize and develop abundant populations within the first year after inundation. More rapid aquatic invertebrate community development in the subtropics can partially be attributed to a longer growing season. Many aquatic invertebrates are active throughout the year in the subtropics, thus providing greater potential for active dispersal, colonization, and population growth than in boreal regions, where ice may cover small lakes from early November to the middle of May (Danell and Sjoberg 1982). Long oviposition periods, asynchronous life cycles, and high growth rates are characteristic of insects at lower latitudes (Sweeney 1984). These conditions increase the potential for colonization and the rapid exploitation of newly formed habitats (Mackay 1992).

There is much evidence that rooted vegetation provides an important food source and important structural habitat for nektonic and benthic macroinvertebrates (Dudley 1988; Minshall 1984; Beckett et al. 1992). The development of rooted vegetation is much more rapid in subtropical wetlands than boreal wetlands. Danell and Sjoberg (1982) reported rooted vegetation attained 30-45 percent cover after 7 years of inundation. Constructed wetlands that are mulched but not planted in subtropical wetlands approach 80 percent vegetation cover within 3 years (Evans and Sullivan 1986b). Current study results indicate that Florida constructed wetlands that are planted approach 80 percent vegetation cover within 3 years of initial inundation.

Benthic Macroinvertebrate Species Assemblages of Natural and Constructed Wetlands

Shifts in species dominance are frequently observed as ecosystems recover from a disturbance (Crocker and Major 1955; Cowles 1899; Olson 1958). For example, prairie pothole marshes in the midwestern U.S. undergo 5- to 20-year cycles due to periodic drought. Voights (1976) described changes in aquatic vegetation and aquatic invertebrate species dominance during various phases of the hydrological cycle characteristic of prairie pothole marshes. The changes in species dominance are a consequence of varying environmental requirements and strategies for existence (Gleason 1926; Connell and Slayter 1977; Danell and Sjoberg 1982).

In the current study, taxa were analyzed for evidence of changes in dominant species assemblages as constructed wetlands age (Table A1). Species were classified as follows based on their pooled mean abundance in each wetland class (Table 7).

Y--abundant in NC wetlands only
ON--abundant in OC and N wetlands
O--abundant in OC wetlands only
YO--abundant in NC and OC wetlands
YN--abundant in NC and N wetlands
N--abundant in N wetlands only
CN--collected only from N wetlands

Table 7. Classification of Selected Major Taxa Based on Pooled Mean Abundance (No./m^2) in Core Samples From Natural and Constructed Wetlands

		Pooled Mean Abundance/Sq.M			
Species Class	Species Assemblages	Constructed	Natural	Constructed 0-3 yrs	Constructed >3 yrs
	CONSTRUCTED WETLAND ASSEMBLAGE*				
Y*	*Dero nivea*	220	22	399	67
YO	*Dero digitata*	88	10	82	93
YO	*Hyalella azteca*	1876	212	1164	2486
O	*Erythemis simplicicollis*	54	12	27	78
Y	*Goeldichironomus holoprasinus*	75	46	146	14
YO*	*Polypedilum illinoense group*	279	77	346	222
O	*Parachironomus hirtalatus*	63	18	29	92
Y*	*Chaoborus punctipennis*	55	3	72	41
	TRANSITIONAL ASSEMBLAGE†				
ON	*Tubificidae sp. B (immature)*	85	92	21	141
ON	*Celina sp.*	81	130	14	137
ON*	*Chironomus (Lobochironomus) sp.*	406	1065	169	610
ON*	*Polypedilum tritum*	142	446	16	250
ON	*Ablabesmyia peleensis type II*	115	172	19	197
ON*	*Tanytarsini Genus A-Roback*	90	240	6	162

Table 7--continued.

		Pooled Mean Abundance/Sq.M			
Species Class	Species Assemblages	Constructed	Natural	Constructed 0-3 yrs	Constructed >3 yrs
	NATURAL WETLAND ASSEMBLAGE‡				
NC	*Crangonyx floridanus*	0	409	0	0
NC	*Laccophilus sp.*	0	50	0	0
N	*Dicrotendipes leucoscelis*	2	361	0	4
N	*Polypedilum trigonus*	161	634	154	167
N*	*Kiefferulus dux*	40	153	27	51
NC	*Limnophyes sp.*	0	152	0	0
NC	*Pseudosmittia sp.*	0	63	0	0
N	*Larsia berneri*	8	176	2	12
NC	*Ablabesmyia rhamphe gr.*	0	93	0	0
N	*Larsia indistincta*	59	235	58	60
NC	*Fittkaumyia prob. serta*	0	104	0	0
N	*Labrundinia neopilosella*	8	121	8	7
N*	*Atrichopogon sp. A*	5	132	0	9
N*	*Chaoborus albatus*	7	61	2	11

* At least 200% more abundant in constructed wetlands
† At least 200% more abundant in old constructed and natural wetlands
‡ At least 200% more abundant in natural wetlands
NC = Not collected from constructed wetlands

A measure of relative abundance was used to classify each species. "Abundant" species were arbitrarily defined as those that are at least 200 percent more abundant in one given wetland type than another. Classes Y, O, and YO were assigned to the constructed wetland assemblage. Class ON constitutes a theoretical transitional assemblage, and the natural wetland assemblage consists of classes N and CN.

Potential reasons for the existence of these associations include chance distribution; differences in water quality, sediment quality, and macrophyte densities between the sites; and competitive and predatory species interactions. Water quality, sediment quality, and hydrological conditions within each wetland influence the community structure of benthic macroinvertebrates. For example, some species of *Labrundinia* prefer acidic waters (Fittkau and Roback 1983) and thus occur at higher population densities in acidic natural wetlands. Some members of the Orthocladiinae (e.g., *Limnophyes* and *Pseudosmittia*) tolerate semi-aquatic conditions; therefore, it is no surprise that these species were collected from natural wetlands that are known to dry periodically. Tube-dwelling *Cladotanytarsus* spp. usually construct cases using sandy substrates (Pinder and Reiss 1983). Peaty substrates of natural wetlands may not contain a sufficient sand fraction to promote this tube-building habit. Possibly related to pH sensitivity and competitive interaction, *Hyalella azteca* was generally more abundant in the constructed wetlands. *Crangonyx* cf. *floridanus* was collected only at natural sites. *Crangonyx* may be well adapted to surviving drought conditions by burrowing into sediments (Pennak 1989).

Temporal Patterns in Abundance of Select Taxonomic Groups

The data were analyzed to reveal any differences in major taxonomic groups among constructed sites of varying age and natural wetlands (Tables A2, A3, B7, B8, B9, and B10). The following section describes patterns and trends in abundance and taxa richness of major taxonomic groups.

Oligochaeta (Aquatic Worms)

Worm assemblages were dominated by the families Tubificidae, Naididae, and Lumbriculidae (Figures 9 through 14). Naidids appeared to be more abundant and diverse in OC wetlands than in NC and N wetlands, but only differences in taxa richness were significant (OC>NC, p= 0.0678; OC>N, p=0.0098). Lumbriculid and tubificid populations were generally higher in OC wetlands than NC wetlands, but differences were not significant.

Oligochaetes feed on detritus and associated microflora (Brinkhurst and Jamieson 1971). Observed trends in abundance are likely a result of accumulation of organic material in the sediments as constructed wetlands age. Peaks in oligochaete abundance occurred in constructed wetlands from 2 to 6 years of age. These peaks may be related to the "trophic surge" noted by Kiefer (1991).

Figure 9. Abundance of Tubificidae (No./M^2) in constructed and natural freshwater marshes in central Florida--Core data.

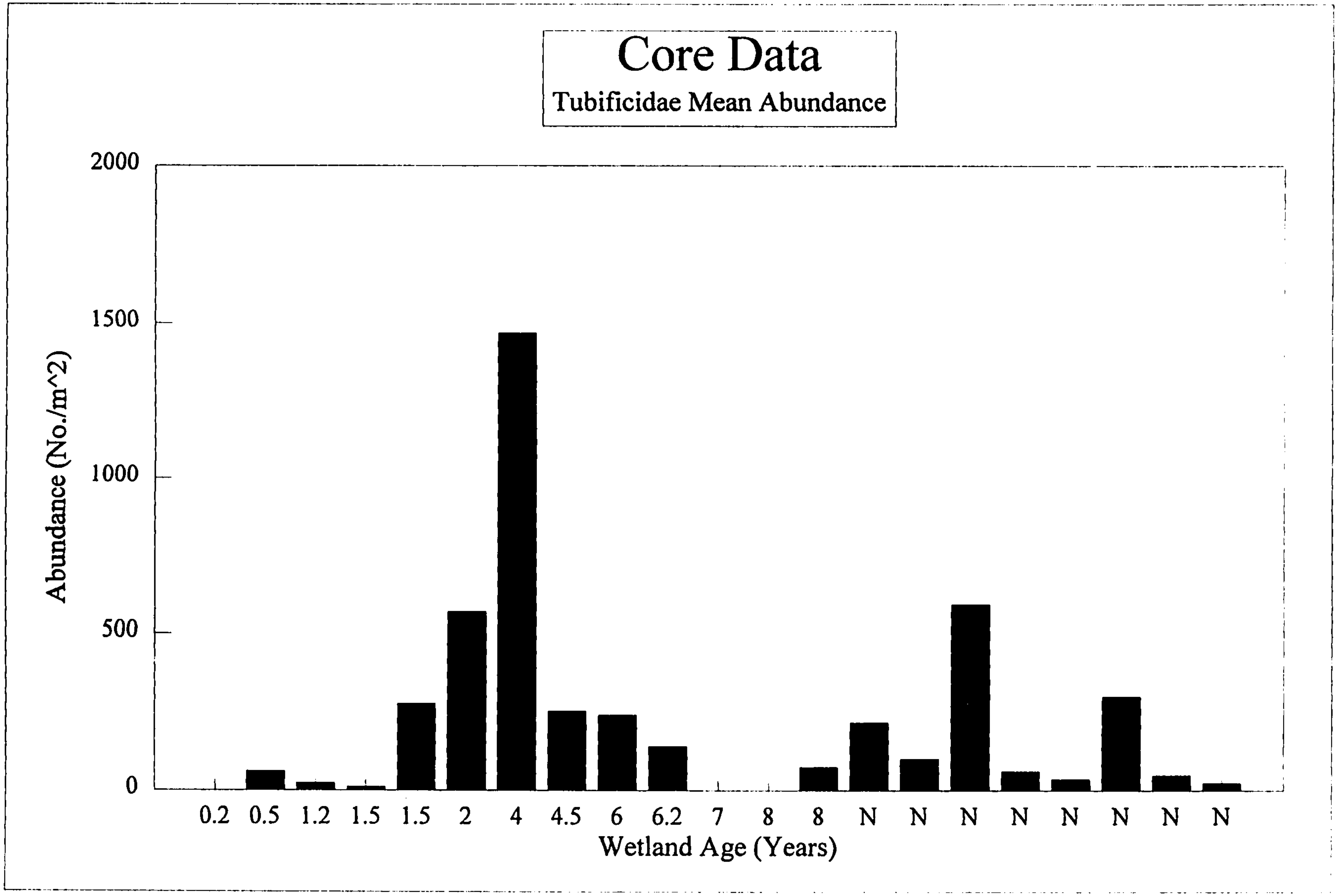

Core Data
Tubificidae Mean Abundance
Abundance (No./m^2)
2000
1500
1000
500
0
0.2
0.5
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
N
Wetland Age (Years)

Figure 10. Abundance of Tubificidae in constructed and natural freshwater marshes in central Florida--Sweep net data.

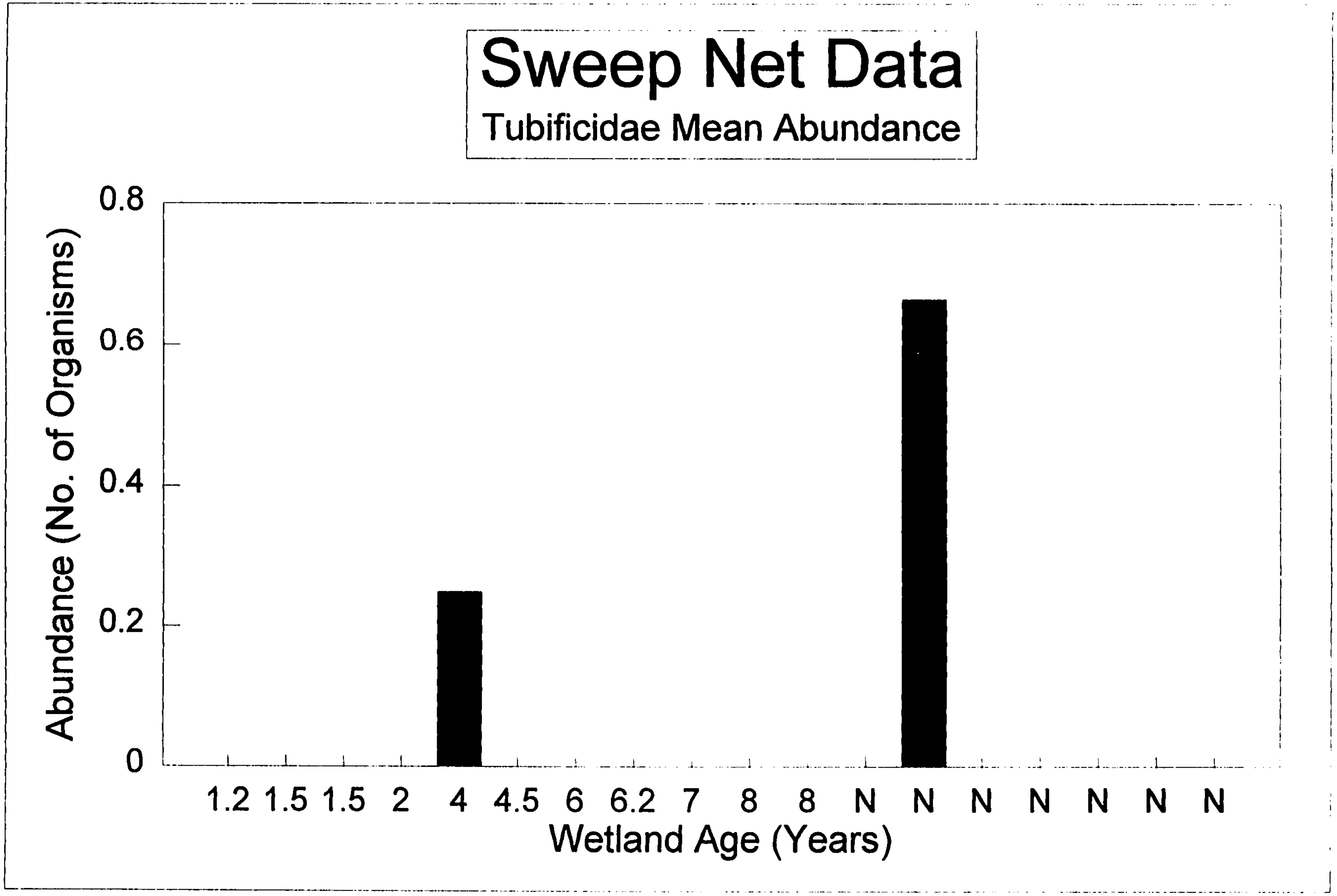

Sweep Net Data
Tubificidae Mean Abundance
Abundance (No. of Organisms)
0.8
0.6
0.4
0.2
0
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
Wetland Age (Years)

Figure 11. Abundance of Naididae (No./M^2) in constructed and natural freshwater marshes in central Florida--Core data.

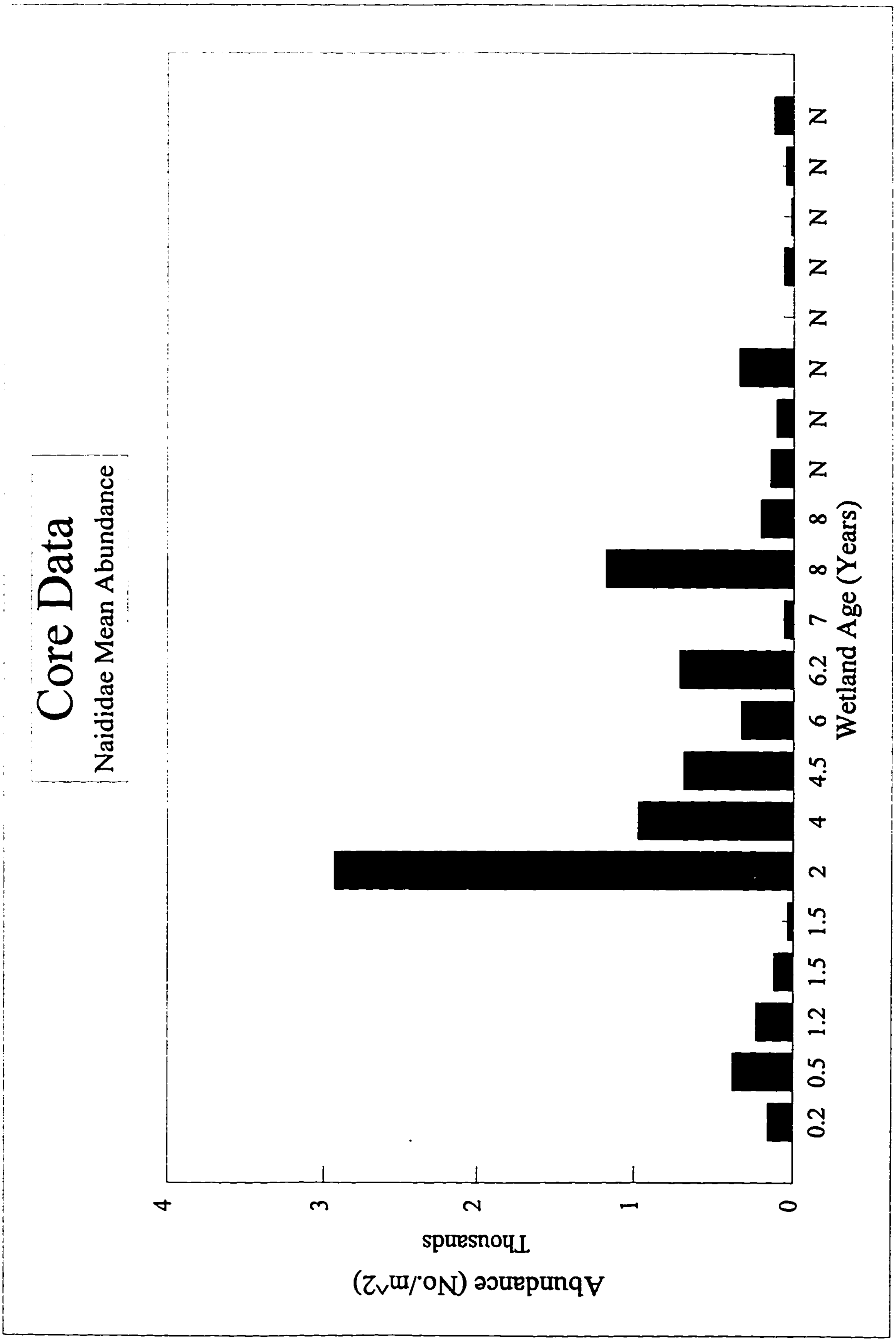

Core Data
Naididae Mean Abundance
Abundance (No./m^2)
Thousands
0
1
2
3
4
0.2
0.5
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
N
Wetland Age (Years)

Figure 12. Abundance of Naididae in constructed and natural freshwater marshes in central Florida--Sweep net data.

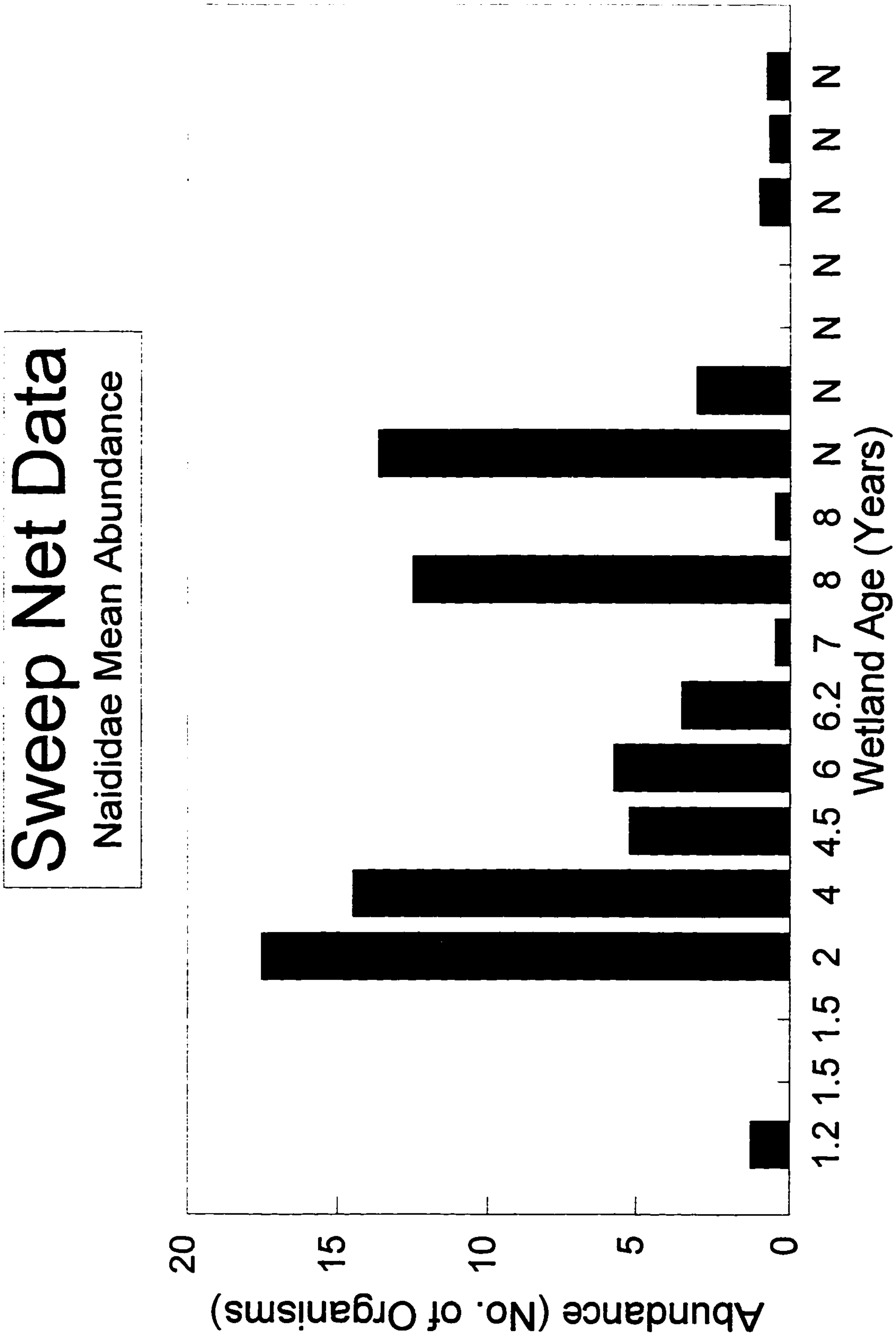

Sweep Net Data
Naididae Mean Abundance
Abundance (No. of Organisms)
0
5
10
15
20
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
N
Wetland Age (Years)

Figure 13. Abundance of Lumbriculidae (No./M^2) in constructed and natural freshwater marshes in central Florida--Core data.

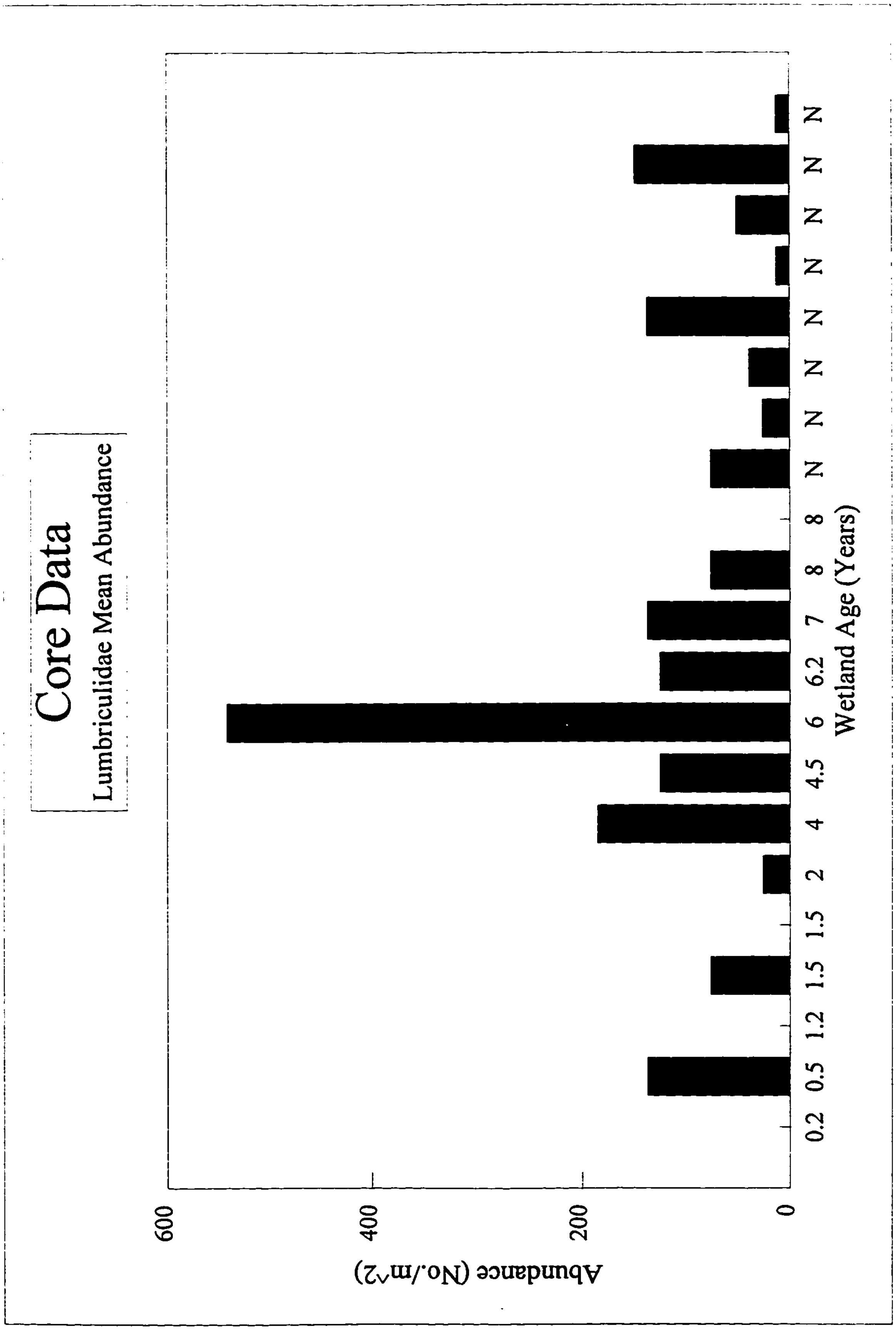
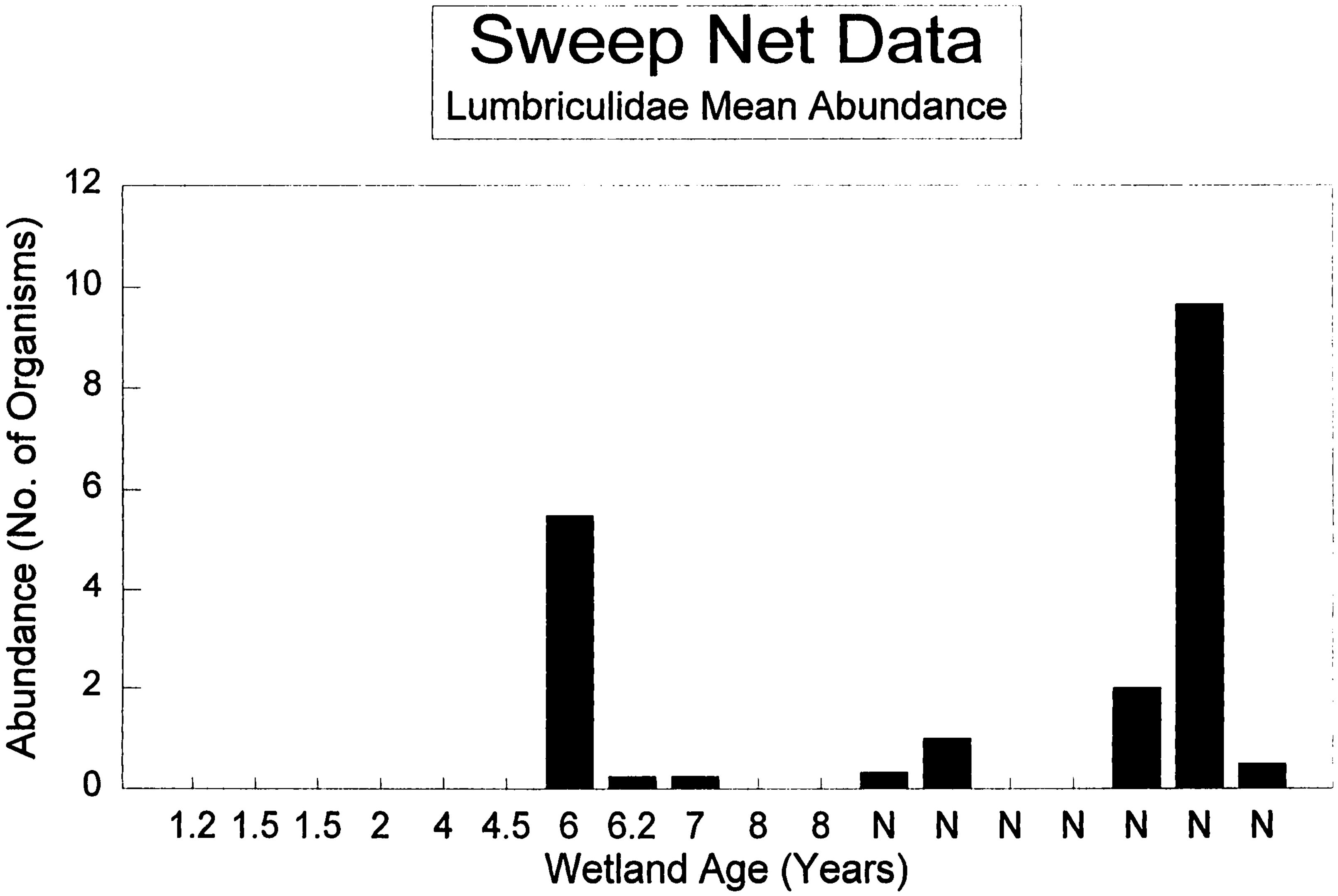

Core Data
Lumbriculidae Mean Abundance
Abundance (No./m^2)
600
400
200
0
0.2
0.5
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
N
Wetland Age (Years)

Figure 14. Abundance of Lumbriculidae in constructed and natural freshwater marshes in central Florida--Sweep net data.


Sweep Net Data
Lumbriculidae Mean Abundance
Abundance (No. of Organisms)
0
2
4
6
8
10
12
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
Wetland Age (Years)

Crustacea (Amphipods and Isopods)

Crustacean abundance is depicted in Figures 15, 16, 17, and 18. Numerically dominant crustaceans included the amphipods, *Hyalella azteca* (Figure 19) and *Crangonyx* cf. *floridanus* (Figure 20), and the isopod, *Caecidotea* sp. The latter two taxa were collected almost exclusively in natural wetlands. *Hyalella* populations reached highest levels in constructed marshes. Reasons for these marked differences in distribution among wetlands are unclear. Females of Hylella are capable of producing multiple broods, giving them an advantage in newly formed habitats (Pennak 1989).

Caecidotea sp. and *C.* cf. *floridanus* may have some competitive advantage in the more acidic natural wetlands. Bousfield (1963) first reported *C.* cf. *floridanus* from Florida, where it is known to occur in swamps, ponds, and cave pools. Breeding possibly occurs throughout the year (Holsinger 1972). Some species of *Crangonyx* are thought to survive drought by burrowing into the sediments (Pennak 1989).

It is not possible to give detailed information on the ecology of Caecidotea sp. without accurate identification at the species level. Unfortunately, sexually mature specimens were not collected, making an accurate species determination difficult using morphological characteristics. However, based on habitat preference and known geographical distribution, the species collected is probably *Caecidotea*

Figure 15. Abundance of Amphipoda (No./M^2) in constructed and natural freshwater marshes in central Florida--Core data.

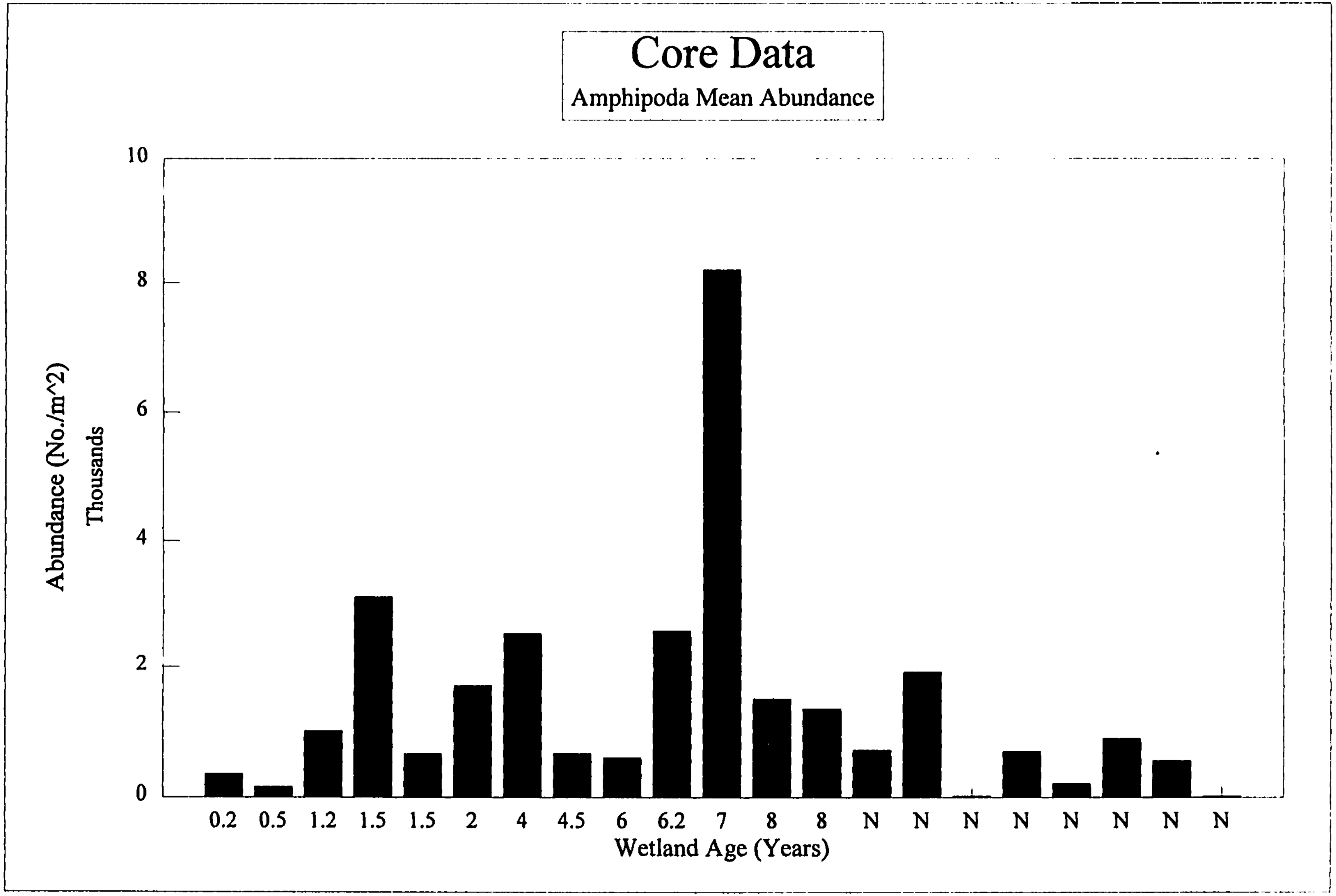

Core Data
Amphipoda Mean Abundance
Abundance (No./m^2)
Thousands
10
8
6
4
2
0
0.2
0.5
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
N
Wetland Age (Years)

Figure 16. Abundance of Amphipoda in constructed and natural freshwater marshes in central Florida--Sweep net data.

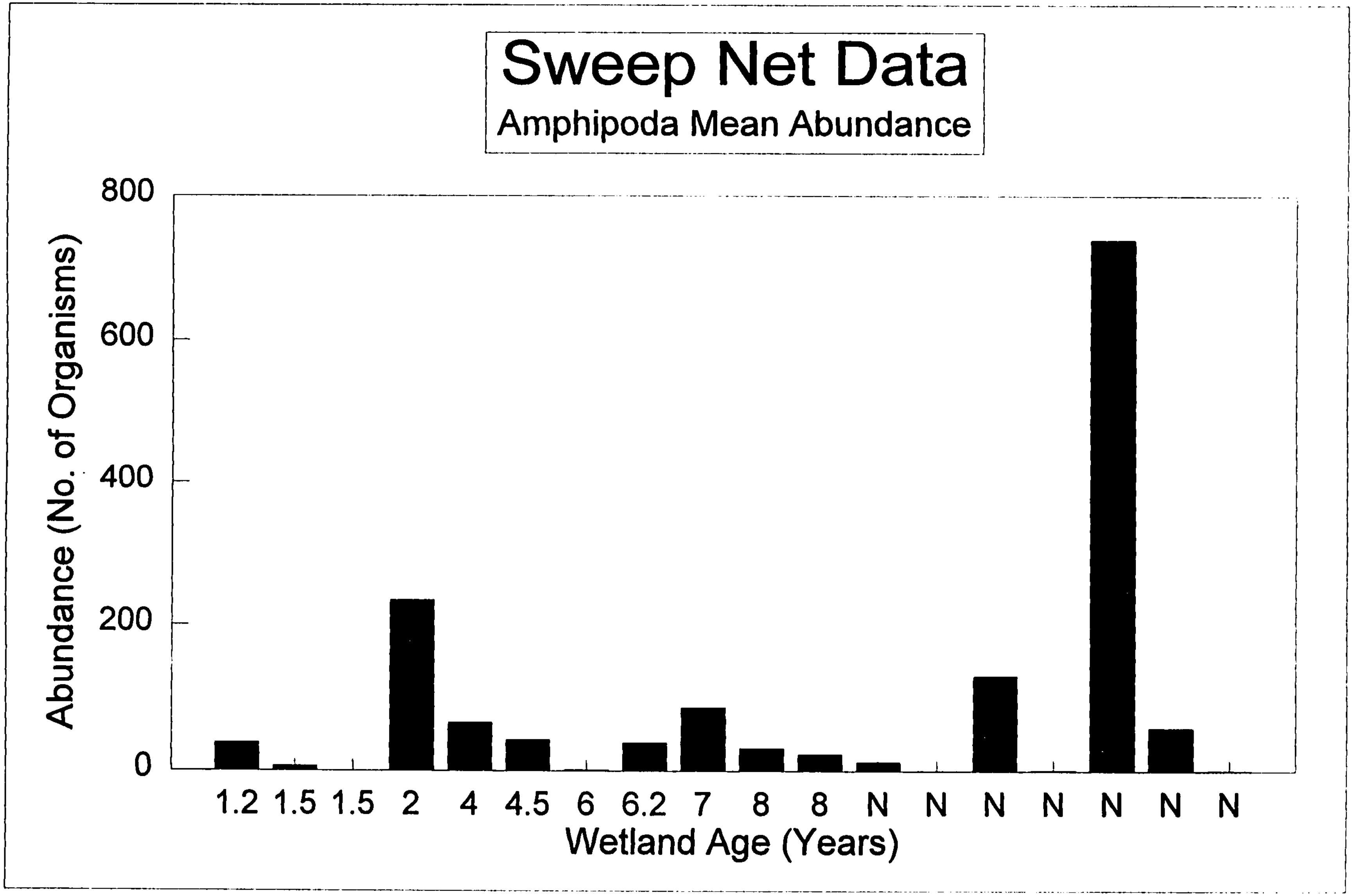

Sweep Net Data
Amphipoda Mean Abundance
Abundance (No. of Organisms)
800
600
400
200
0
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
Wetland Age (Years)

Figure 17. Abundance of Isopoda (No./M^2) in constructed and natural freshwater marshes in central Florida--Core data.

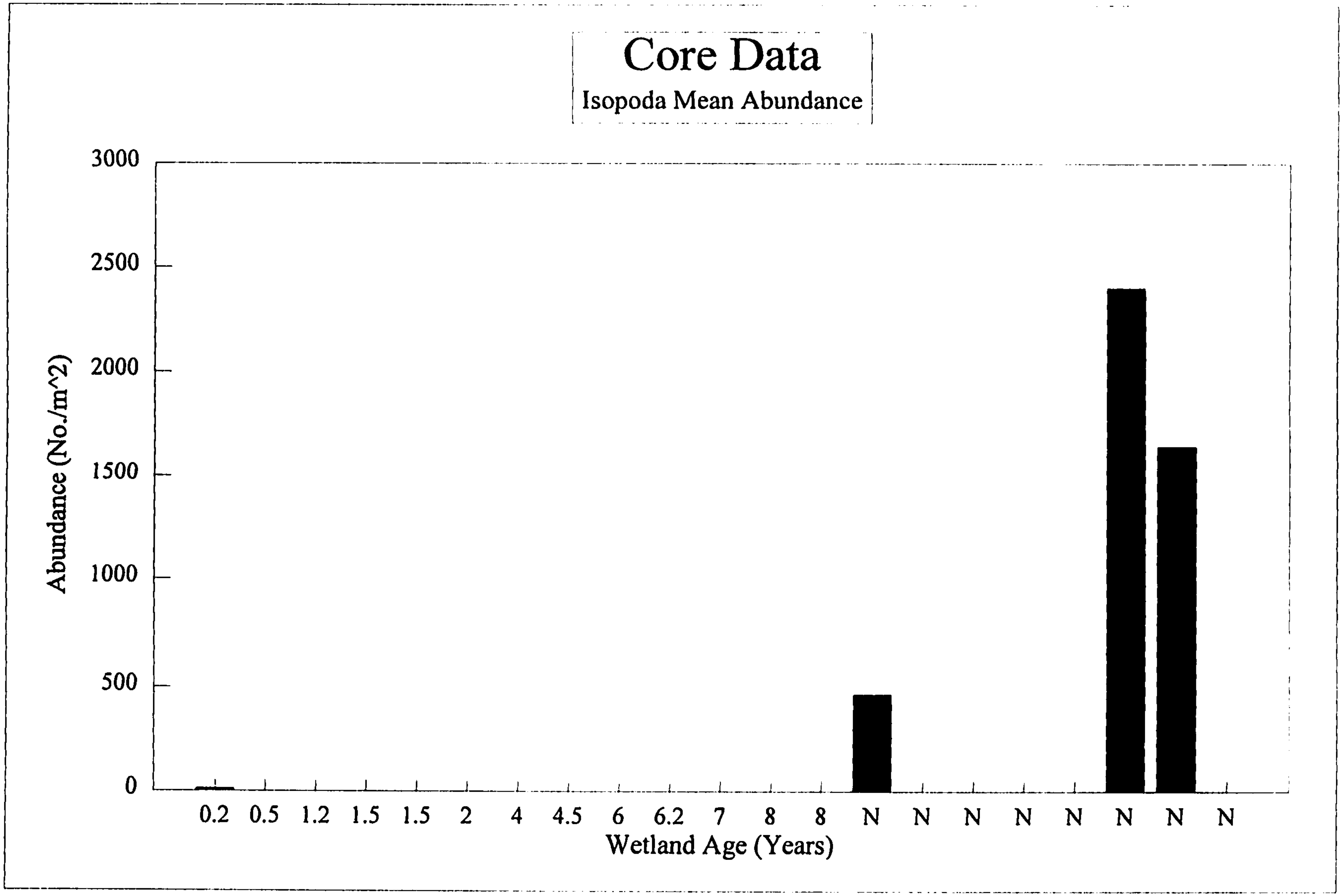

Core Data
Isopoda Mean Abundance
Abundance (No./m^2)
3000
2500
2000
1500
1000
500
0
0.2
0.5
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
N
Wetland Age (Years)

Figure 18. Abundance of Isopoda in constructed and natural freshwater marshes in central Florida--Sweep net data.

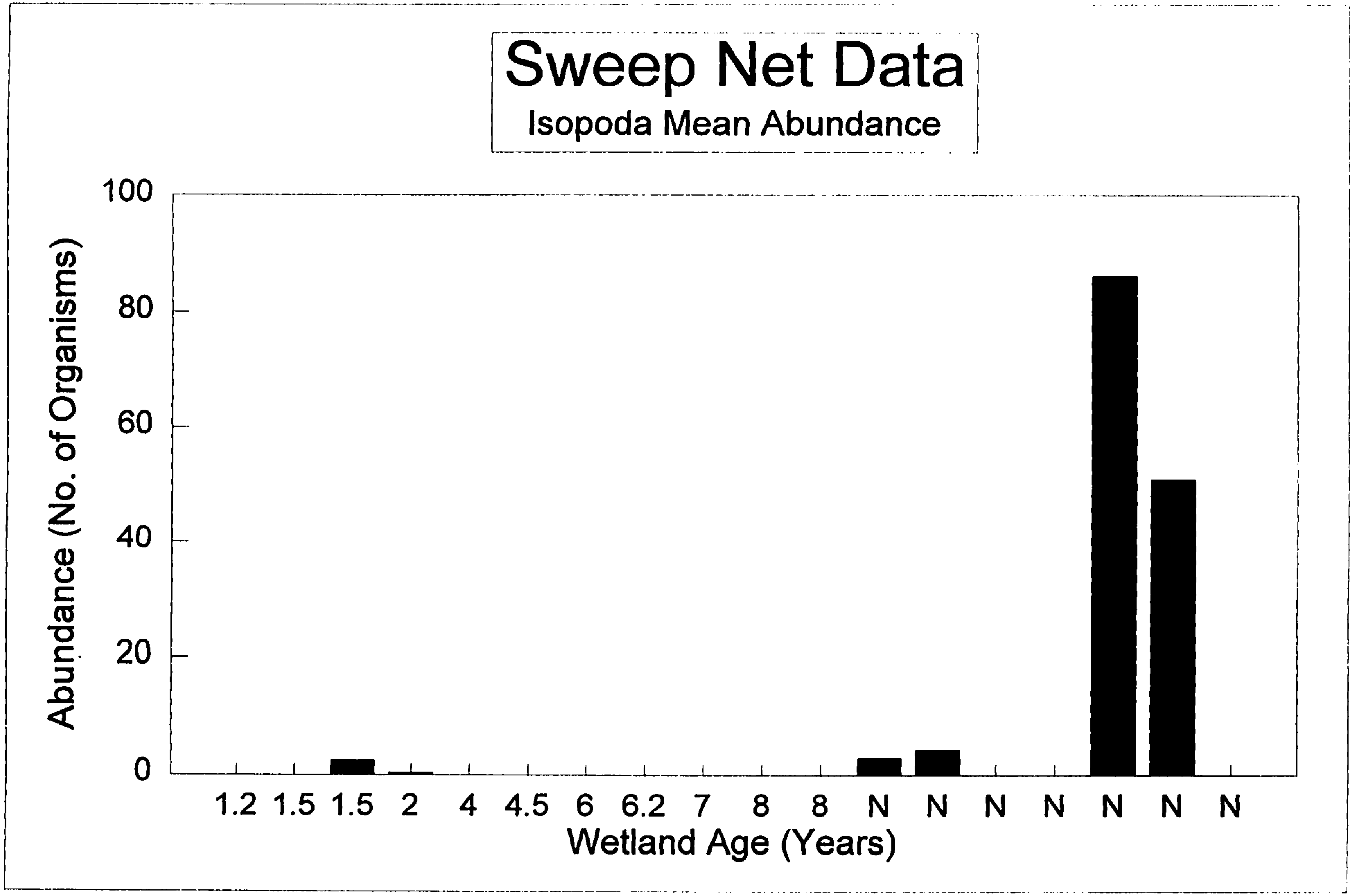

Sweep Net Data
Isopoda Mean Abundance
Abundance (No. of Organisms)
100
80
60
40
20
0
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
Wetland Age (Years)

Figure 19. Abundance of Hyalella azteca in constructed and natural freshwater marshes in central Florida--Sweep net data.

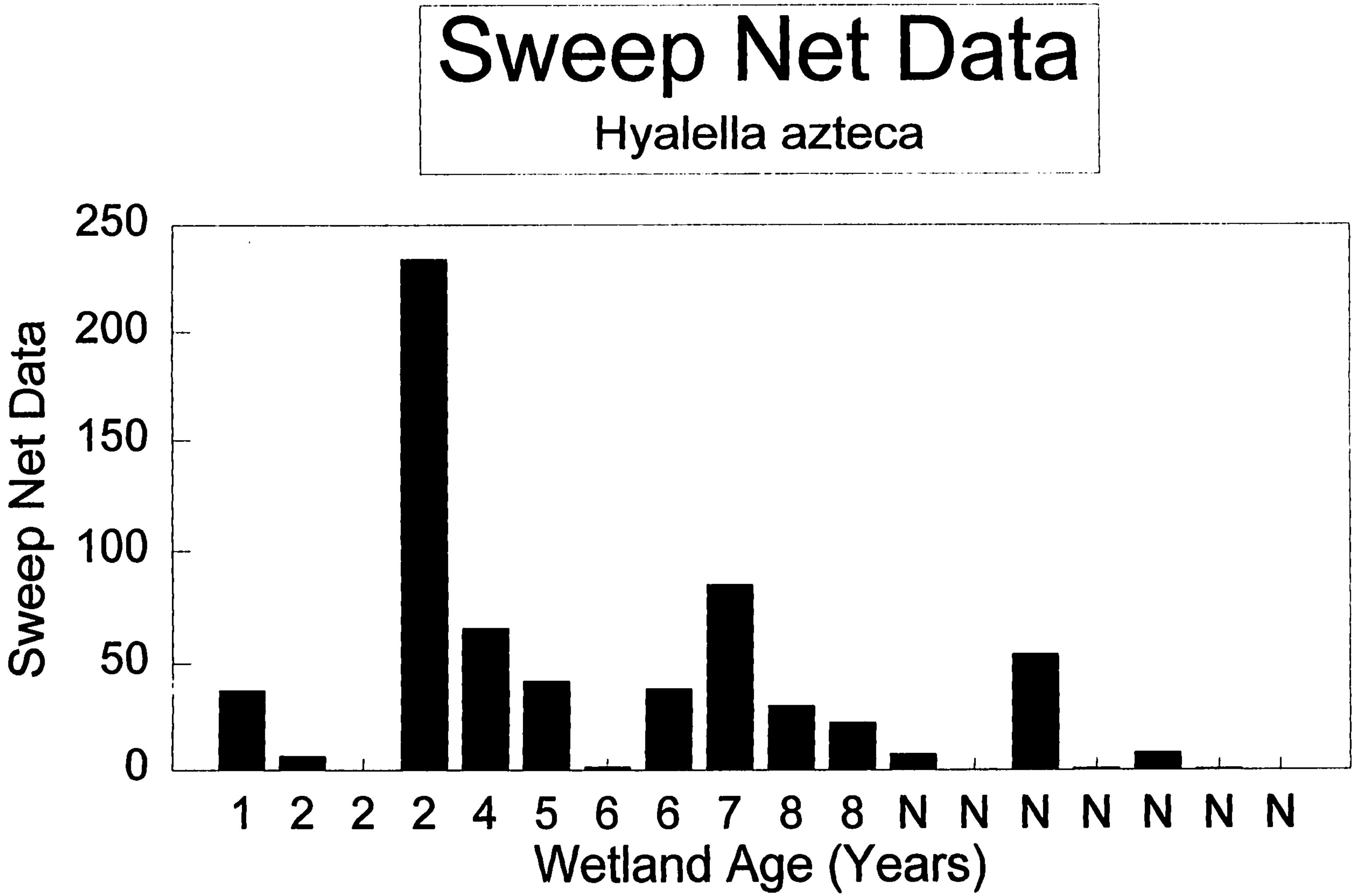
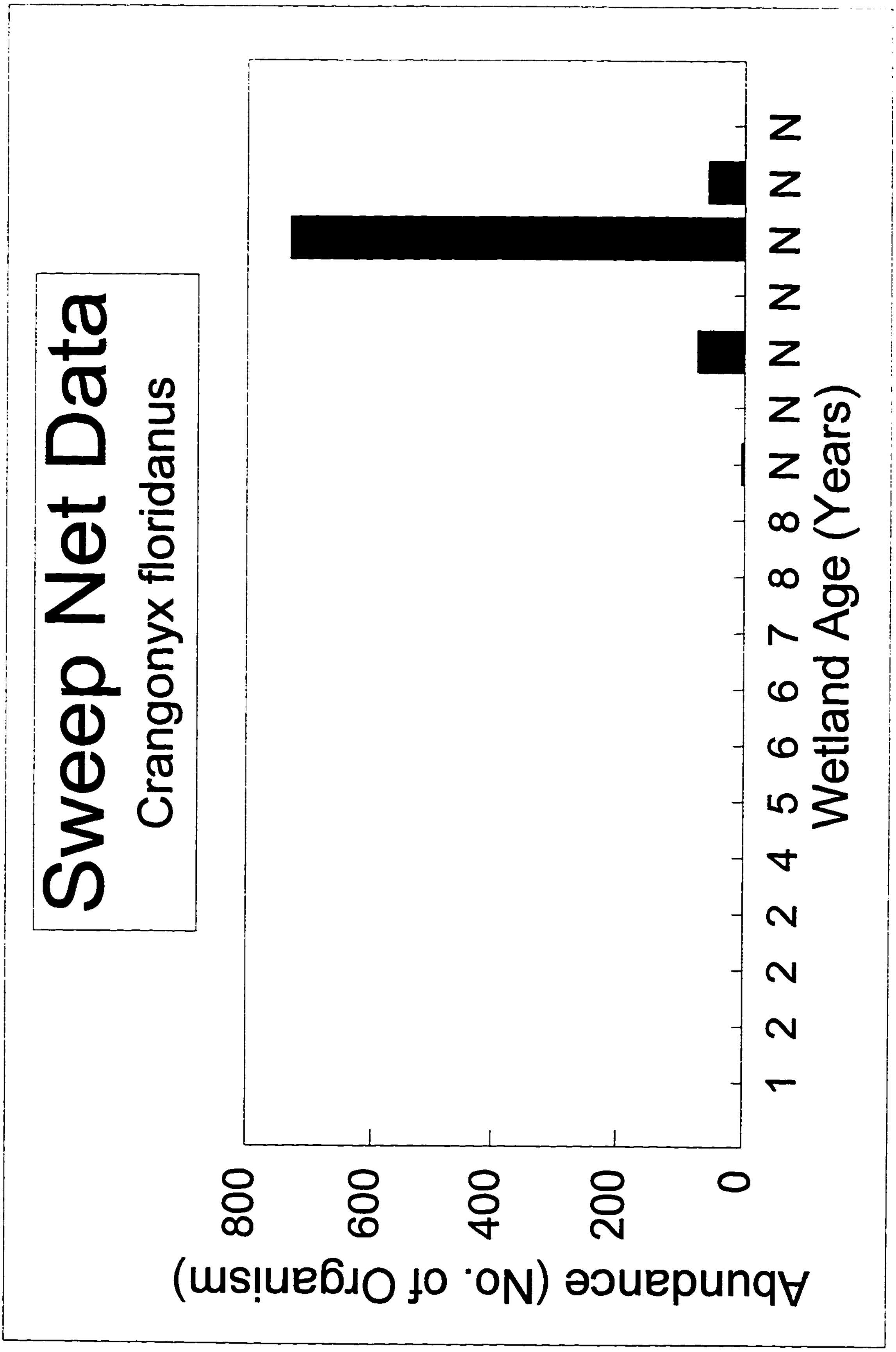

Sweep Net Data
Hyalella azteca
Sweep Net Data
0
50
100
150
200
250
1
2
2
2
4
5
6
6
7
8
8
N
N
N
N
N
N
N
Wetland Age (Years)

Figure 20. Abundance of Crangonyx cf. floridanus in constructed and natural freshwater marshes in central Florida--Sweep net data.


Sweep Net Data
Crangonyx floridanus
Abundance (No. of Organism)
800
600
400
200
0
1
2
2
2
4
5
6
6
7
8
8
N
N
N
N
N
N
N
Wetland Age (Years)

obtusus. This species is known from swamps, roadside ditches, temporary ponds, rivers, and small streams in Florida, Georgia, and Louisiana (Williams 1976). There is no known information regarding the ecology of this species in the published literature.

Gibbons and Mackie (1991) reported elevated reproduction of *Hyalella* in habitats of increasing sulphate, calcium, hardness, alkalinity, conductivity, seston, sediment particle size, and organic fraction of fine sediments. These characteristics are known to increase with eutrophication. It is quite possible that *Hyalella* is more prevalent in constructed wetlands due to their high trophic state (based on chlorophyll a). Grapentine and Rosenberg (1992) reported that *Hyalella* populations declined in Canadian lakes with pH less than 5.8 and that no organisms were observed in lakes with pH less than 5.4. During the current study, *Hyalella* were collected in waters with pH as low as 4.6. Furthermore, they were observed to be relatively abundant in one natural wetland (R4) with a pH of 5.2. *Hyalella* are perhaps more tolerant to acidic conditions in the subtropics than in temperate regions.

Calcium is a major component of shell formation in molluscs and can influence the distribution of some crustaceans (Wetzel 1983). Calcium bioavailability may explain in part the differences in temperate and subtropical pH tolerance ranges. Limestone and soils rich in calcium are common in the study area. Calcium concentrations were not measured during the current study. Intensive laboratory and field experimentation such as that conducted by Grapentine and Rosenberg (1992) may be required to gain a more complete understanding of causative relationships influencing distribution of these species in Florida wetlands.

Hyalella, *Crangonyx*, and *Caecidotea* are all omnivorous scavengers, feeding on both living and dead plants and animals (Pennak 1989). All three species exist in the natural wetlands studied, but only *Hyalella* is important in constructed wetlands. The strong dominance of *Hyalella* in constructed wetlands suggests that it is replacing/filling the trophic niches that *Caecidotea* and *Crangonyx* hold in natural wetlands. This replacement of ecological/trophic function suggests that invertebrate communities within constructed and natural wetlands may differ structurally due to varying water quality (i.e., pH) or other environmental conditions, while serving similar ecological functions.

Odonata (Dragonflies and Damselflies)

Odonate populations appear to be as abundant and as rich in taxa in constructed wetlands as they are in natural wetlands, with the exception of wetlands that were less than two years old (Figures 21 and 22). These observations support the hypothesis that organisms with longer life cycles are less likely to proliferate during the earliest stages of

Figure 21. Abundance of Odonata (No./M^2) in constructed and natural freshwater marshes in central Florida--Core data.

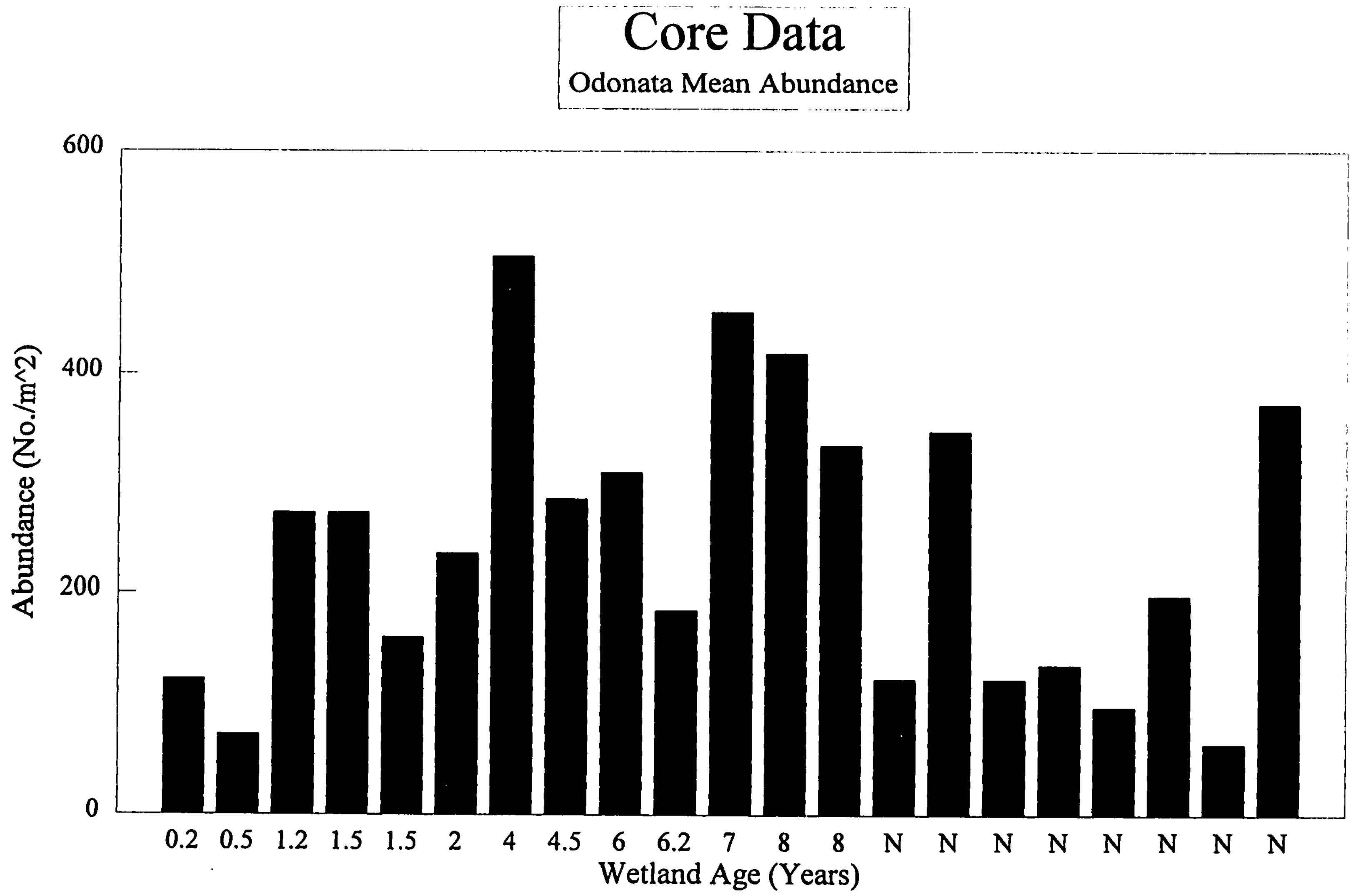
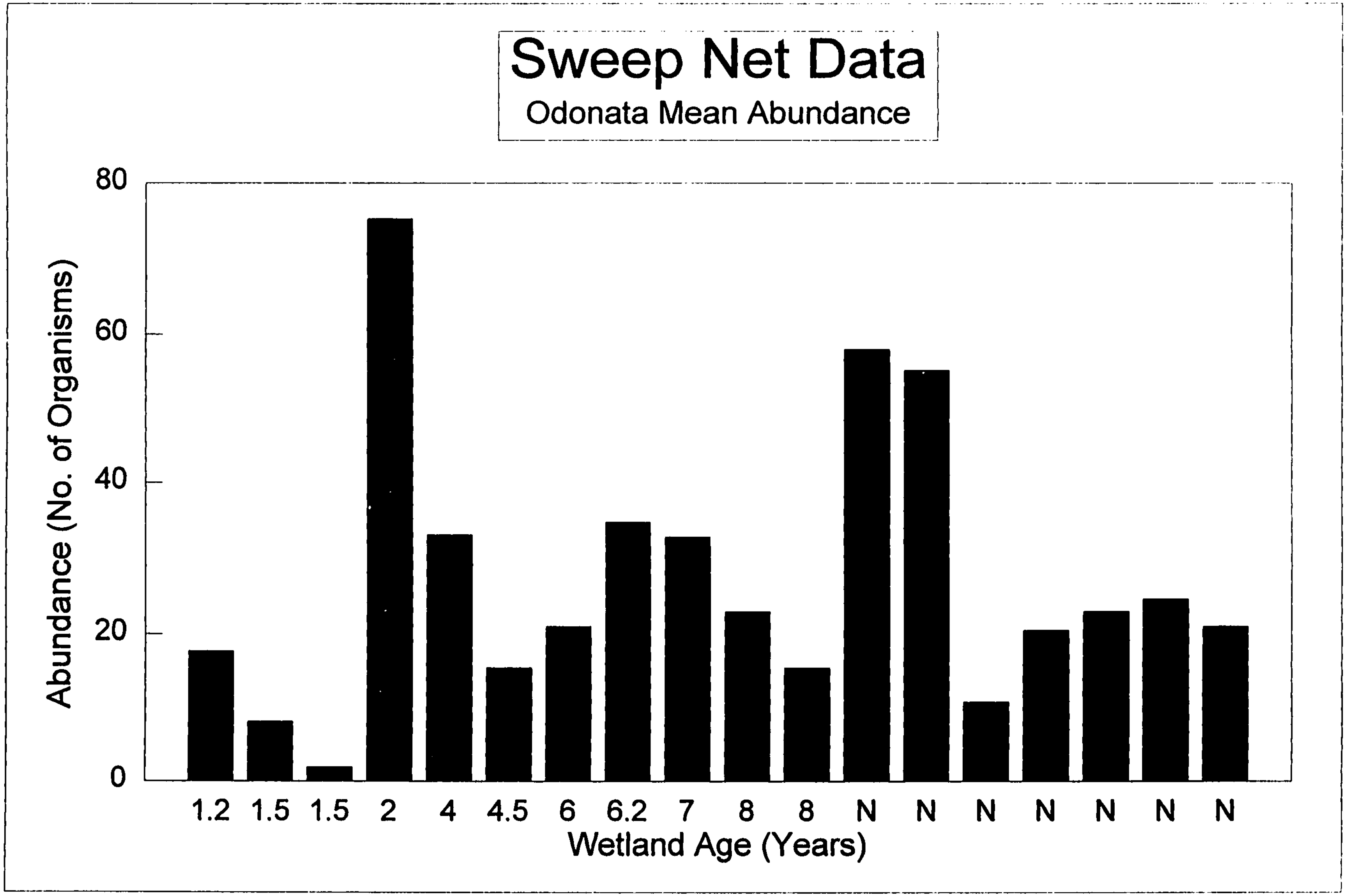

Core Data
Odonata Mean Abundance
Abundance (No./m^2)
600
400
200
0
0.2
0.5
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
N
Wetland Age (Years)

Figure 22. Abundance of Odonata in constructed and natural freshwater marshes in central Florida--Sweep net data.


Sweep Net Data
Odonata Mean Abundance
Abundance (No. of Organisms)
80
60
40
20
0
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
Wetland Age (Years)

constructed wetland development. However, differences between adonate abundance in newly constructed and older constructed were not significant. Common taxa included *Ischnura* spp., *Enallagma* spp., *Erythemis simplicicollis*, *Pachydiplax longipennis*, and *Coryphaeschna ingens*. *Anax junius* and *Erythrodiplax connata* were commonly collected only in natural wetlands.

Coleoptera (Beetles)

Beetles are most effectively collected using a sweep net because they spend a large portion of their lives swimming actively within the water column. Therefore, the following discussion focuses primarily on sweep net data. Coleoptera abundance patterns in core and sweep net samples are illustrated in Figures 23 and 24, respectively. Beetle populations increased with wetland age during the first 1 to 2 years of constructed wetland development. There were no significant differences in abundance between wetland types. Considering core data, constructed wetlands younger than 3 years of age appear to support population levels similar to those of natural wetlands. Significantly more beetle taxa occurred in natural wetlands than in constructed wetlands regardless of sampling method ($p=0.0066$).

Berosus sp. appears to be an important early colonizer of constructed wetlands. Data collected by others support this conclusion (Evans and Sullivan 1984, 1986a), but reasons for the early success of *Berosus* are unknown. It is possible

Figure 23. Abundance of Coleoptera (No./M^2) in constructed and natural freshwater marshes in central Florida--Core data.

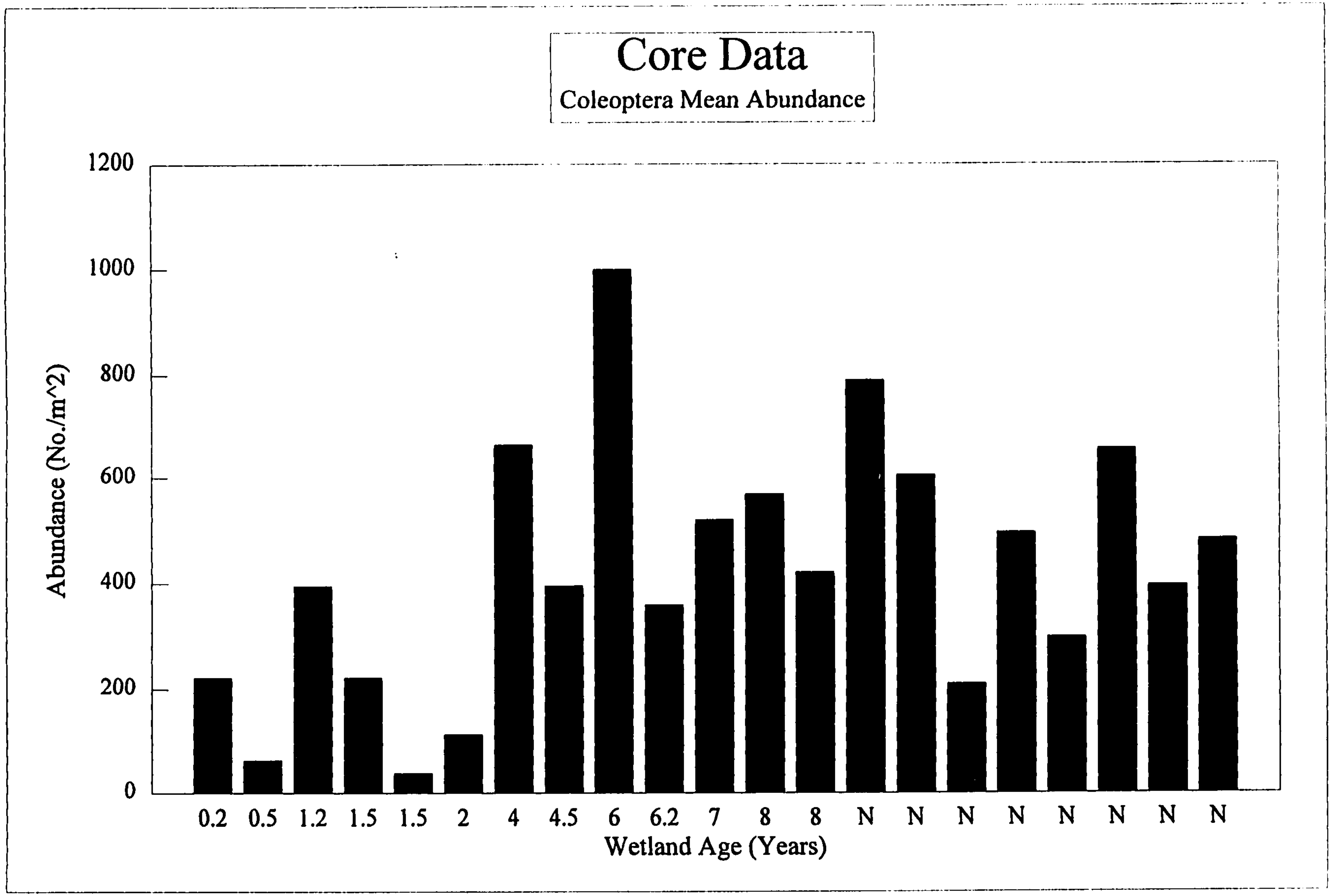
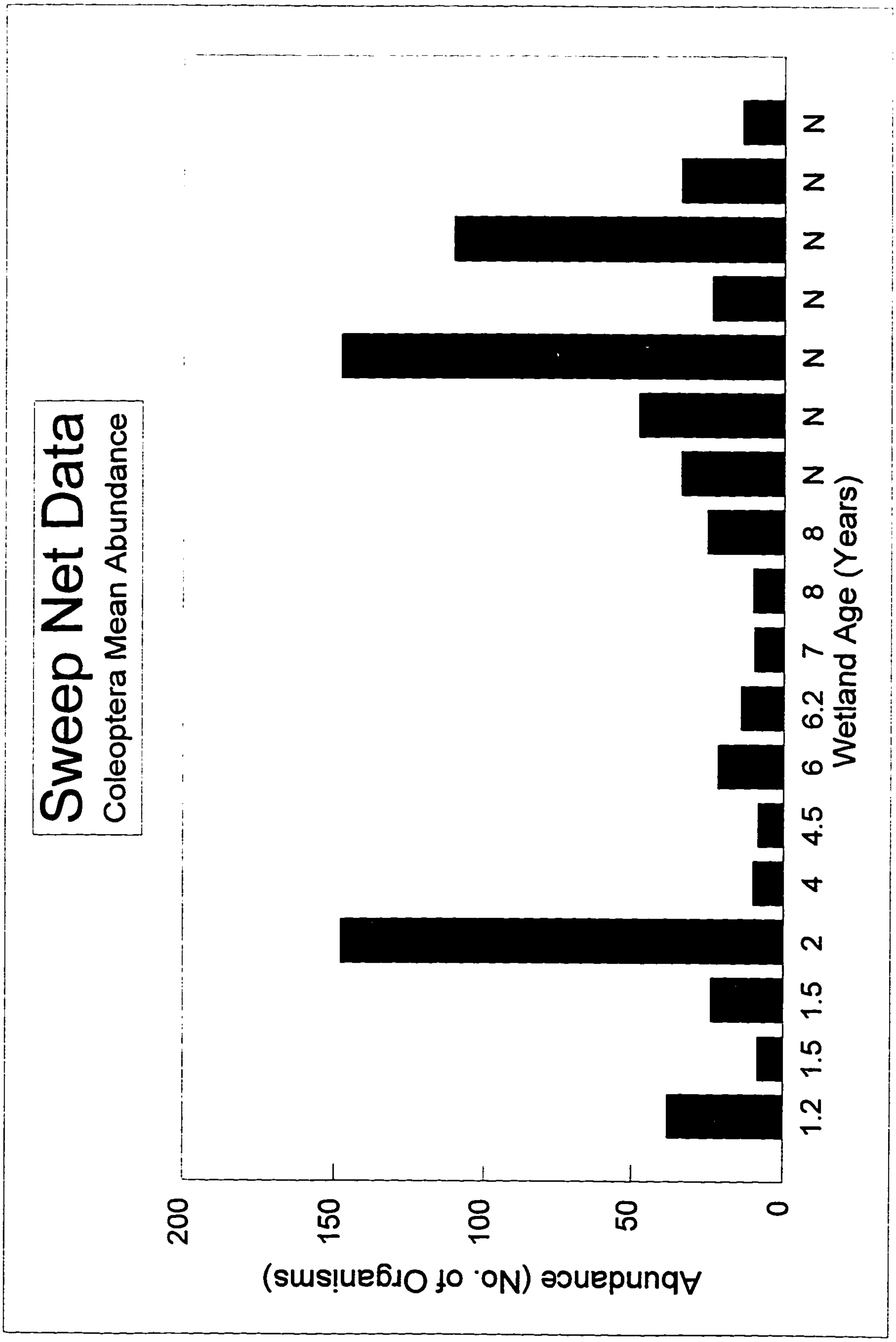

Core Data
Coleoptera Mean Abundance
Abundance (No./m^2)
1200
1000
800
600
400
200
0
0.2
0.5
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
N
Wetland Age (Years)

Figure 24. Abundance of Coleoptera in constructed and natural freshwater marshes in central Florida--Sweep net data.


Sweep Net Data
Coleoptera Mean Abundance
Abundance (No. of Organisms)
200
150
100
50
0
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
Wetland Age (Years)

that this genus is a strong flier and undergoes frequent migratory flights, enabling adults to rapidly colonize newly constructed marshes.

Celina spp. and *Scirtes* spp. tended to be more abundant in OC wetlands than in NC and N wetlands, while *Cybister* and *Coptotomus* were most abundant in constructed wetlands. *Laccophilus* sp. was commonly collected at the most acidic natural sites and was rarely recorded at constructed sites. *Copelatus* and *Derallus* occurred in OC and N wetlands but were rare or absent in NC wetlands. *Pachydrus* and *Paracymus* were only collected from natural wetlands, as were *Desmopachria*, a genus well-adapted to life in ephemeral wetlands. Most other genera were evenly distributed among the wetland sites.

It appears that various beetle genera have "preferences" with regard to natural and constructed wetlands. The implication is that some species of beetles could serve as useful biological indicators in measuring wetland reclamation success.

Ephemeroptera (Mayflies)

Caenis and *Callibaetis* were the only two mayfly genera collected during the study (Figures 25 and 26). Most other mayflies require consistently higher dissolved oxygen concentrations than are characteristic of freshwater marshes (Berner and Pescador 1988). There was no discernible trend of mayfly abundance with constructed wetland age, but *Caenis diminuta*, like the beetle *Berosus*, appears to be an important

Figure 25. Abundance of Ephemeroptera (No./M^2) in constructed and natural freshwater marshes in central Florida--Core data.

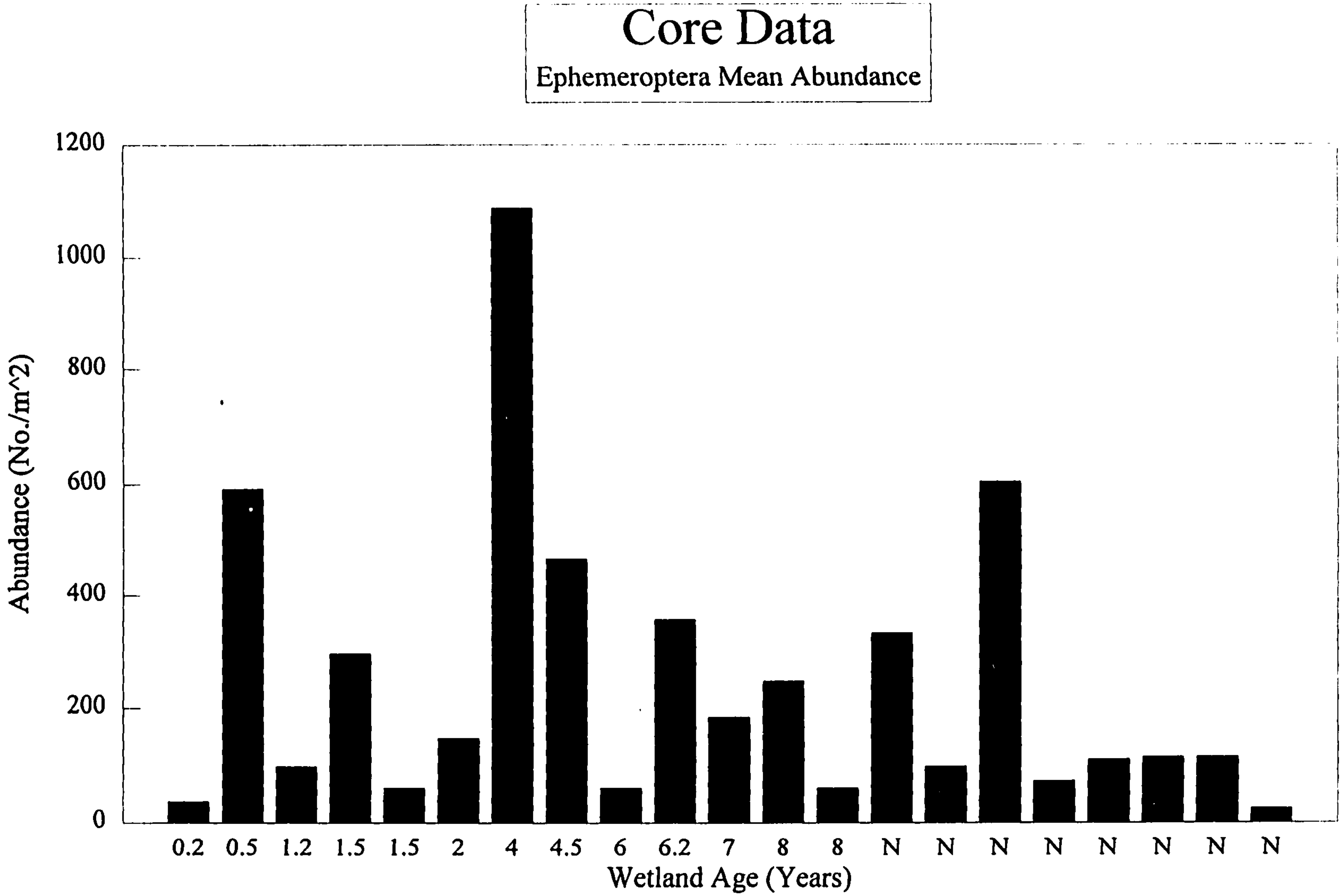
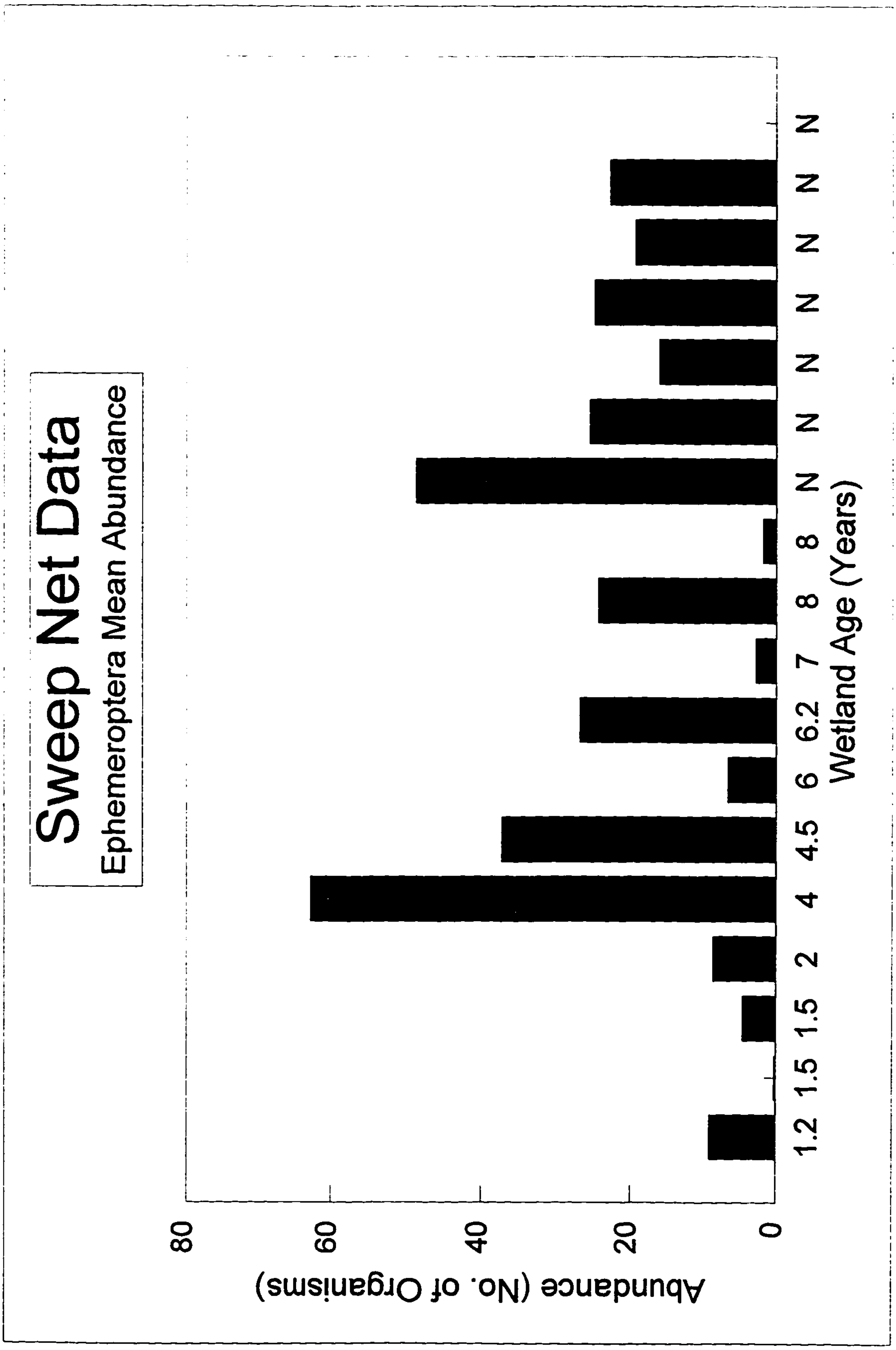

Core Data
Ephemeroptera Mean Abundance
Abundance (No./m^2)
1200
1000
800
600
400
200
0
0.2
0.5
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
N
Wetland Age (Years)

Figure 26. Abundance of Ephemeroptera in constructed and natural freshwater marshes in central Florida--Sweep net data.


Sweep Net Data
Ephemeroptera Mean Abundance
Abundance (No. of Organisms)
0
20
40
60
80
Wetland Age (Years)
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
N

early colonizer of constructed marshes. These results support the findings of previous studies (Evans and Sullivan 1984; Evans 1989).

Chironomidae (Nonbiting Midges)

Chironomini

Within the core data, no discernible pattern in abundance with wetland age was evident, and there were no significant differences in abundance or taxa richness among the wetland types at the Tribe level (Figure 27).

Some species such as *Dicrotendipes leucoscelis* and *Kiefferulus dux* reached highest population levels in natural marshes. In contrast, *Glyptotendipes*, *Goeldichironomus carus*, and *Goeldichironomus amazonicus* reached peak abundances in constructed wetlands. *Polypedilum trigonus* occurred at relatively low population densities (< 50 per square meter) in constructed wetlands less than 3 years old, whereas natural wetlands supported 2 to 24 times that density. *Polypedilum tritum* and *Polypedilum illinoense* did not exhibit discernible trends with constructed wetland age.

Within the sweep net data, Chironomini were significantly more abundant in natural wetlands than in constructed wetlands ($p < 0.01$) (Figure 28).

Figure 27. Abundance of Chironomini (No./M^2) in constructed and natural freshwater marshes in central Florida--Core data.

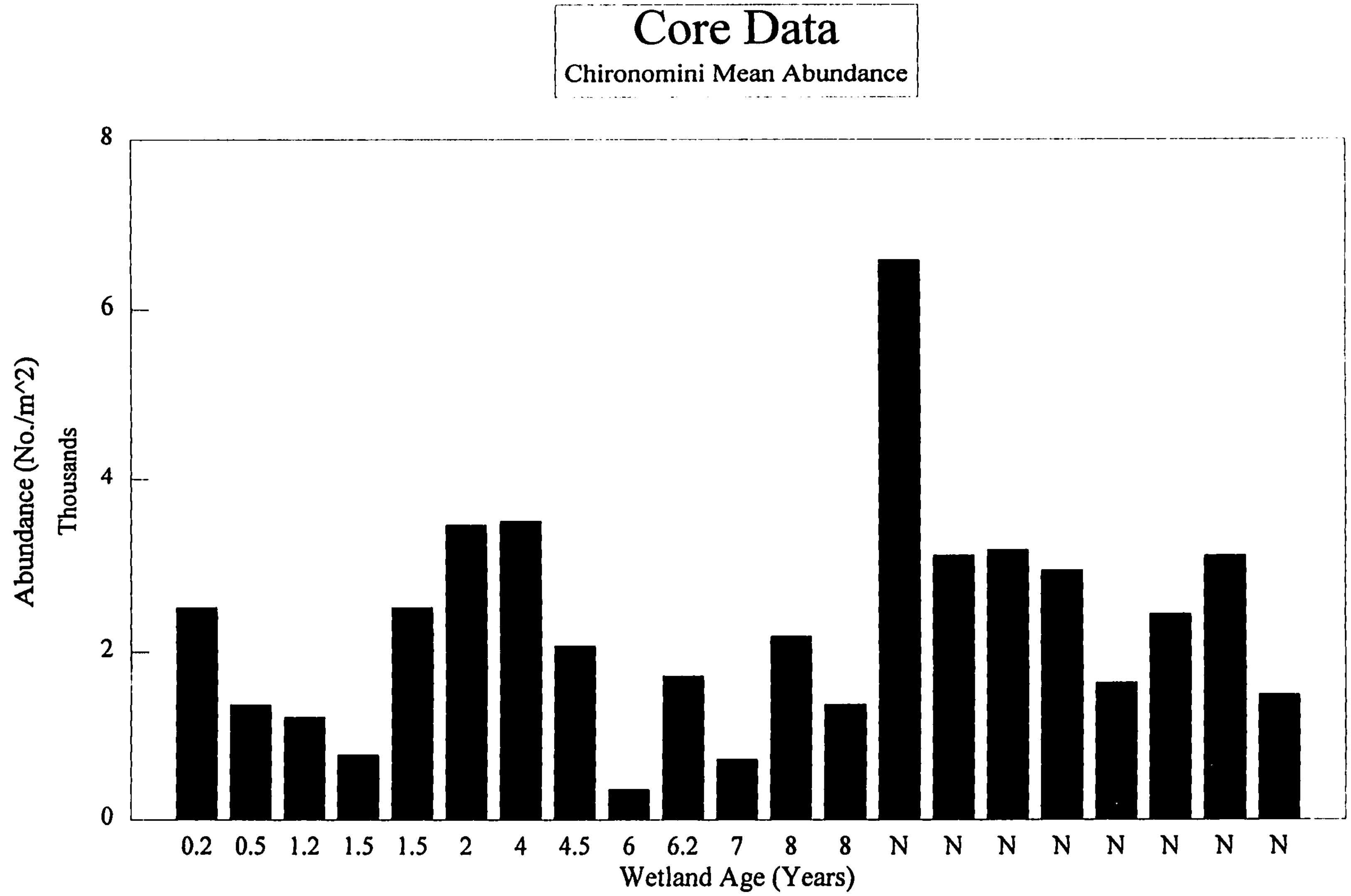
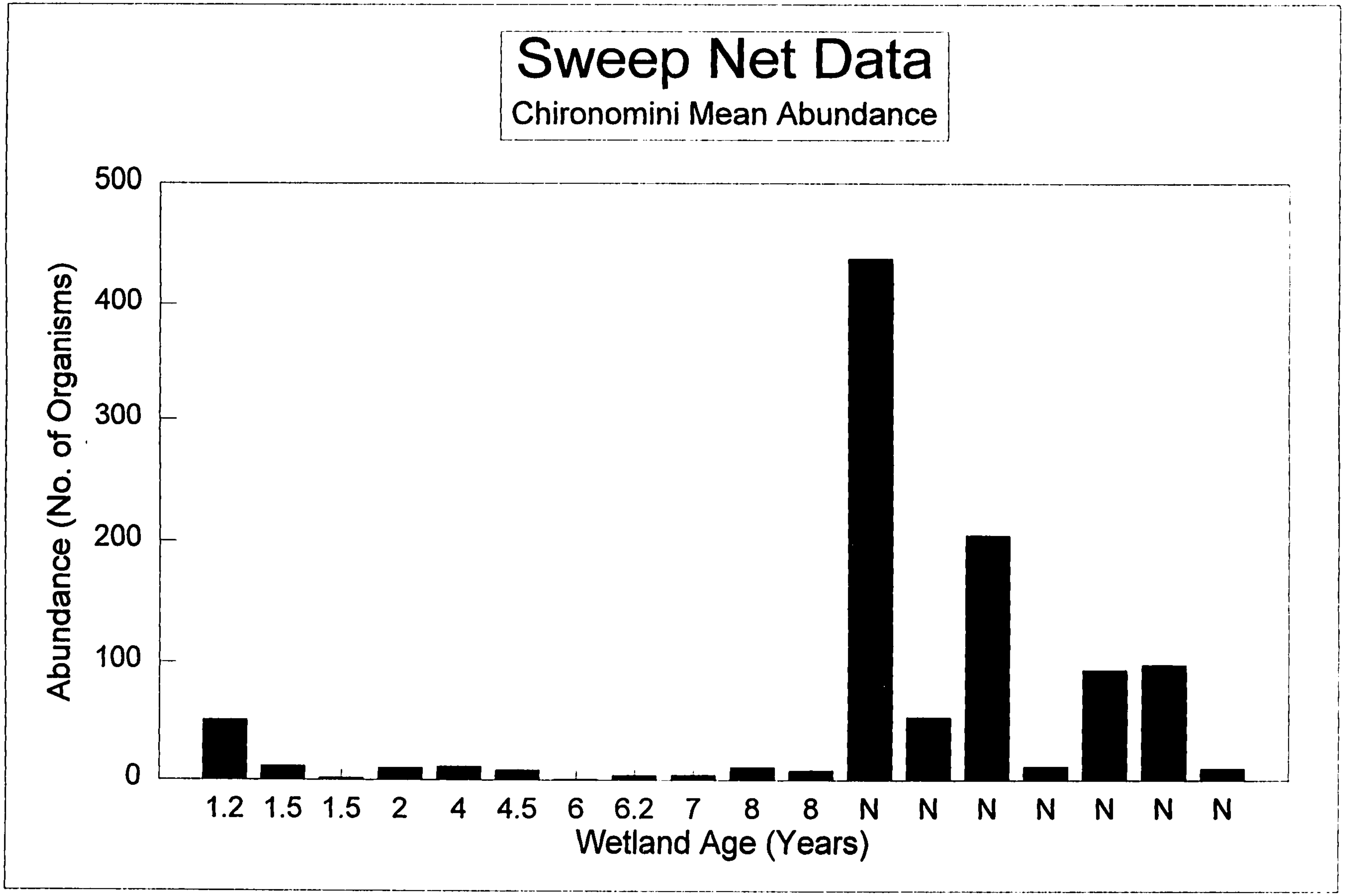

Core Data
Chironomini Mean Abundance
Abundance (No./m^2)
Thousands
8
6
4
2
0
0.2
0.5
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
N
Wetland Age (Years)

Figure 28. Abundance of Chironomini in constructed and natural freshwater marshes in central Florida--Sweep net data.


Sweep Net Data
Chironomini Mean Abundance
Abundance (No. of Organisms)
500
400
300
200
100
0
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
Wetland Age (Years)

Tanytarsini

Tanytarsini in constructed wetlands less than 1 year old were more than twice as abundant as populations in most older constructed wetlands, but there was no significant difference in abundance or taxa richness at the Tribe level (Figures 29 and 30). Abundance peaks in newly constructed marshes consisted primarily of *Nimbocera pinderi* and *Tanytarsus* sp. 4-Rutter, suggesting that they may be important early colonizers.

Orthocladiinae

Both abundance and taxa richness of orthoclads were significantly higher in natural than constructed wetlands (p=0.0003). In natural marsh sediments, orthoclad abundance ranged from approximately 100 to 750 individuals per square meter (Figures 31 and 32). The highest density occurring in constructed marshes was less than 100 individuals per square meter, consisting primarily of *Cricotopus* spp. Dominant taxa in natural marshes included *Limnophyes* sp., *Pseudosmittia* sp., *Psectrocladius* (*Monopsectrocladius*) sp., and *Corynoneura* sp. (Figure 34). The former two taxa commonly occur in semi-terrestrial habitats (Cranston et al. 1983). These taxa are likely to be reliable indicators of hydrological functions of both constructed and natural marshes.

Tanypodinae

Abundance and tax richness in the subfamily Tanypodinae (Figures 33 and 34) were significantly lower in constructed

Figure 29. Abundance of Tanytarsini (No./M^2) in constructed and natural freshwater marshes in central Florida--Core data.

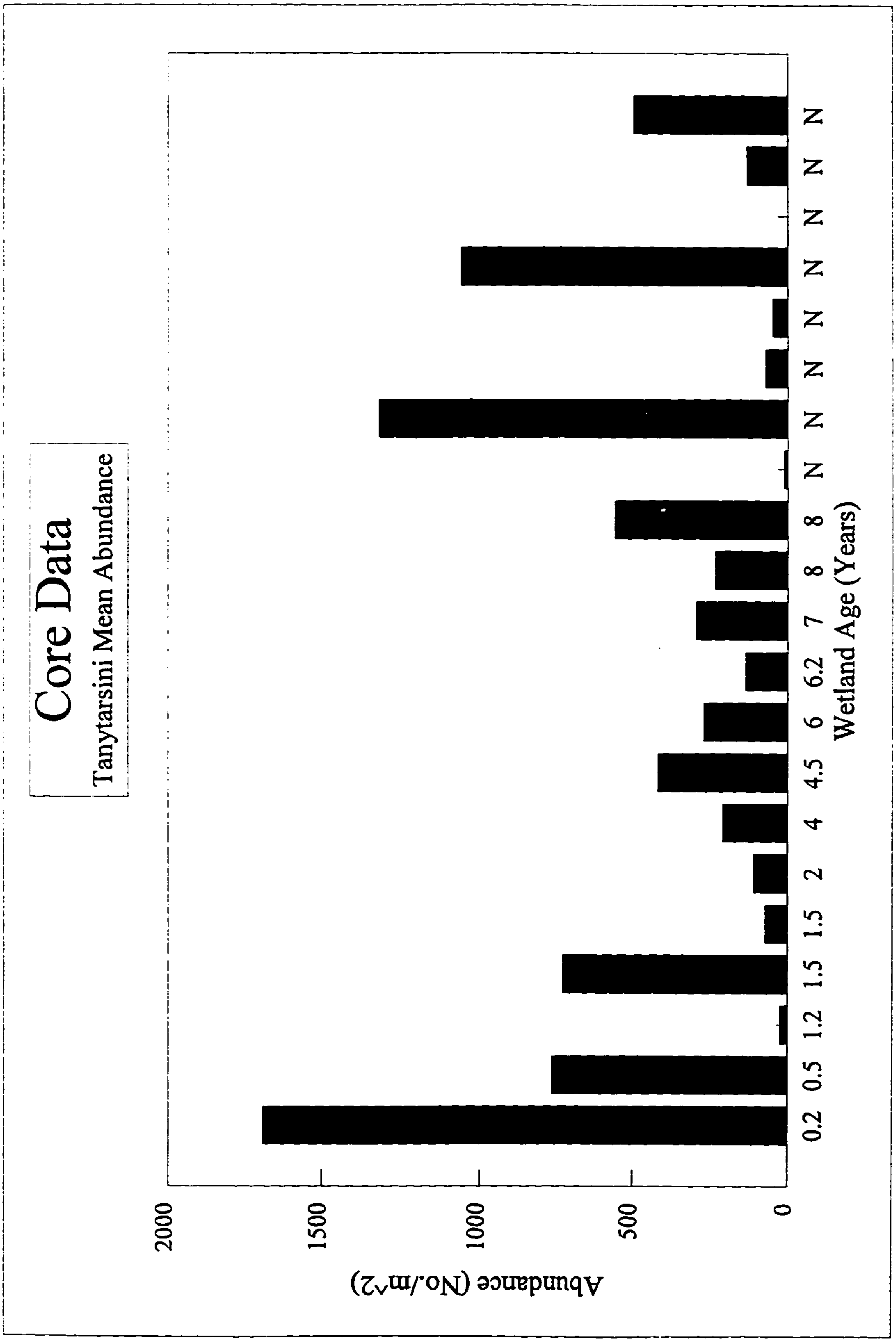

Core Data
Tanytarsini Mean Abundance
Abundance (No./m^2)
2000
1500
1000
500
0
0.2
0.5
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
N
Wetland Age (Years)

Figure 30. Abundance of Tanytarsini in constructed and natural freshwater marshes in central Florida--Sweep net data.

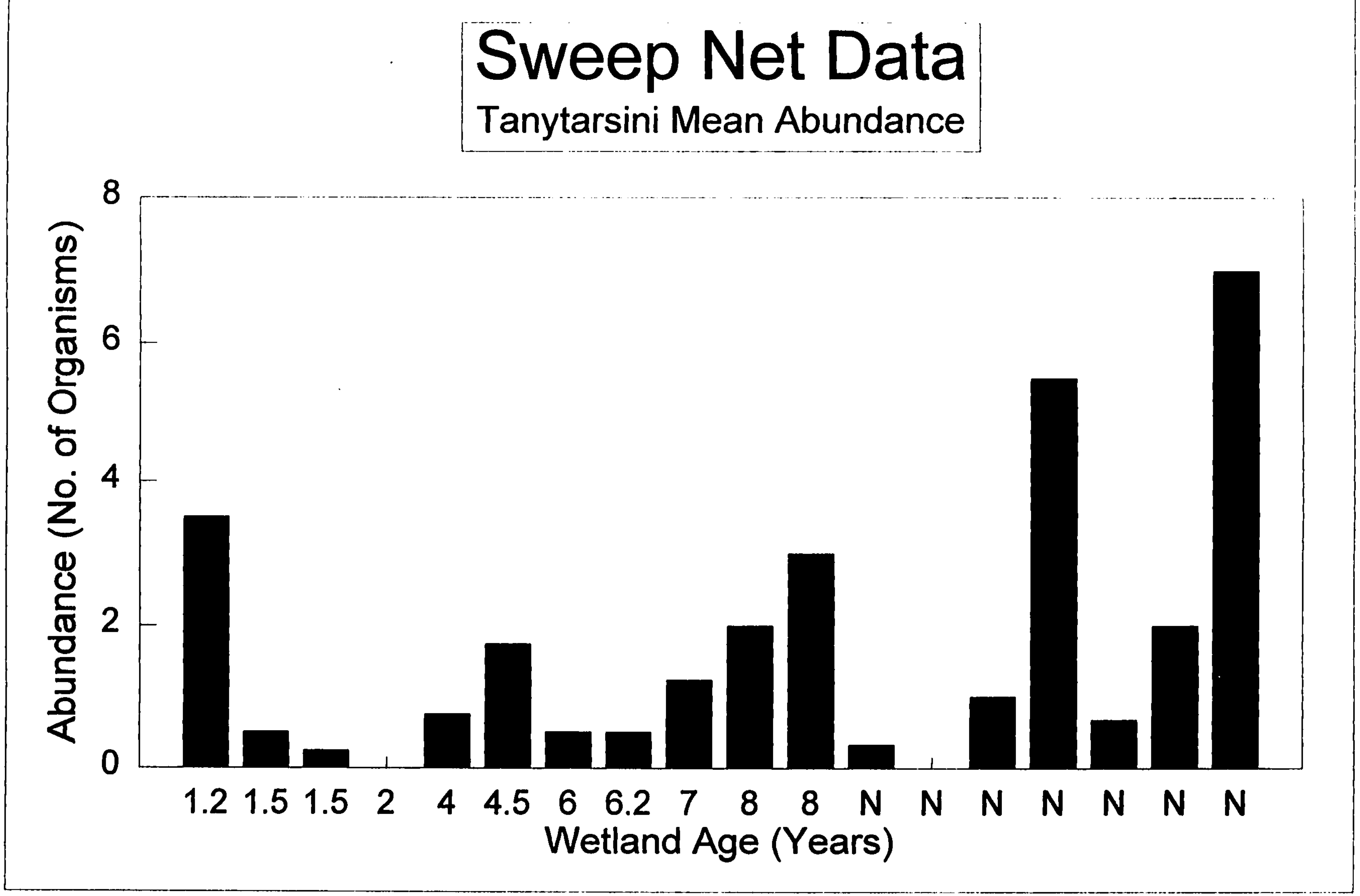
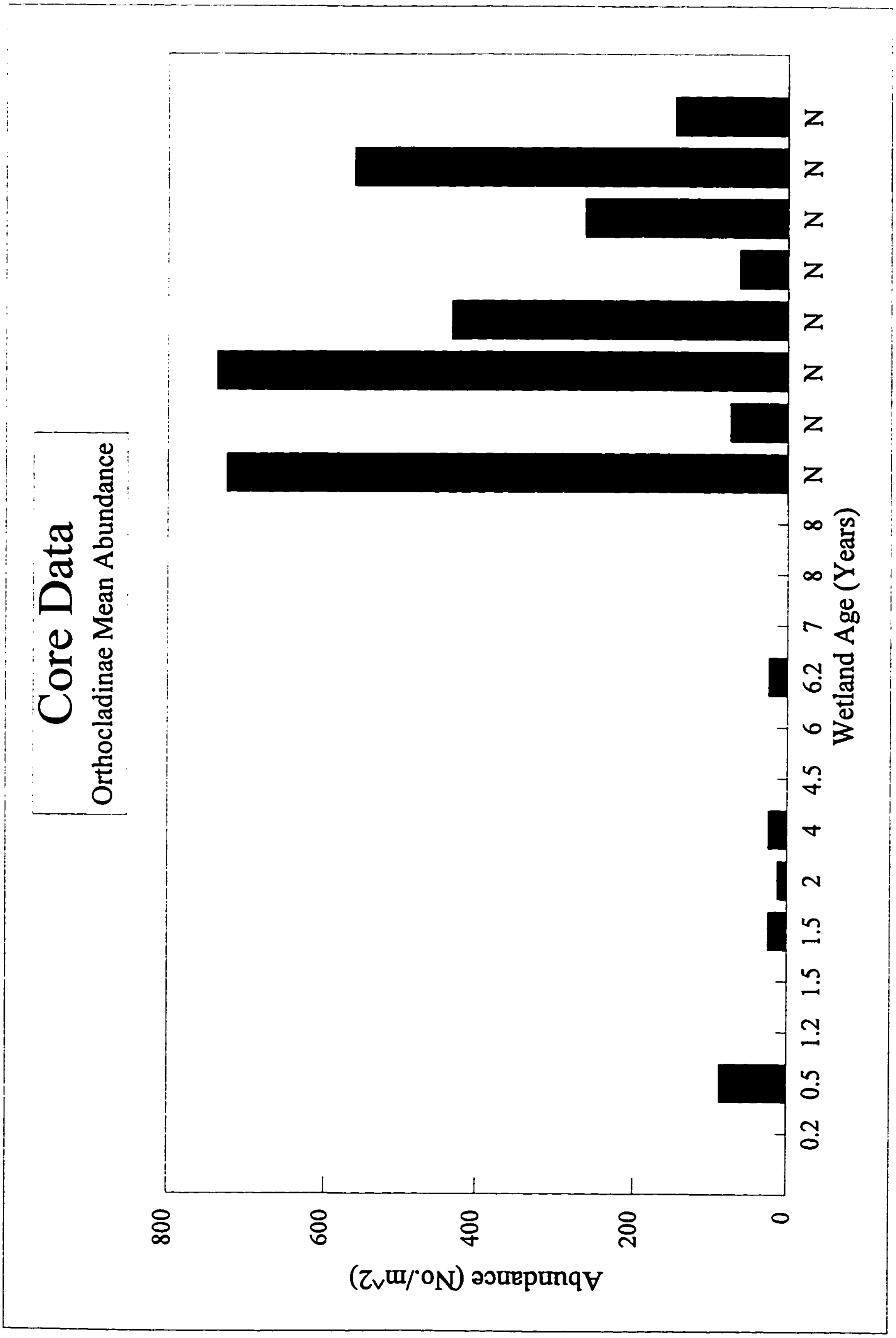

Sweep Net Data
Tanytarsini Mean Abundance
Abundance (No. of Organisms)
0
2
4
6
8
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
Wetland Age (Years)

Figure 31. Abundance of Orthocladiinae (No./M^2) in constructed and natural freshwater marshes in central Florida--Core data.


Core Data

Orthocladinae Mean Abundance

Figure 32. Abundance of Orthocladiinae in constructed and natural freshwater marshes in central Florida--Sweep net data.

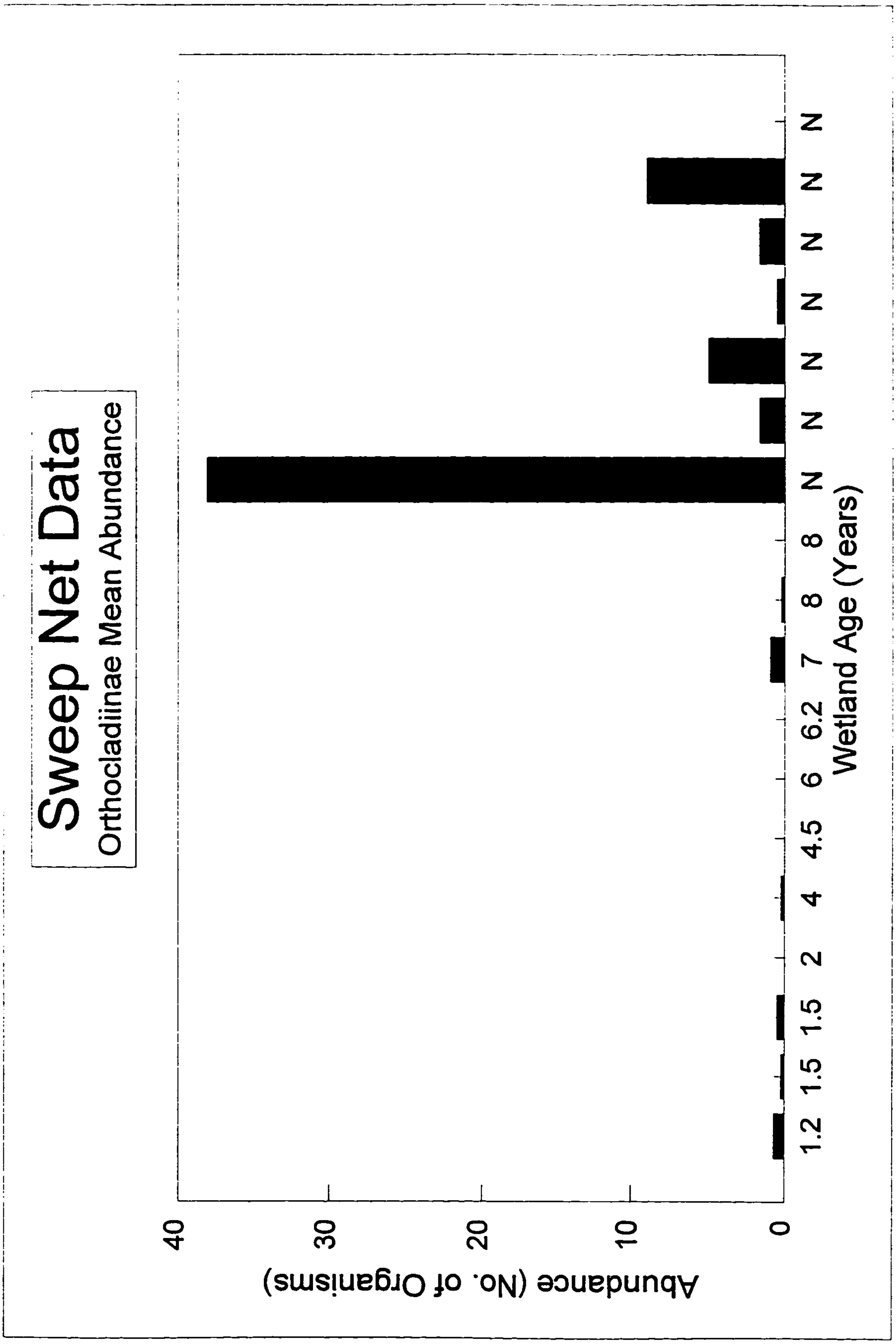
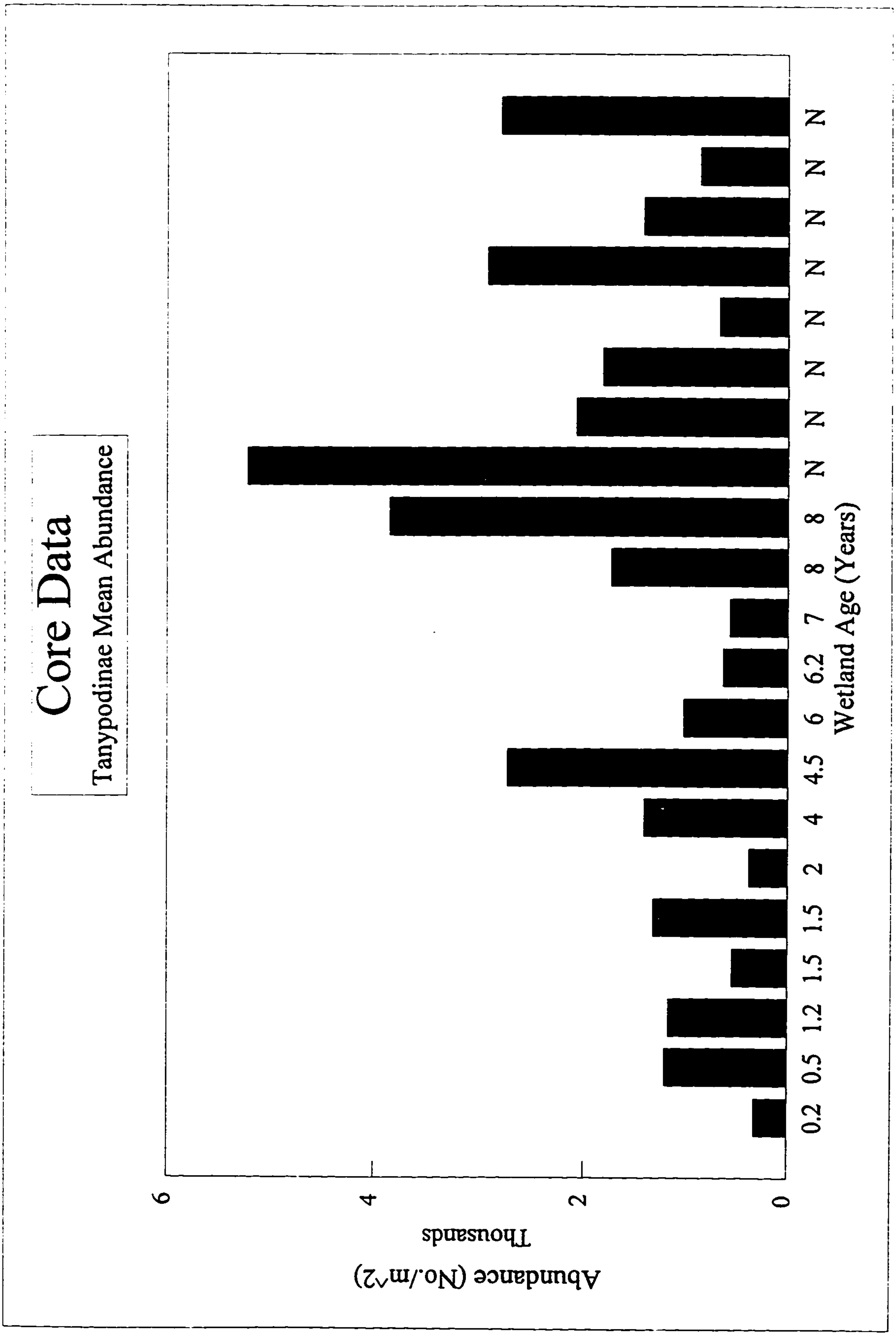

Sweep Net Data
Orthocladiinae Mean Abundance
Abundance (No. of Organisms)
40
30
20
10
0
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
Wetland Age (Years)

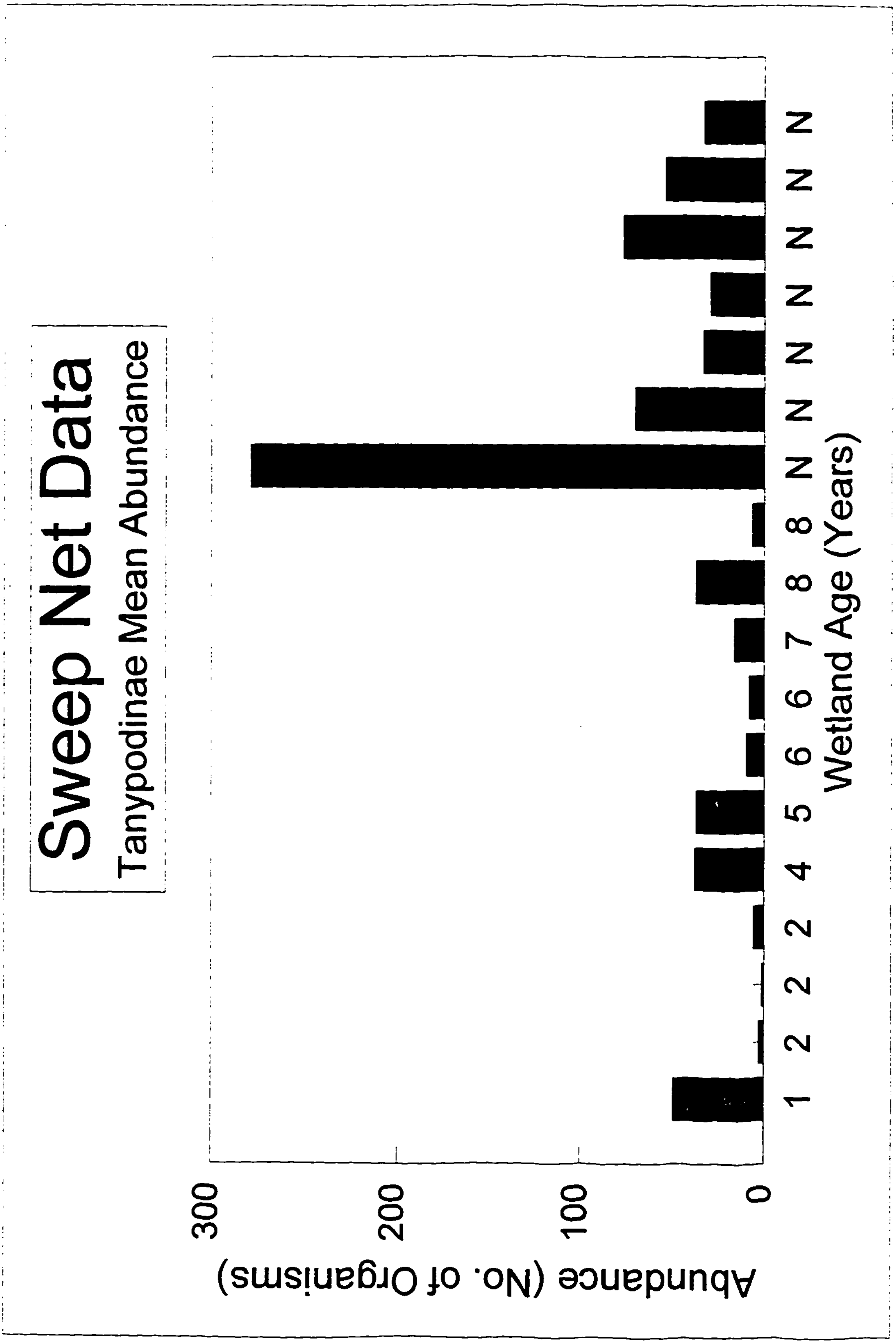
Figure 33. Abundance of Tanypodinae (No./M^2) in constructed and natural freshwater marshes in central Florida--Core data.



Core Data

Tanypodinae Mean Abundance

Figure 34. Abundance of Tanypodinae in constructed and natural freshwater marshes in central Florida--Sweep net data.


Sweep Net Data
Tanypodinae Mean Abundance
Abundance (No. of Organisms)
300
200
100
0
1
2
2
2
4
5
6
6
7
8
8
N
N
N
N
N
N
N
Wetland Age (Years)

marsh than in natural marsh ($p < 0.01$). *Fittkauimyia* cf. *serta*, *Natarsia* sp., *Larsia berneri*, *Larsia indistincta*, *Labrundinia virescens*, and *Labrundinia neopilosella* occurred in higher densities in natural marshes than constructed marshes. *Labrundinia* spp. tend to be acidophilic, perhaps undergoing enhanced growth and survival rates in the more acid waters of natural marshes (Fittkau and Roback 1983; Hudson et al. 1990) *Paramerina* sp. attained highest densities in constructed wetlands over 3 years of age. *Larsia decolorata* and *Monopelopia boliekae* were commonly observed at moderate to high densities in constructed wetlands of all ages as well as in natural marshes. The Tanypodinae have some potential to be indicators of marsh development, although differences between new and old constructed marshes were not significant.

Gastropoda (Snails)

Snail populations were abundant in newly constructed wetlands, but populations appeared to decline dramatically in OC wetlands (Figures 35 and 36). There was a significantly higher abundance ($p=0.0081$) and taxa richness ($p=0.0029$) of gastropods in NC wetlands than in OC wetlands. It is possible that periphyton growth may be limited in OC and N wetlands due to nutrient and light limitation.

The observed decline in snail populations may also be due to establishment of predator populations such as the hemipteran, *Belostoma* spp. Kesler and Munns (1989) concluded

Figure 35. Abundance of Gastropoda (No./M^2) in constructed and natural freshwater marshes in central Florida--Core data.

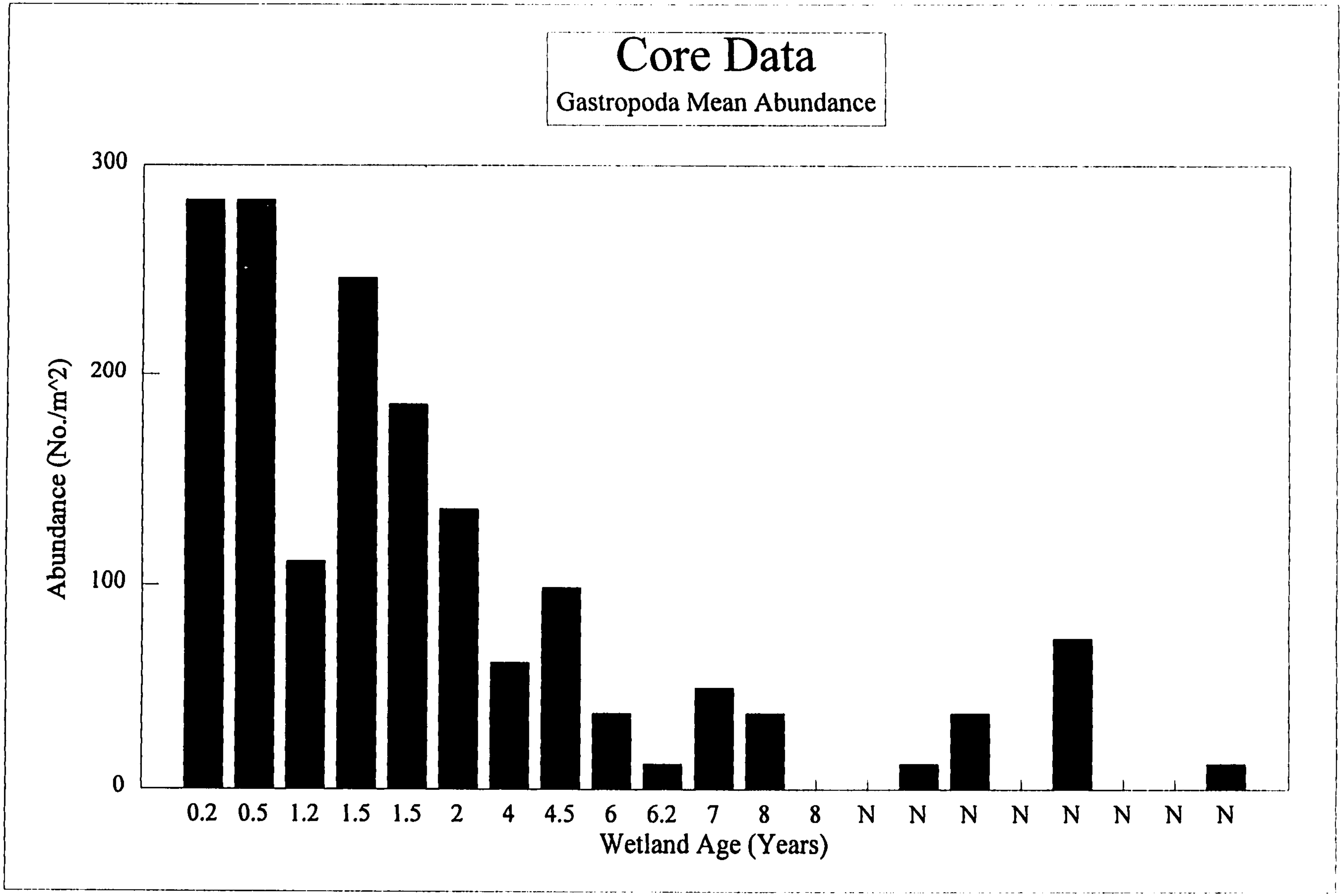
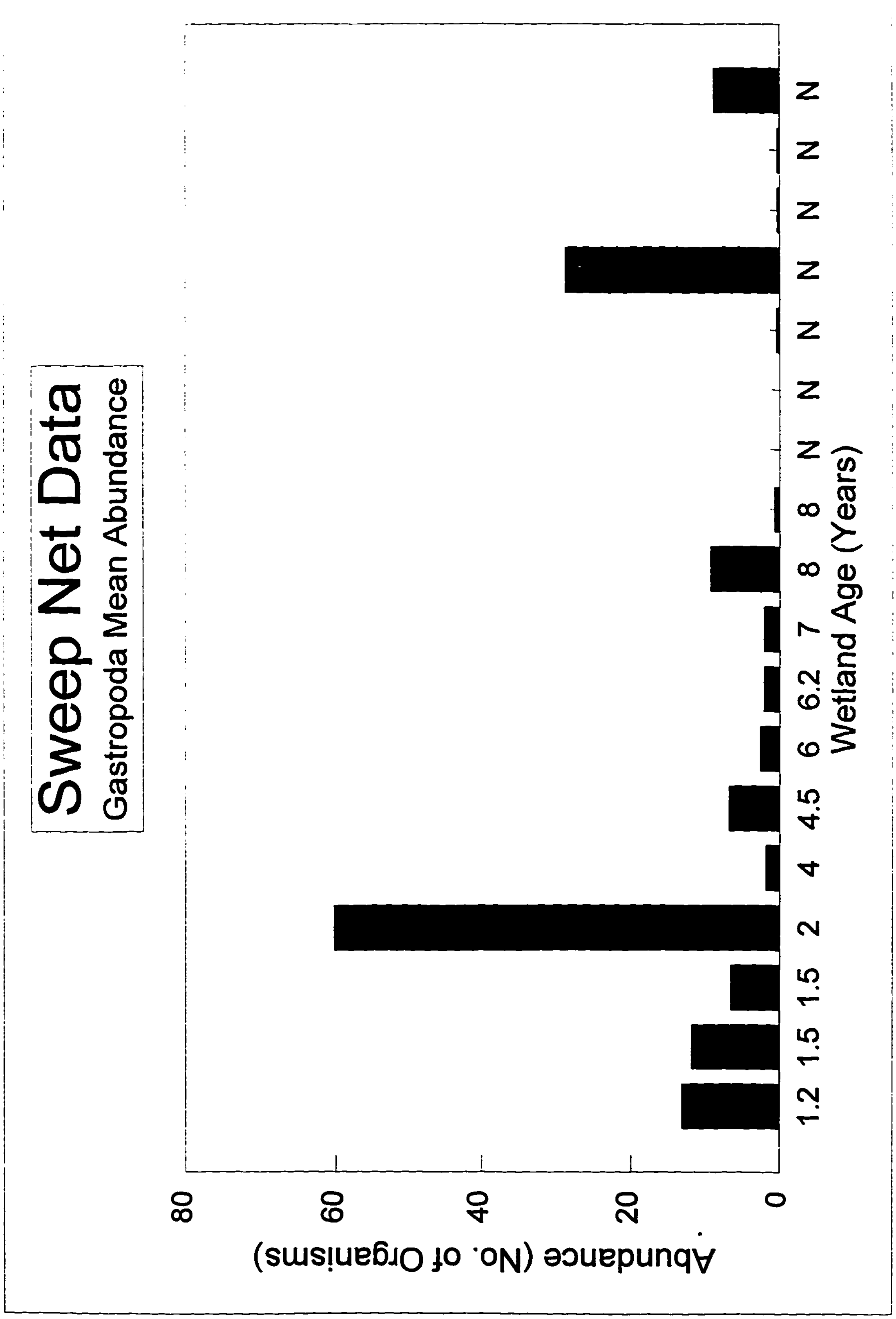

Core Data
Gastropoda Mean Abundance
Abundance (No./m^2)
300
200
100
0
0.2
0.5
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
N
Wetland Age (Years)

Figure 36. Abundance of Gastropoda in constructed and natural freshwater marshes in central Florida--Sweep net data.


Sweep Net Data
Gastropoda Mean Abundance
Abundance (No. of Organisms)
0
20
40
60
80
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
Wetland Age (Years)

that predation by *Belostoma* can play an important role in structuring snail assemblages. Since *Belostoma* appear to be equally distributed among the wetland sites, the data do not support this explanation for the decline in snail populations.

Snail populations were also very low in natural wetlands. Some natural wetlands might have been acidic enough to prevent gastropod shell formation. Acidic waters are characteristically low in calcium carbonate, a key compound required for shell formation (Pennak 1989). Low pH results in the dissolution of calcium carbonate. Calcium ions may also be bound by humic substances, which are abundant in natural emergent marshes. The data support the hypothesis that calcium carbonate is a limiting factor for gastropods in natural wetlands with low pH. Among natural wetlands, snail populations were highest where pH was above 6.0. No snails were observed in wetland R3, where pH was approximately 4.6. However, results are inconclusive since algal populations, a food source for snails, are in natural wetlands with highest pH values. Since pH did not cause the snail decline in constructed wetlands, I conclude that snail populations were most likely controlled by the availability of algal food resources.

Other Major Taxonomic Groups

Tipulids, other miscellaneous dipterans, and trichopterans were significantly more abundant in natural marshes than in constructed marshes (p=0.0016, 0.0001, and 0.0696, respectively). Culicids (p=0.0059 and 0.0111) and lepidopterans (p=0.0087 and 0.0055) were more abundant in OC and N wetlands than in NC wetlands. *Stratiomys* sp. was significantly more abundant in NC wetlands than in OC or natural wetlands (p=0.0493 and 0.0311, respectively).

Natural wetlands supported a significantly higher number of taxa of tipulids, ceratopogonids, and other miscellaneous dipterans than constructed wetlands (p=0.0046, 0.0008, and 0.0001, respectively). Lepidopterans were more diverse in OC and N wetlands than in NC wetlands (p=0.0331 and 0.0325, respectively), and more species of leeches (Hirudinea) occurred in constructed marshes than in natural marshes (p=0.0581).

Feeding Guild Analysis

Abundance of individual feeding guilds was highly variable among the constructed and natural wetlands studied (Figures 37 through 46). Other than a decline of scraper populations with increasing wetland age, there were no consistent trends in respective feeding guilds with constructed wetland development. All feeding guilds of newly constructed wetlands attained abundance levels within or above the range found in natural wetlands during the first 18 months of constructed wetland development. Mean abundance values for respective feeding guilds (Tables A4 and A5) indicate similar abundance rankings of feeding guilds in NC,

Figure 37. Abundance (No./M^2) of collector-gather and collector-filterer feeding guilds of macroinvertebrates in constructed and natural freshwater marshes in central Florida--Core data.

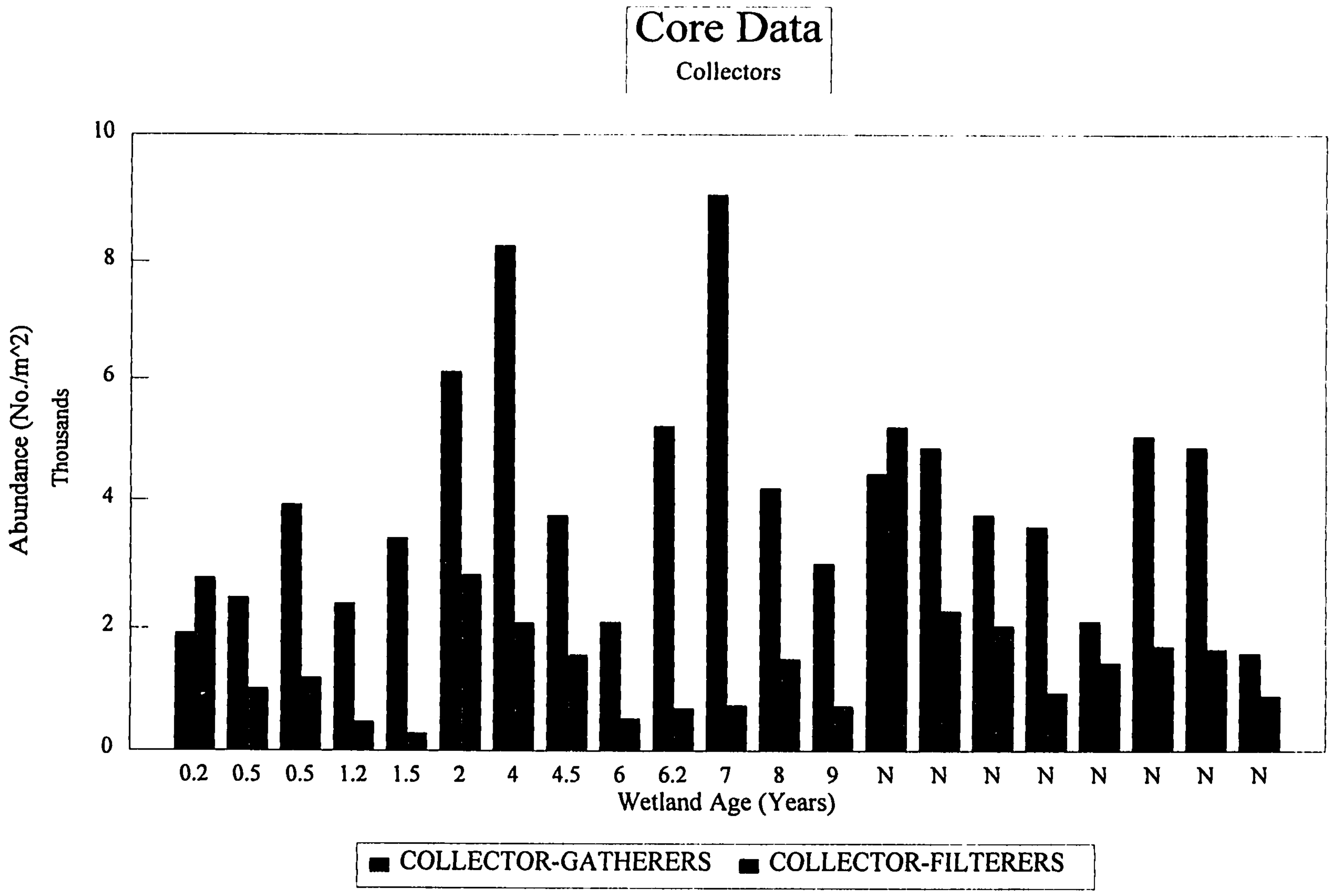

Core Data
Collectors
Abundance (No./m^2)
Thousands
10
8
6
4
2
0
0.2
0.5
0.5
1.2
1.5
2
4
4.5
6
6.2
7
8
9
N
N
N
N
N
N
N
N
Wetland Age (Years)
COLLECTOR-GATHERERS
COLLECTOR-FILTERERS

Figure 38. Abundance of the collector-gatherer feeding guild of macroinvertebrates in constructed and natural freshwater marshes in central Florida--Sweep net data.

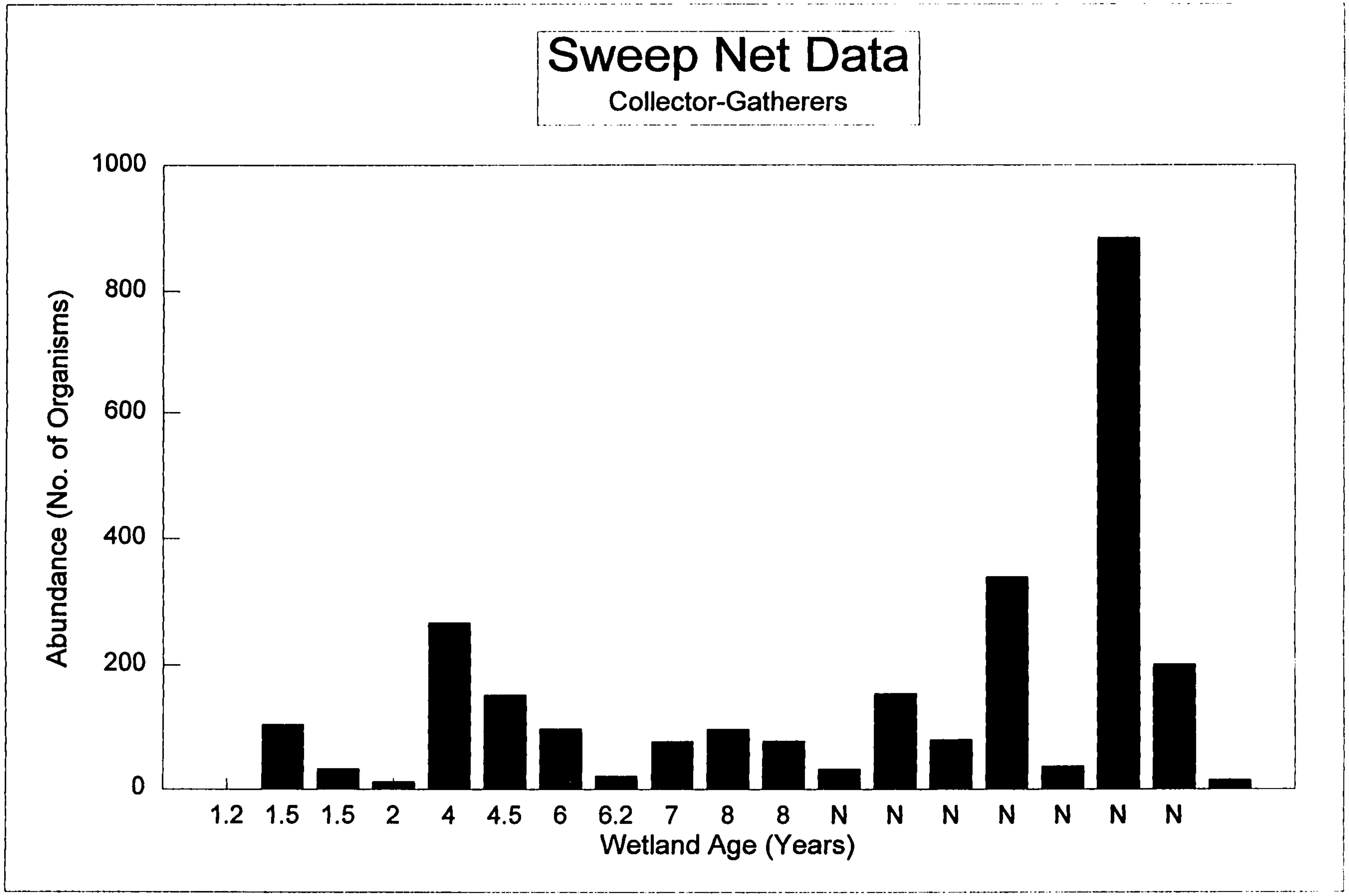

Sweep Net Data
Collector-Gatherers
Abundance (No. of Organisms)
1000
800
600
400
200
0
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
Wetland Age (Years)

Figure 39. Abundance of the collector-filterer feeding guild of macroinvertebrates in constructed and natural freshwater marshes in central Florida--Sweep net data.

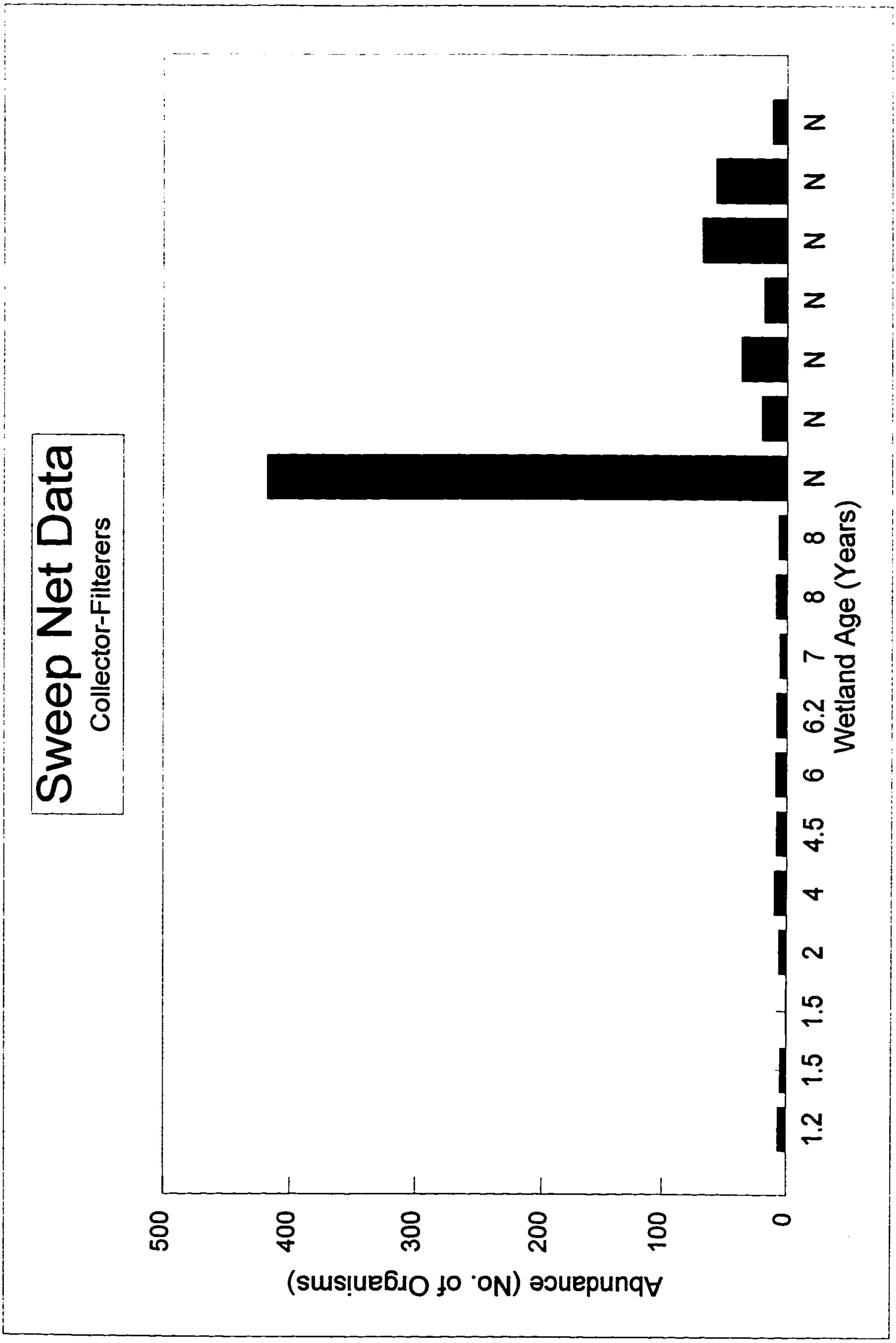

Sweep Net Data
Collector-Filterers
Abundance (No. of Organisms)
0
100
200
300
400
500
Wetland Age (Years)
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N

Figure 40. Abundance of the scraper feeding guild of macroinvertebrates (No./M^2) in constructed and natural freshwater marshes in central Florida--Core data.

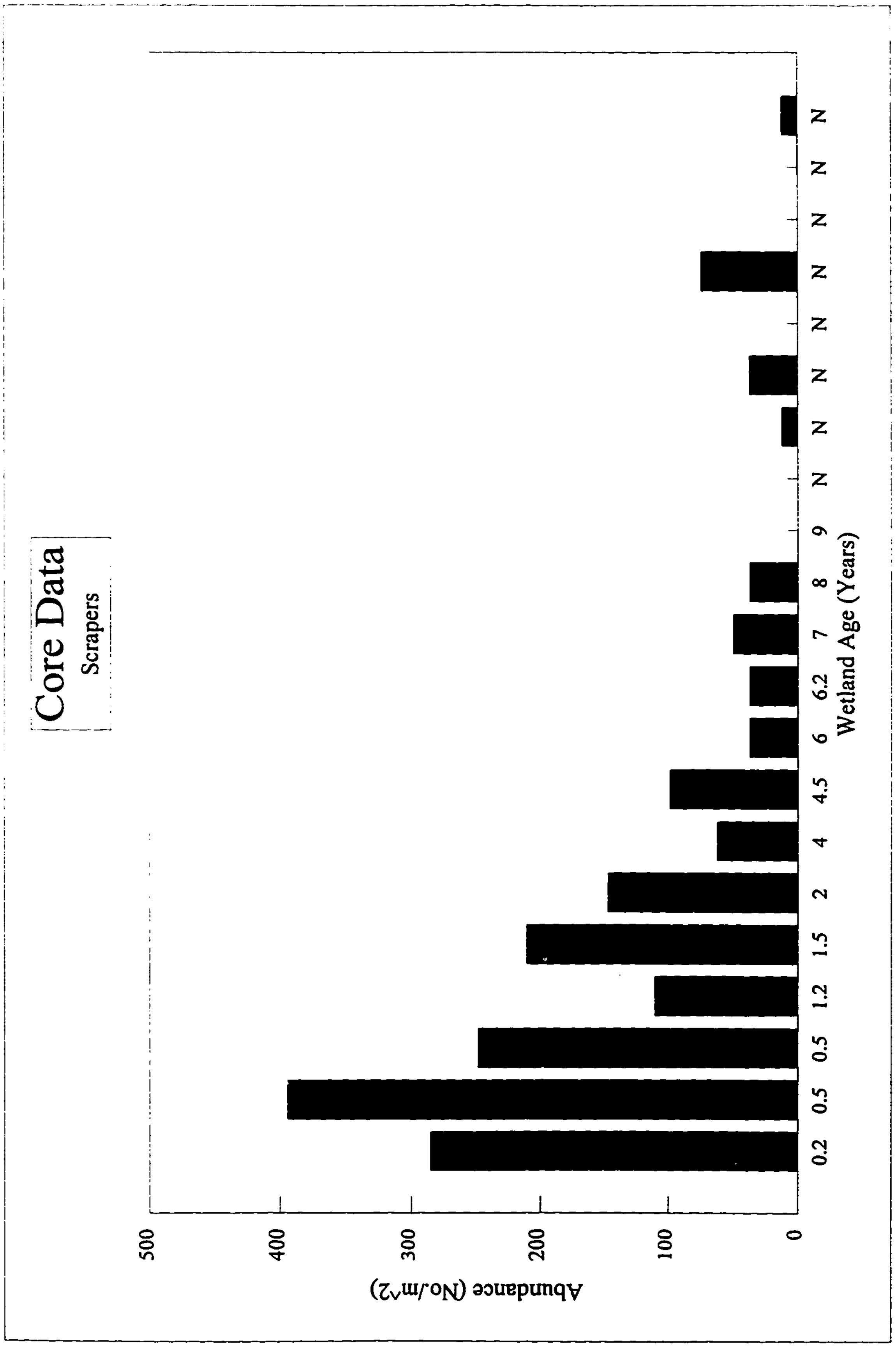

Core Data
Scrapers
Abundance (No./m^2)
500
400
300
200
100
0
0.2
0.5
0.5
1.2
1.5
2
4
4.5
6
6.2
7
8
9
N
N
N
N
N
N
N
N
Wetland Age (Years)

Figure 41. Abundance of the scraper feeding guild of macroinvertebrates in constructed and natural freshwater marshes in central Florida--Sweep net data.

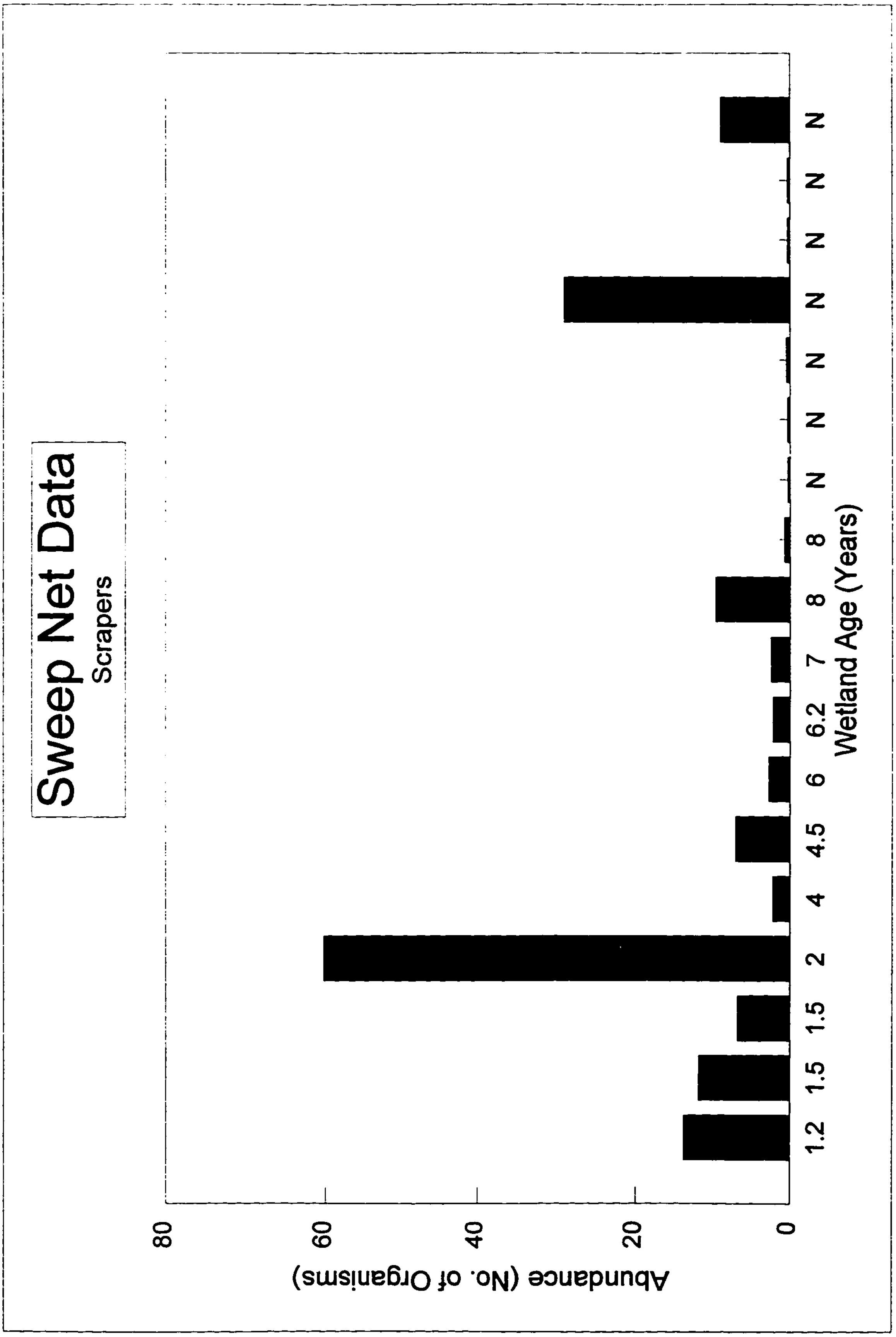

Sweep Net Data
Scrapers
Abundance (No. of Organisms)
0
20
40
60
80
Wetland Age (Years)
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N

Figure 42. Abundance of the shredder feeding guild of macroinvertebrates (No./M^2) in constructed and natural freshwater marshes in central Florida--Core data.

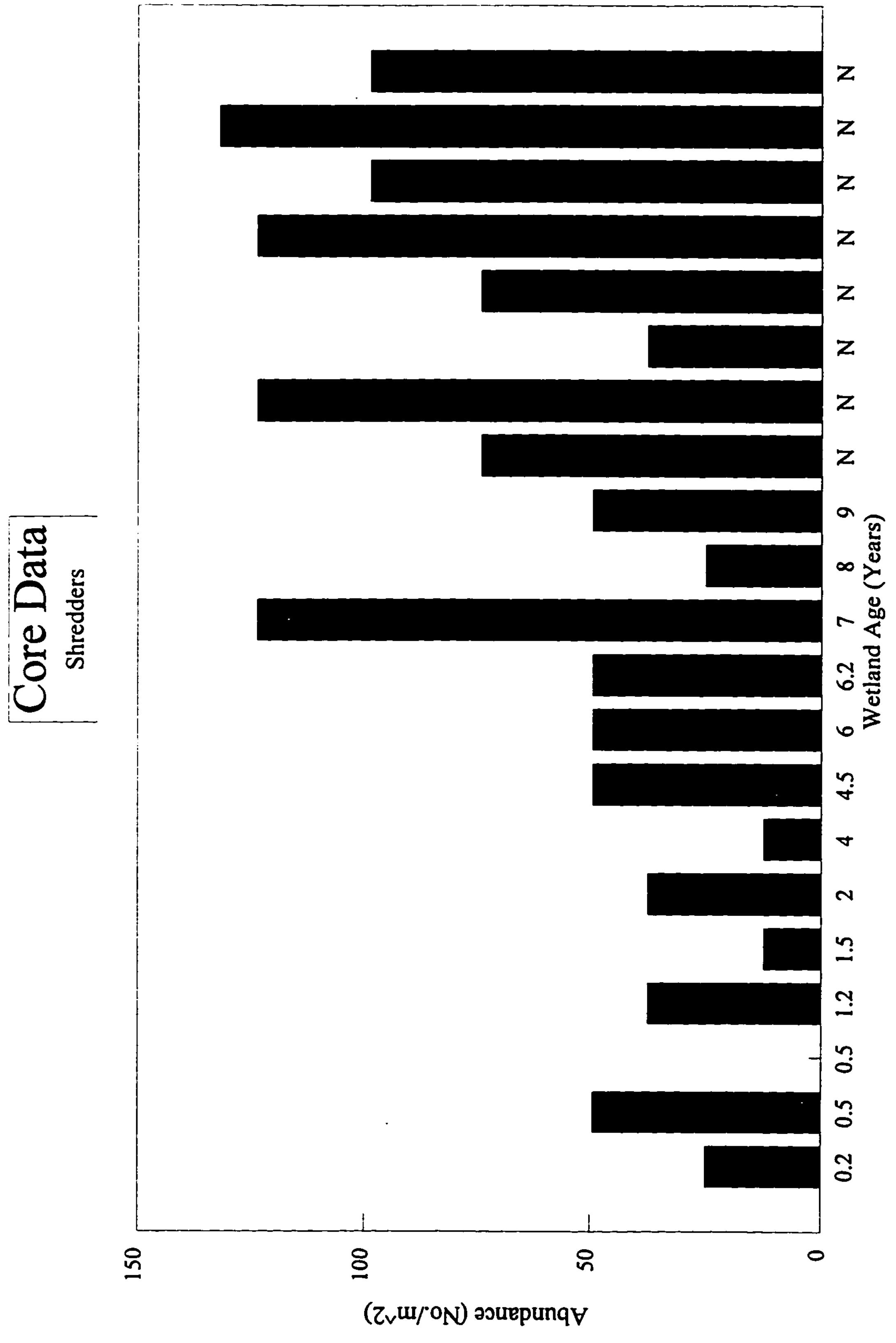

Core Data
Shredders
Abundance (No./m^2)
150
100
50
0
Wetland Age (Years)
0.2
0.5
0.5
1.2
1.5
2
4
4.5
6
6.2
7
8
9
N
N
N
N
N
N
N
N

Figure 43. Abundance of the shredder feeding guild of macroinvertebrates in constructed and natural freshwater marshes in central Florida--Sweep net data.

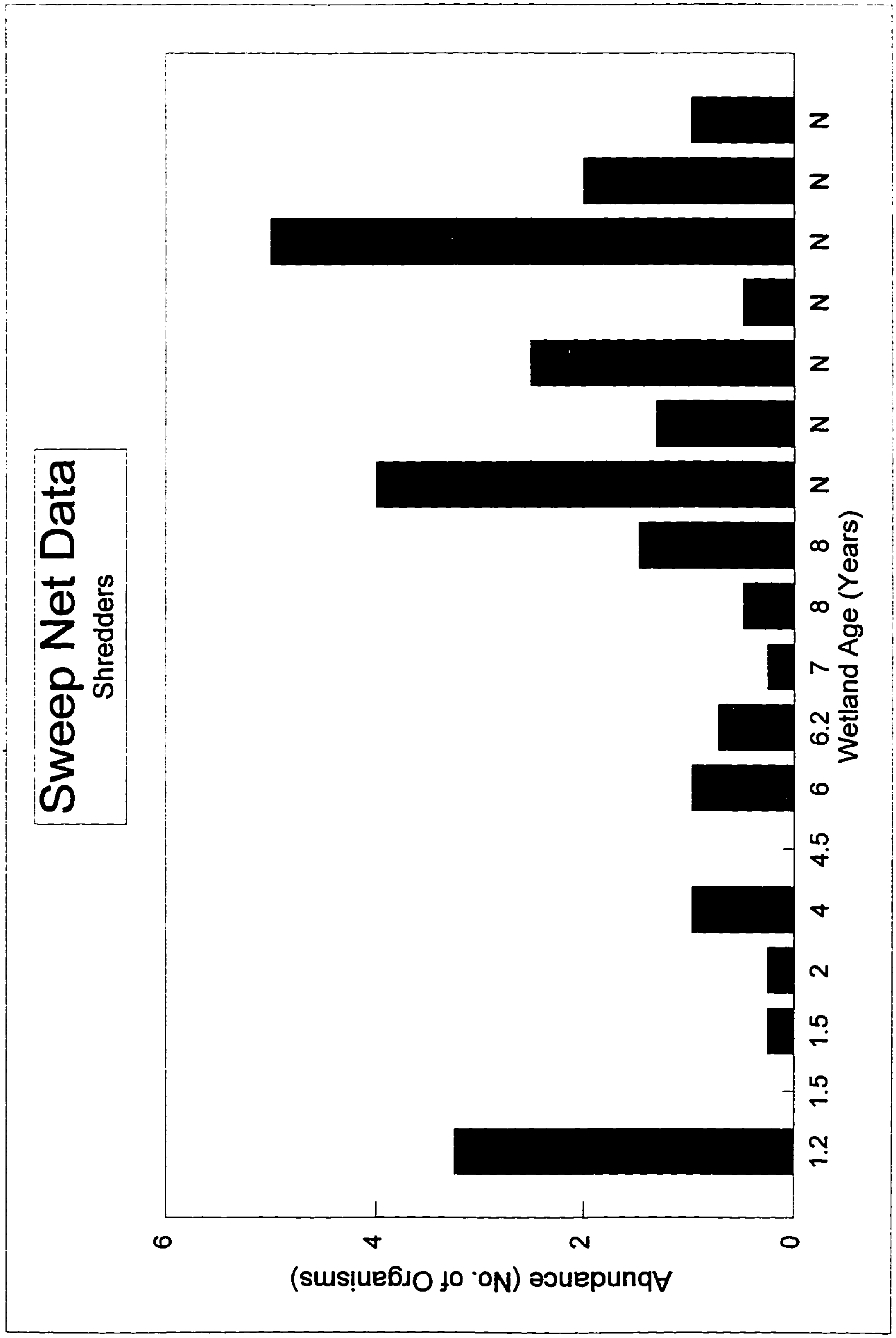

Sweep Net Data
Shredders
Abundance (No. of Organisms)
0
2
4
6
Wetland Age (Years)
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N

Figure 44. Abundance (No./M^2) of predator-engulfer and predator-piercer feeding guilds of macroinvertebrates in constructed and natural freshwater marshes in central Florida--Core data.

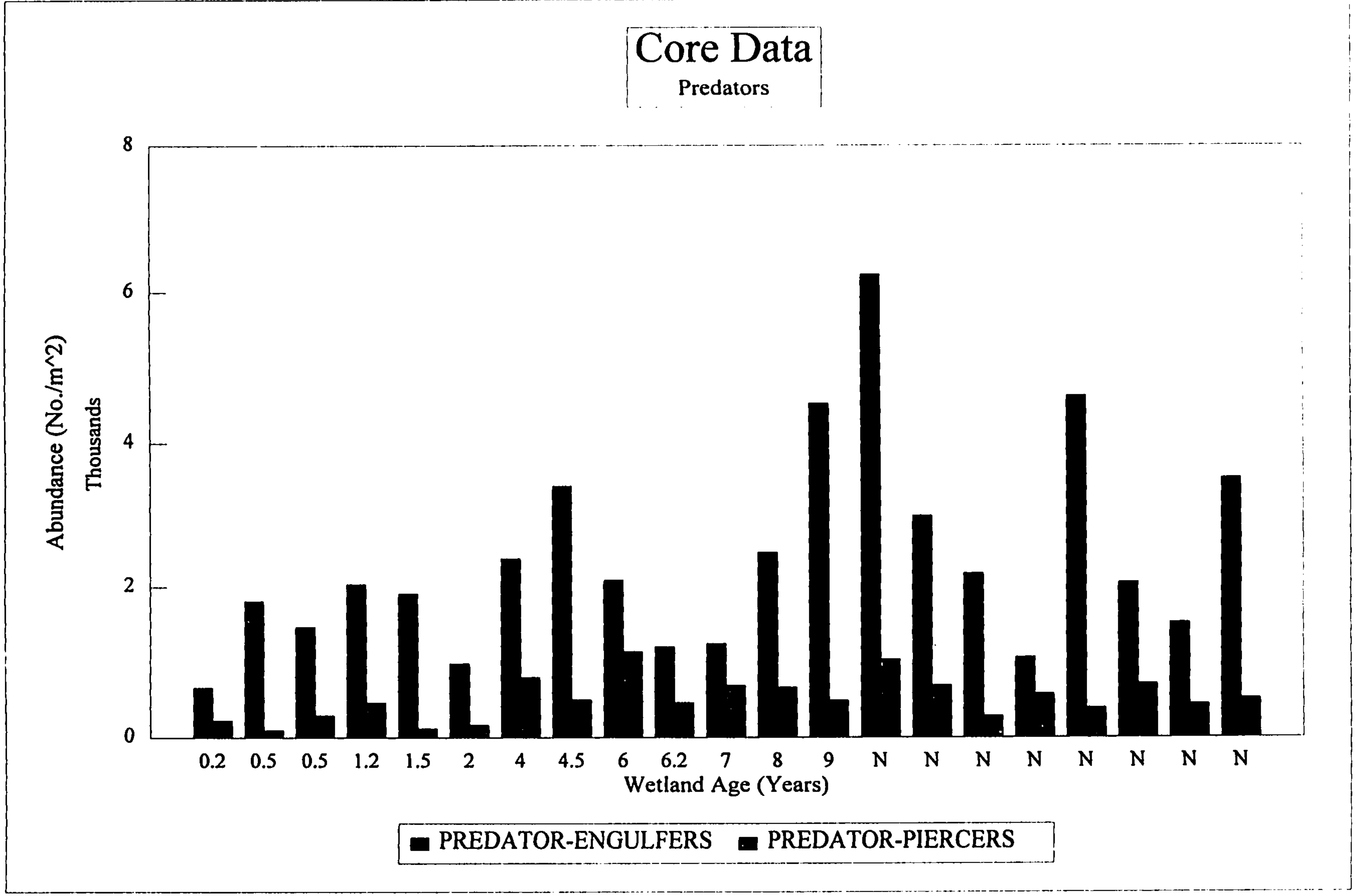

Core Data
Predators
Abundance (No./m^2)
Thousands
0
2
4
6
8
0.2
0.5
0.5
1.2
1.5
2
4
4.5
6
6.2
7
8
9
N
N
N
N
N
N
N
N
Wetland Age (Years)
■ PREDATOR-ENGULFERS
■ PREDATOR-PIERCERS

Figure 45. Abundance of the predator-engulfer feeding guild of macroinvertebrates in constructed and natural freshwater marshes in central Florida--Sweep net data.

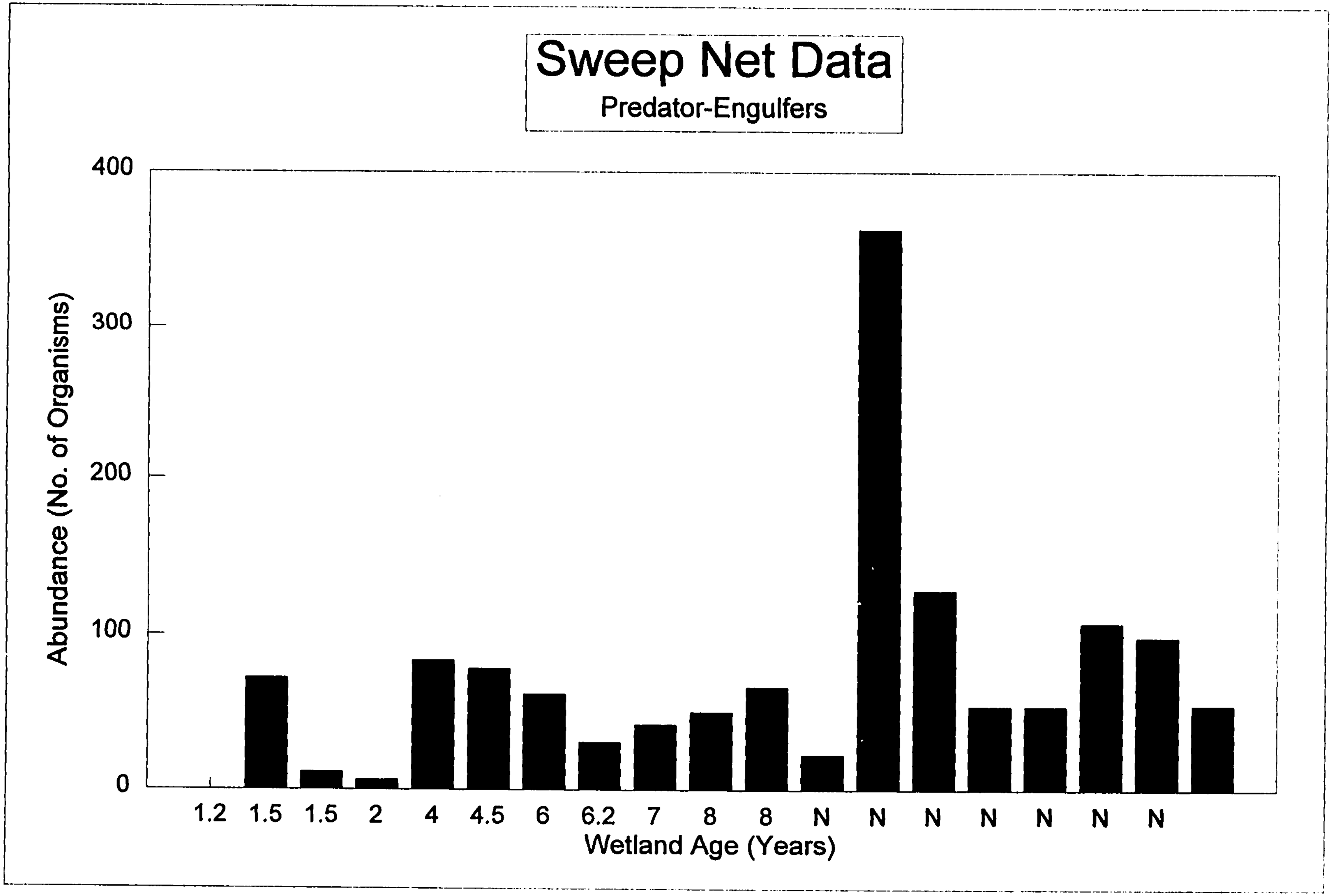
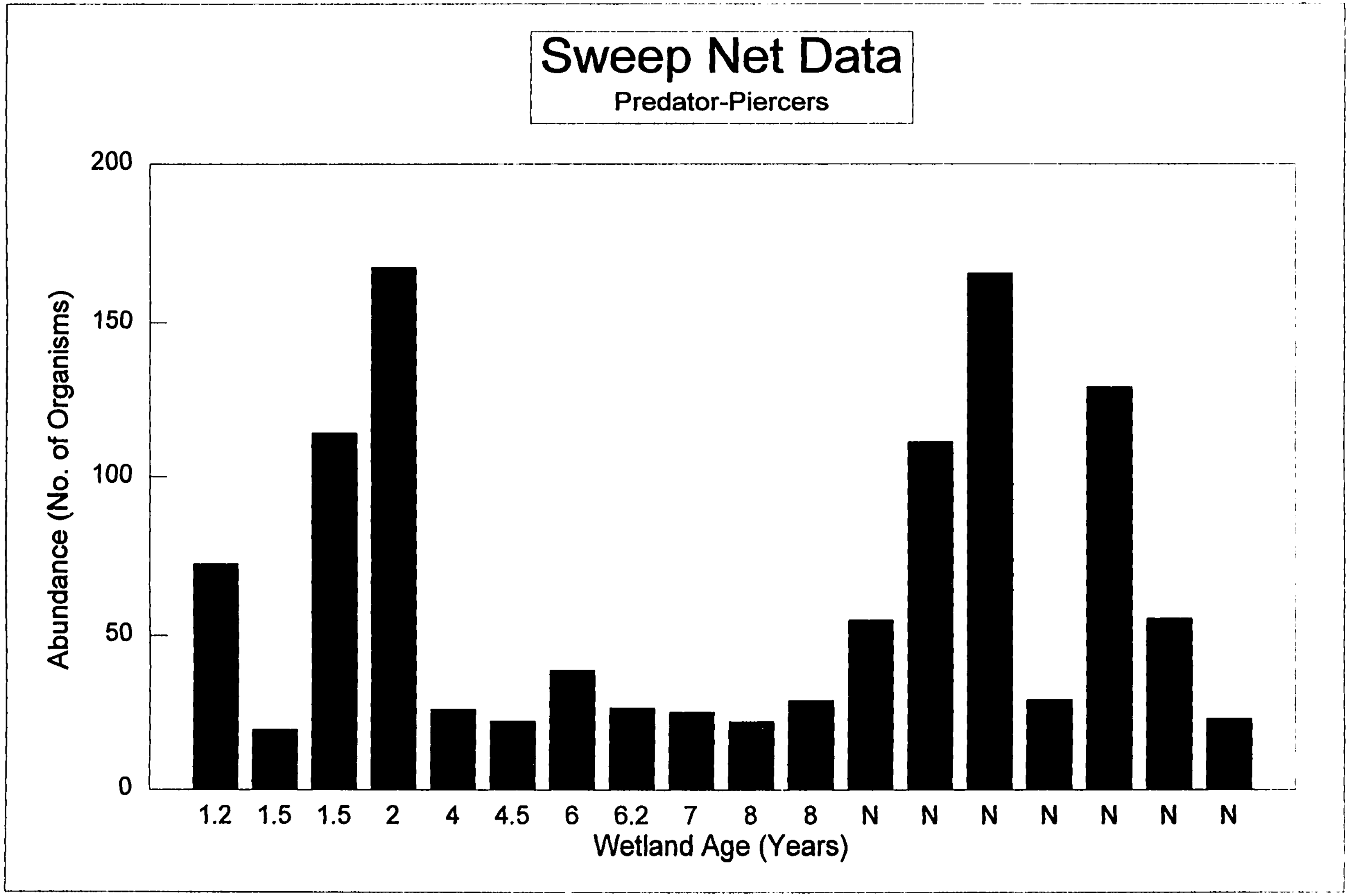

Sweep Net Data
Predator-Engulfers
400
300
200
100
0
Abundance (No. of Organisms)
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
Wetland Age (Years)

Figure 46. Abundance of the predator-piercer feeding guild of macroinvertebrates in constructed and natural freshwater marshes in central Florida--Sweep net data.


Sweep Net Data
Predator-Piercers
Abundance (No. of Organisms)
200
150
100
50
0
1.2
1.5
1.5
2
4
4.5
6
6.2
7
8
8
N
N
N
N
N
N
N
Wetland Age (Years)

OC, and N wetlands, except for scrapers and shredders (Tables B5 and B6). Shredders were significantly more abundant in N wetlands ($p = 0.0009$), and scrapers were most prevalent in NC wetlands.

Collector-Gatherers

Organisms that feed by gathering food materials such as algae and detritus were the most abundant of all the feeding guilds (Figures 37 and 38). There were no significant differences in abundance among wetland type. This is consistent with the hypothesis in that food availability (detritus and algae) is apparently not limited for collector-gatherers, even in newly constructed wetlands. The expected peak in abundance due to algal blooms (a food resource) early in constructed wetland development was not realized, perhaps because algal growth was primarily in the form of filamentous algae rather than easily consumed nanoplankton. This hypothesis is untested.

As constructed wetlands age, detritus tends to accumulate at the sediment-water interface because plant production exceeds decomposition rates. The increase in detritus noted by Kiefer (1991) during the development of constructed wetlands probably has a positive influence on collector-gatherer population inhabiting sediments. The peak in core data in wetlands 2 to 4 years of age depicted in Figure 37 coincides with the "trophic surge" identified by Kiefer (1991). This provides indirect evidence that food collector-gatherer populations may be responding to detritus levels during early stages of constructed wetland development.

Collector-Filterers

For unknown reasons, filtering organisms were significantly more abundant in natural wetlands than in constructed wetlands ($p=0.0015$). Peak densities also occurred in P90 and CS88, both NC wetlands (Figures 37 and 39). Filterers are often abundant where phytoplankton populations are most plentiful. However, the data do not demonstrate a high correlation between filter-feeding organisms and chlorophyll a concentration (trophic state), perhaps due to a predominance of toxic, unmanageable, or unpalatable algae in constructed wetlands (Porter 1977). The lack of such a relationship with chlorophyll levels could also be due to the presence of suspended inorganic particulate matter (silt) which can interfere with filtering mechanisms (Wotton 1994). Based on sediment data, siltation tends to be more prevalent during the early stages of constructed wetland development. These are hypotheses yet to be tested.

Scrapers

Scraping organisms, consisting primarily of snails, exhibited a distinct decline in abundance with increasing constructed wetland age (Figures 40 and 41). Scrapers were significantly more abundant in NC wetlands than in OC ($p=0.0066$) and natural wetlands ($p=0.0011$). Within core data, abundance was highest (100 to 400 per square meter) in NC wetlands and lower in OC wetlands (0 to 100 per square meter). Natural wetlands supported very low densities (0 to 65 per square meter).

The decline of scrapers with wetland age is likely due to a decline in periphyton growth (food limitation), water quality (decrease in pH), or an increase in predator populations (Kesler and Munns 1989). Chlorophyll measurements suggest that phytoplankton, and perhaps periphyton populations, are relatively low in older constructed and natural wetlands (Kiefer 1991). Furthermore, just as scraper abundance declined with increasing wetland age, percent cover of filamentous algae decreased with increasing wetland age. Therefore, available evidence suggests that food limitation (algae) was the most likely cause of the decline in scraper populations as constructed wetlands develop over time.

The natural wetlands studied are more acidic than constructed wetlands, perhaps limiting shell production (Pennak 1989). Food limitation and water quality (particularly pH) were the most likely causes of the observed decline in snail populations. Since pH did not cause the decline of snails in constructed wetlands, food limitation algae was probably the primary causative factor.

Waterfowl are known to feed heavily on snails (Bellrose and Trudeau 1988), but they are not prevalent in many of the wetlands that support low snail populations. Centrarchids, which also may feed on snails, are limited or absent in many of the natural wetlands. Shallow open water is the preferred feeding habitat of most wading birds; therefore, use of constructed marshes by birds usually declines with the development of dense macrophyte cover. The lack of major predators in OC and N wetlands makes it unlikely that predation has a large influence on snail populations.

Shredders

Shredders were significantly more abundant in natural wetlands than in constructed wetlands (p=0.0009) (Figures 42 and 43). Kiefer (1991) showed that coarse organic material, the primary food source of shredders, was most prevalent in OC wetlands and natural wetlands. An abundance of coarse detritus may partially explain why shredders were more abundant in natural wetlands. There was no direct evidence of this relationship because sediments were not analyzed in the natural wetlands. Shredders were not as abundant in older constructed wetlands perhaps because coarse organic material did not have sufficient time to accumulate.

Predators-Engulfers

Among constructed wetlands, engulfers were most abundant in OC wetlands (Figures 44 and 45). With the exception of R1, natural wetlands supported a similar range of engulfer population densities to those occurring in OC wetlands. It appears that there is little or no correlation between predator-engulfer abundance and constructed wetland age. However, consistent with the original hypothesis, their abundance was significantly higher in natural wetlands than in constructed wetlands (p=0.0174).

Predators-Piercers

Within core samples (Figure 44), benthic piercers, consisting primarily of aquatic beetles, were less abundant and did not vary as much between wetlands as other feeding guilds (engulfers, collectors, scrapers). Many of the species belonging to this feeding guild are semi-aquatic or occur primarily in the water column and are not sampled effectively using coring techniques (see Comparison of Sampling Methods). Populations in NC wetlands (0 to 400 per square meter) appeared to be lower than in OC wetlands (500 to more than 1000 per square meter). Densities in natural wetlands, ranging from 200 to 1000 per square meter, were also slightly higher than in NC wetlands. Differences between wetland types were not significant.

Sweep net samples collected from newly constructed and natural marshes contained significantly more predator-piercers than samples collected from older constructed marshes (p=0.0079 and 0.0060, respectively). The relatively high abundance observed in newly constructed marshes was not expected. A large majority of predator-piercers were aquatic beetles. The high populations observed in newly constructed marshes were, perhaps, a result of rapid immigration via migratory flights coupled with a rapidly growing food supply (deposit feeders). Unlike predator-engulfers (primarily dragonflies and damselflies), adult beetles are aquatic life forms and are immediately able to capitalize on available aquatic food resources. Eggs must be deposited and early life stages must develop before dragonflies and damselflies can make use of aquatic food resources. In essence, beetles have the qualities of a successful opportunist during early wetland development in spite of their relatively long life cycles.

Predator-Prey Relationships

There was a slight upward trend of predator abundance with constructed wetland age. Nonpredaceous invertebrates also attained peak abundance in OC wetlands. Prey populations were relatively low in G81, R5, N3, FG86, and CS83, where predator populations tended to be highest. Predation appears to play a less important role in limiting benthic invertebrate populations in NC wetlands than in OC or N wetlands. Factors other than predation and food availability, such as colonization and reproduction rates, may have a more important influence on benthic invertebrate population levels in NC wetlands.

Evidence for Influence of Vegetation Communities (percent cover) on Macroinvertebrate Communities

Total Abundance of Macroinvertebrates

Constructed sites--Core data

Total abundance of organisms collected with a corer in winter tended to increase with percent cover of emergent vegetation (Table B1), but results were insignificant (p=0.06, R-square=0.34). In wetlands where dissolved oxygen can be limited, particularly in the sediments, rooted plants offer oxygenated refugia for aquatic macroinvertebrates in the thin microlayer associated with plant surfaces. Macrophytes with extensive root systems can oxidize sediments (Chen and Barko 1988), perhaps rendering them more habitable for a more diverse and abundant benthic fauna.

Nest-building centrarchid sunfish create open patches among littoral vegetation when they construct nests. Thorp (1988) reported macroinvertebrate densities can be significantly lower in centrarchid nests than in adjacent vegetated areas. Beckett et al. (1992) found significantly higher invertebrate densities in sediments underlying macrophytes than in sediments in unvegetated patches. Temperature, dissolved oxygen, and organic content of sediments were eliminated as causative factors.

Both Thorp (1988) and Beckett et al. (1992) attributed lower macroinvertebrate densities in open patches to sediment disturbance and enhanced predation rates. In vegetated areas fish have been observed to consume benthic invertebrates at half the rate observed in open areas, suggesting vegetation serves to reduce predation pressure by interfering with the search and capture of prey organisms (Hershey 1985).

In the summer, total macroinvertebrate abundance in core samples tended to decrease with percent cover of filamentous algae (p=0.045, R-square=0.38). Filamentous algal mats primarily consisted of blue-green algae. Lower invertebrate production among blue-green algal mats may have occurred due to a number of factors. As a food resource for macroinvertebrates, blue-green algae may be unmanageable or unpalatable. Some blue-greens are also capable of producing toxins that may inhibit growth or cause mortality in invertebrates (Porter 1973).

Constructed wetlands--Sweep net data

There were no significant relationships between abundance of macroinvertebrates in sweep net samples and vegetation cover (Table B1). Observations of higher macroinvertebrate densities on aquatic plants than on mineral substrates are well documented (Minshall 1984; Murkin et al. 1983; Beckett et al. 1992). One of the primary factors causing this difference is thought to be the greater surface area provided by vascular plants (Krecker 1939; Gerrish and Bristow 1979). Epiphytic plant growth and "aufwuchs" attached to plant surfaces can provide an ample food resource for grazing invertebrates (Cattaneo and Kalff 1980; Cattaneo 1983), and senescing vegetation can provide an important detrital food resource (Smock and Stoneburner 1980).

Vertebrate predation pressure was reduced in cattail stands in the Delta Marsh, Manitoba, via an indirect mechanism. Yellow perch (*Perca flavescens*) avoided cattail stands during this period (Suthers and Gee 1986). Dissolved oxygen levels were reduced in the cattail stands during midsummer, apparently rendering the avoidance behavior in yellow perch. Murkin et al. (1992) observed higher macroinvertebrate densities in cattail stands than in open areas in spite of low dissolved oxygen levels, attributing the higher populations to lower vertebrate predation pressure in the cattail stands.

Voights (1976) observed highest macroinvertebrate density in prairie pothole wetlands when emergent vegetation was interspersed with open areas. Voights' observations suggest that newly constructed sites with patchy vegetation might support a more abundant invertebrate community than natural wetlands which are characterized by extremely dense stands of emergent vegetation without open areas. Sweep net results indicate no relationship between total organism abundance and emergent vegetation density as observed by Voights (1976).

The manner in which sweep net samples were collected is not appropriate for demonstrating the effect of rooted macrophytes on macroinvertebrate community structure. This provides some explanation of the lack of the expected relationship. Sweep net samples included sediments. Where vegetation was sparse, practically the entire sample was made up of organisms that live on or in the sediments. This sampling method is not appropriate for demonstrating the effect of vegetation surface area on organism abundance because organisms collected at the sediment-water interface confound the issue. In the absence of vegetation, samples consist of organisms living in the sediments. Conversely, when vegetation is dense it is difficult to include sediments in the sweep sample. The exclusion of sediments from sweep net samples would provide a better measure of the effect of rooted macrophytes on macroinvertebrate community structure in the water column.

Core samples provide an adequate measure of the effect of rooted macrophytes on macroinvertebrates living associated with sediments. It is likely that surface area, protection from predation, and sediment stabilization afforded by rooted macrophytes has an influence of macroinvertebrate production in newly constructed wetlands. However, the results of this study do not provide strong evidence for such relationships.

Natural sites

Organism abundance in sweep samples collected in winter was negatively correlated with total percent plant cover (p=0.0173, R-square=0.71). This result conflicts with the hypothesis that surface area of vascular plants enhances potential for macroinvertebrate population density. Possible explanations for the observed relationship include application of agricultural pesticides and fertilizers, biological oxygen demand, and the effect of filamentous algae (food chain). During the wet season, macroinvertebrate abundance in sweep samples was negatively correlated with percent cover of filamentous algae (p=0.0035, R-square=0.84). Although the values appear to be significant, there were information gaps in the filamentous algae data, casting some doubt on the validity of the regression. Since the wetlands with the highest total plant cover also exhibited the highest algal cover, it is difficult to separate the two regressions. It is quite possible that both regressions were a result of algal cover. When algal cover was greater than 20 percent, organism abundance was relatively low. It is also possible that watershed management practices affect some of the natural wetlands.

There were no significant trends in core data from natural wetlands.

Species Richness of Macroinvertebrates

Constructed wetlands

In winter cores (dry season), species richness tended to increase with total plant cover (p=0.0228, R-square=0.46). Winter sweep species richness suggests a positive relationship with emergent vegetation cover (p=0.0196, R-square=0.51). Habitat diversity generally increases with increasing vegetation cover. The observed trends support the tenets of niche theory discussed by Hutchinson (1959), which predicts an increase in species richness with increasing habitat diversity. Reasons why these trends only occur during winter are not evident. Other factors apparently override the effect of habitat diversity in summer.

Natural wetlands

No significant trends in species richness were observed in natural wetlands. However, taxa richness tended to increase with total plant cover (p=0.041, R-square=0.60), possibly due to the habitat complexity offered by vegetation.

Macroinvertebrate Diversity

Constructed wetlands

During the summer, in constructed wetlands, diversity tended to be lower with increasing floating plant cover (sweep: p=0.017, R-square=0.49; core: p=0.0564, R-square=0.35). There is little confidence in the core sample regression because of a low R-square value and gaps in the data. Dense mats of floating vegetation can eliminate light required for photosynthesis and can interfere with mixing and oxygenation at the air-water interface, causing hypoxia in underlying waters. Oxygen tended to be lower in wetlands with dense floating vegetation. For example, CS83 had a very dense cover (114 percent) and mean dissolved oxygen concentration was 2.1 mg/l at the surface and 0.7 mg/l at the bottom (Kiefer 1991). Lack of sufficient oxygen can reduce taxa richness and species equitability, thus leading to a reduction in diversity values (Wetzel 1983).

Natural wetlands

No significant trends in Shannon-Weiner diversity were observed in natural wetlands. Diversity tended to decrease with increasing percent cover of filamentous algae (p=0.031, R-square=0.64). However, this relationship is somewhat questionable due to gaps in the data. This observation supports the notion that filamentous algae may limit the growth and reproductive potential of some macroinvertebrate species. The lack of significant relationships in natural wetlands may be due to a narrower range in percent cover within natural systems as opposed to constructed wetlands which exhibited considerable variation in vegetation cover among the sites.

Individual Macroinvertebrate Taxa

Constructed wetlands--Core samples

Abundance of *Chironomus* (*Lobochironomus*) sp. increased with emergent plant cover in constructed wetlands (p=0.0013, R-square=0.70). *Kiefferulus dux* abundance tended to be positively correlated with constructed wetland slope (p=0.0353, R-square=0.40). *Mansonia titillans* abundance tended to be positively correlated with submergent plant cover in constructed wetlands (p=0.0135, R-square=0.51). Since this species depends on macrophytes for both attachment and oxygen supply, abundance is likely a reflection of the number of suitable sites for attachment (macrophyte density). *Natarsia* sp. abundance increased with total plant cover (p=0.0012, R-square=0.71) and age (p=0.0211, R-square=0.85) of constructed wetlands. This trend was also observed in natural wetlands (p=0.0096, R-square=0.77). Although these values indicate significant relationships, gaps in the data render them somewhat questionable. The reason for these relationships is unknown. Although Natarsia sp. have been reported to occur in freshwater marshes (Evans and Sullivan 1988; Hudson et al. 1990), their association with macrophytes is not well-documented.

Constructed wetlands--Sweep net data

There were no significant trends in individual taxa abundance among sweep net samples collected in constructed wetlands.

Natural wetlands--Core data

Natarsia sp. increased in abundance with total plant cover in natural wetlands (p=0.0096, R-square=0.77). The chironomids, *Dicrotendipes leucoscelis* and *Labrundinia neopilosella* demonstrated a negative relationship with filamentous algae cover in natural wetlands (p=0.0019, R-square=0.88; and p=0.0076, R-square=0.78, respectively). There is low confidence in these regressions due to gaps in the filamentous algae data. When filamentous algal cover exceeded 20 percent, abundance of the above-mentioned chironomids was relatively low.

Natural wetlands--Sweep net data

The chironomid, *Natarsia* sp. and the beetles, *Desmopachria* sp. and *Laccophilus gentilis*, increased in abundance with emergent vegetation cover (p=0.0667, R-square=0.52; p=0.0347, R-square=0.62; and p=0.0391, R-square=0.48, respectively).

Dicrotendipes leucoscelis, *Labrundinia neopilosella*, and larvae of the beetle, *Laccophilus* sp. were negatively correlated with filamentous algae cover in natural wetlands (p=0.0031, R-square=0.85; p=0.0001, R-square=0.97; and p=0.0149, R-square=0.73, respectively). Again, there were gaps in the data. When filamentous algae exceeded 20 percent cover, abundance of the above-mentioned taxa was relatively low.

Chironomus (*Lobochironomus*) sp. tended to decrease with increasing total plant cover in natural wetlands (p=0.0227, R-square=0.68). Gaps in the total plant cover data make this relationship somewhat questionable.

Negative correlations between *Dicrotendipes leucoscelis*, *Labrundinia neopilosella*, and filamentous algae cover may be related to pH. Natural wetlands supporting the densest algal growth (30 and 35 percent cover, respectively) were relatively high in pH. Algal growth was probably responsible for elevating pH. The influence of algal photosynthesis on pH is well documented (Wetzel 1983). The two species mentioned above are acidophilic (Beck 1977; Hudson et al.

1990), possibly explaining their negative correlation with algal cover.

The negative relationship between abundance of *Labrundinia virescens* and total plant cover in natural wetlands may also be related to filamentous algae cover and elevated pH levels. In general, wetlands with the highest total plant cover also supported the highest algal cover.

Relationships between Sediment Quality and Aquatic Macroinvertebrate Communities

Substrates can directly influence an organism's ability to attach, burrow, feed, escape from predation, construct cases, or deposit eggs. Cladotanytarsus sp., for example, may be limited to sandy substrates due to their habit of building cases constructed of sand grains. Most species, however, are generalists in terms of substrate preference (Minshall 1984). Even species that tend to prefer specific sediment conditions occur, at least in small numbers, on a wide range of sediment types (Ali and Mulla 1976).

Silt Content

Silt content of sediments tended to be negatively correlated with wetland age (p=0.0601, R-square=0.76), raising the possibility that siltation is reduced as constructed wetlands age (Table B2). Furthermore, sediments of constructed wetlands with steep slopes exhibited significantly higher percent silt content than those with gentle slopes (p=0.0157, R-square=0.76). These relationships are perhaps best explained by vegetation development and concurrent bank stabilization as constructed wetlands age. Transport of silt from the watershed into the wetland via surfacewater runoff increases with slope, possibly leading to the higher silt content observed in steep-sloped wetlands.

There were no significant relationships between total invertebrate abundance and sediment composition, including percent silt content. Taxa richness ($p=0.0634$, R-square= 0.41) and species diversity ($p=0.0479$, R-square=0.45) of core samples in the wet season tended to be negatively correlated with percent silt content, but results were insignificant during the dry season. If siltation is responsible for a decline in invertebrate species richness and species diversity, the effect is expected to be greatest during the wet season, as the results suggest.

DeMarch (1976) observed that silt was important in influencing the distribution of aquatic insects. Chutter (1969) recorded lower abundance and species richness in streams where there were large amounts of silt and sand. Similar observations have been made by other investigators (Nuttall and Beilby 1973; Nuttall 1972). Silt can affect feeding success and rate of growth by either making food less manageable or by diluting organic content (Wotton 1994). Reice (1974, 1977) reported slower processing of leaf litter and fewer kinds and abundances of leaf-processing insects on silt than on other substrates.

Perhaps siltation in newly constructed wetlands was not severe enough to cause a significant reduction in total organism abundance. However, even moderate increases in percent silt content may render sediments less favorable habitat for some organisms. For example, abundance of the filter feeder, *Chironomus* (*Lobochironomus*) sp., tended to be negatively correlated with silt content (p=0.0236, R-square=0.54). Another chironomid that feeds by collecting organic materials, *Kiefferulus dux*, exhibited a similar relationship to silt content (p=0.0229, R-square=0.55). These relationships may be due to interference of silt with feeding success. Undoubtedly some organisms prefer to live in silty substrates, but there were no positive correlations with silt during the current study.

Organic Content

Organic materials in sediments, especially fine particulate organic matter (FPOM) (<1 mm), are an important source of food for macroinvertebrates, but they also provide case-building materials and physical habitat. There were no significant relationships between sediment organic content and organism abundance, species richness, or diversity in constructed wetlands.

Perhaps there were no apparent relationships between sediment organic content and macroinvertebrate community structure because organic food resources were always in sufficient supply. In Florida freshwater marshes, plant production exceeds decomposition and organic peat accumulates over time. In such a setting, organic material is likely to be in excess of macroinvertebrate requirements and is not likely to be a limiting factor. Similar results have been observed in lotic systems when ample organic matter is available (Minshall and Minshall 1977; Peckarsky 1980; Williams 1980).

The methods used by Kiefer (1991) estimated the organic fraction of sediments but did not account for organic particle size. It is possible that correlations are not apparent because the method does not distinguish between FPOM (<1 mm) and coarser organic matter. FPOM is an important food source for macroinvertebrates, and when it has been analyzed separately, strong correlations have been observed (Rabeni and Minshall 1977; Short et al. 1980).

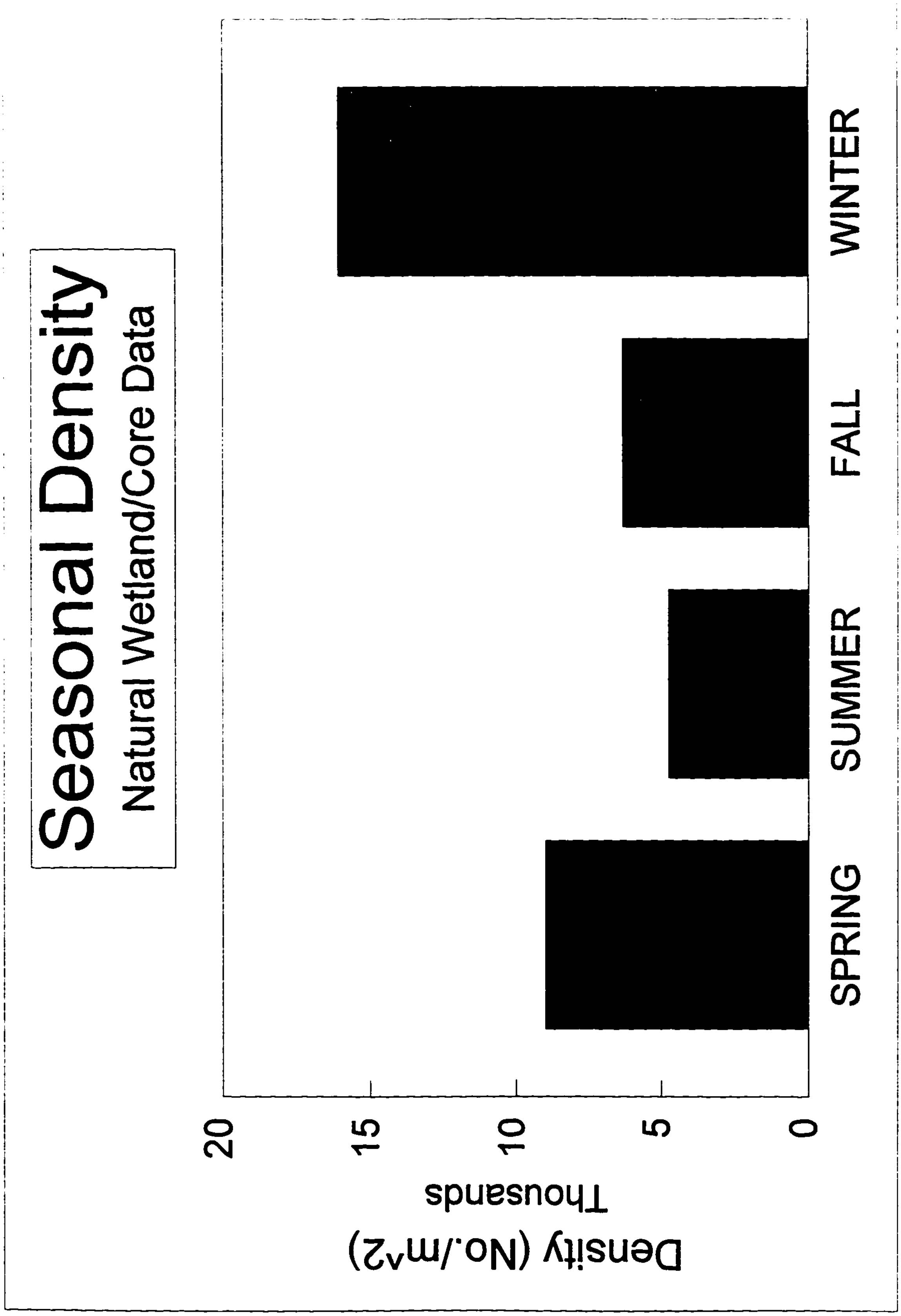
Seasonal Patterns in Abundance and Other Select Parameters of Benthic Macroinvertebrate Populations in Natural and Constructed Wetlands

Seasonal Abundance in Natural Wetlands

Core data

Organism abundance in natural wetlands was highest in the winter and lowest during summer and fall (Figure 47). Almost all species dominating benthic macroinvertebrate assemblages of the natural wetlands exhibited similar seasonal patterns of abundance, peaking during winter months and declining in the spring and summer. Such uniform changes are rare among biological communities, unless they occur in response to

Figure 47. Seasonal abundance of macroinvertebrates (No./M^2) in natural freshwater marshes in central Florida--Core data.


Seasonal Density
Natural Wetland/Core Data
Density (No./m^2)
Thousands
20
15
10
5
0
SPRING
SUMMER
FALL
WINTER

allogenic forces, such as those imposed by hydrological pulsing.

Sweep net samples

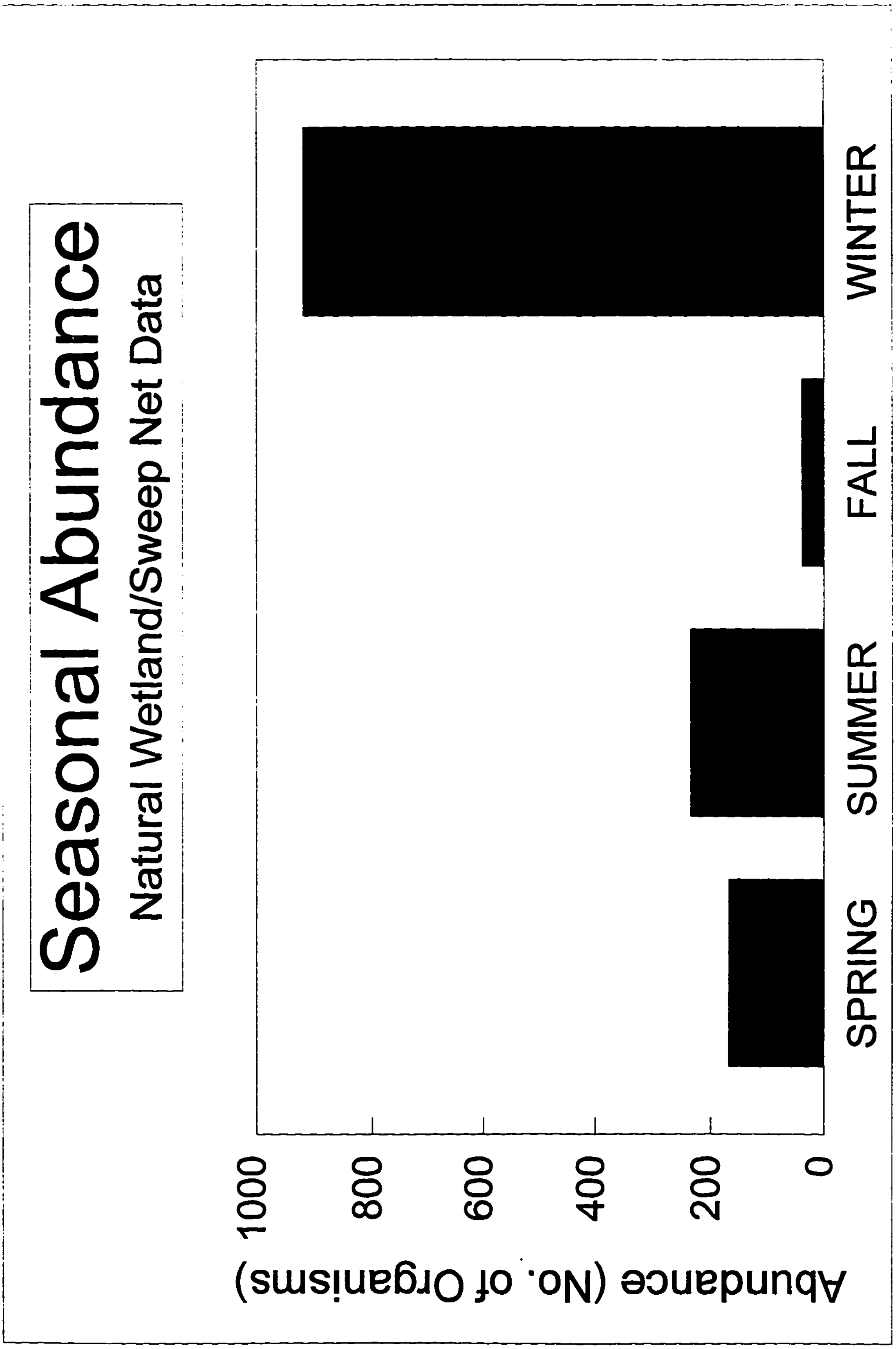
Seasonal patterns in abundance within sweep net samples were similar to patterns exhibited by core data (Figure 48). Mean abundance ranged from a low of 42 organisms in the fall to a high of 916 in winter months. Many of the natural wetlands were dry or nearly so during the fall sampling period. Nonburrowing invertebrates likely migrated to permanent water bodies or were desiccated during this period, explaining the low abundance of organisms. Burrowing organisms represented in core data maintained moderate population levels during the drydown period (6301 individuals/m^2). Data for the fall sampling period consisted of only one natural wetland because other wetlands were dry, thus analysis of the fall period should be regarded with some caution. It was not possible to obtain meaningful sweep samples from dry wetlands. The seasonal pattern of macroinvertebrate abundance observed in natural wetlands may be a function of wetland hydrology, food quality and quantity, and temperature and their influence on population densities and fecundity.

Seasonal Abundance in Constructed Wetlands

Core data

In contrast to natural wetlands, there were no consistent seasonal patterns in macroinvertebrate abundance in

Figure 48. Seasonal abundance of macroinvertebrates in natural freshwater marshes in central Florida--Sweep net data.


Seasonal Abundance
Natural Wetland/Sweep Net Data
Abundance (No. of Organisms)
1000
800
600
400
200
0
SPRING
SUMMER
FALL
WINTER

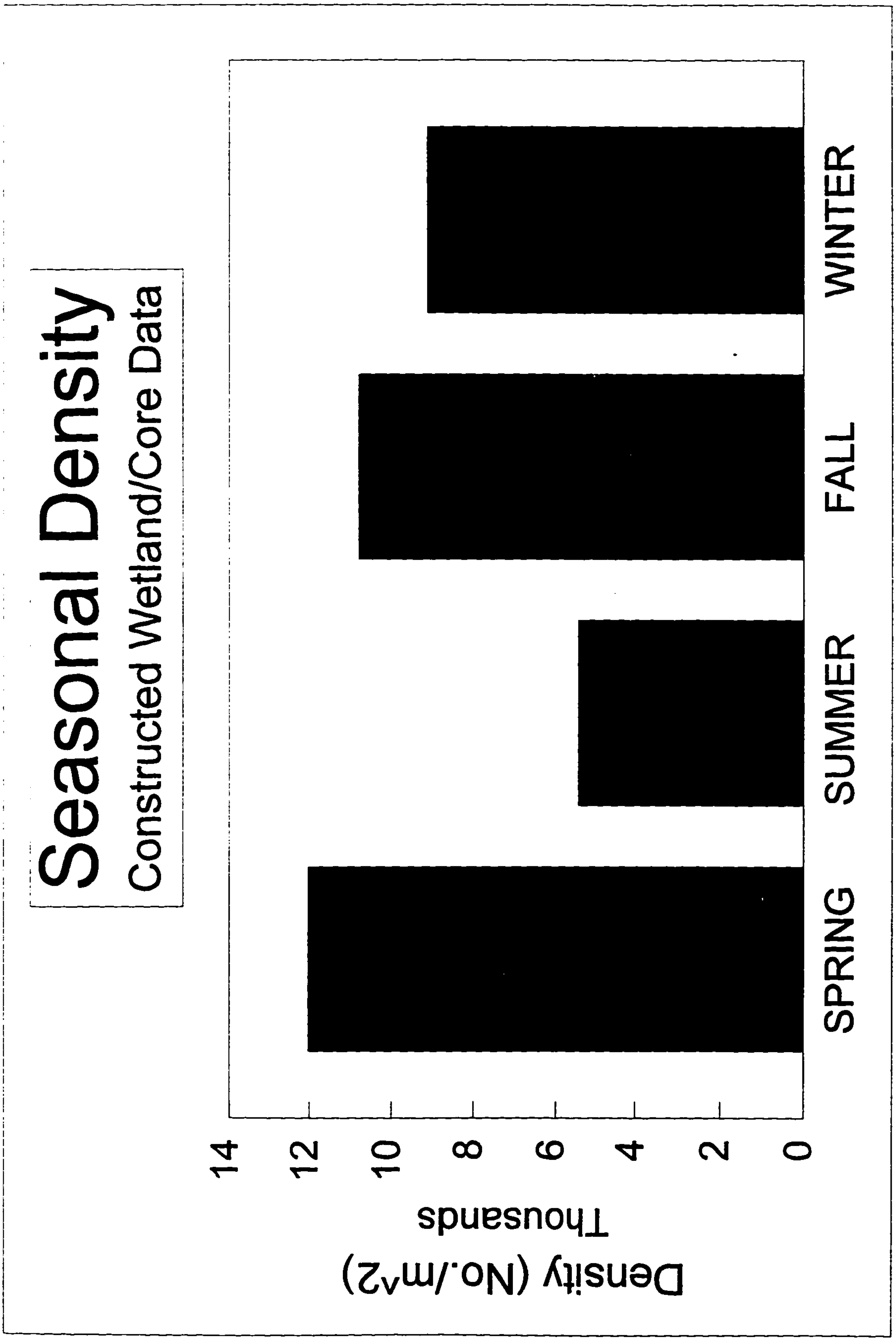
constructed wetlands (Figure 49). The seasonality of dominant species in constructed wetlands differed from those of natural wetlands. Two species exhibited little change in abundance with season. Four species were most abundant in the fall and declined rapidly in winter. Four other species were most abundant in spring and/or summer.

Macroinvertebrate abundance in constructed wetlands did not correlate well with seasonal patterns in chlorophyll concentration. This may be explained by considering the quality of food in constructed wetlands. In some newly constructed wetlands filamentous blue green and green algal mats were observed. Some filamentous algae are known to be difficult for many herbivores to graze effectively due to their large size and shape (Porter 1973). Many blue-green algae release toxic or inhibitory substances and are avoided by herbivores. For these reasons, algal biomass may be high in newly constructed wetlands, but limited nutritive value of dominant algal species may inhibit invertebrate production. To confirm or support this hypothesis, it is necessary to examine algal species assemblages with respect to their food value to aquatic invertebrates. Species composition of algal communities in the natural and constructed wetlands studied are unknown.

Sweep net samples

Organism abundance in sweep net samples collected in constructed wetlands peaked in winter (378 organisms per

Figure 49. Seasonal abundance of macroinvertebrates (No./M^2) in constructed freshwater marshes in central Florida--Core data.


Seasonal Density
Constructed Wetland/Core Data
Density (No./m^2)
Thousands
0
2
4
6
8
10
12
14
SPRING
SUMMER
FALL
WINTER

sampling event) (Figure 50). This peak in abundance may be caused by hydrological factors as well as temperature and food availability (explained in the following sections). However, there was no drydown phase in the constructed wetlands studied.

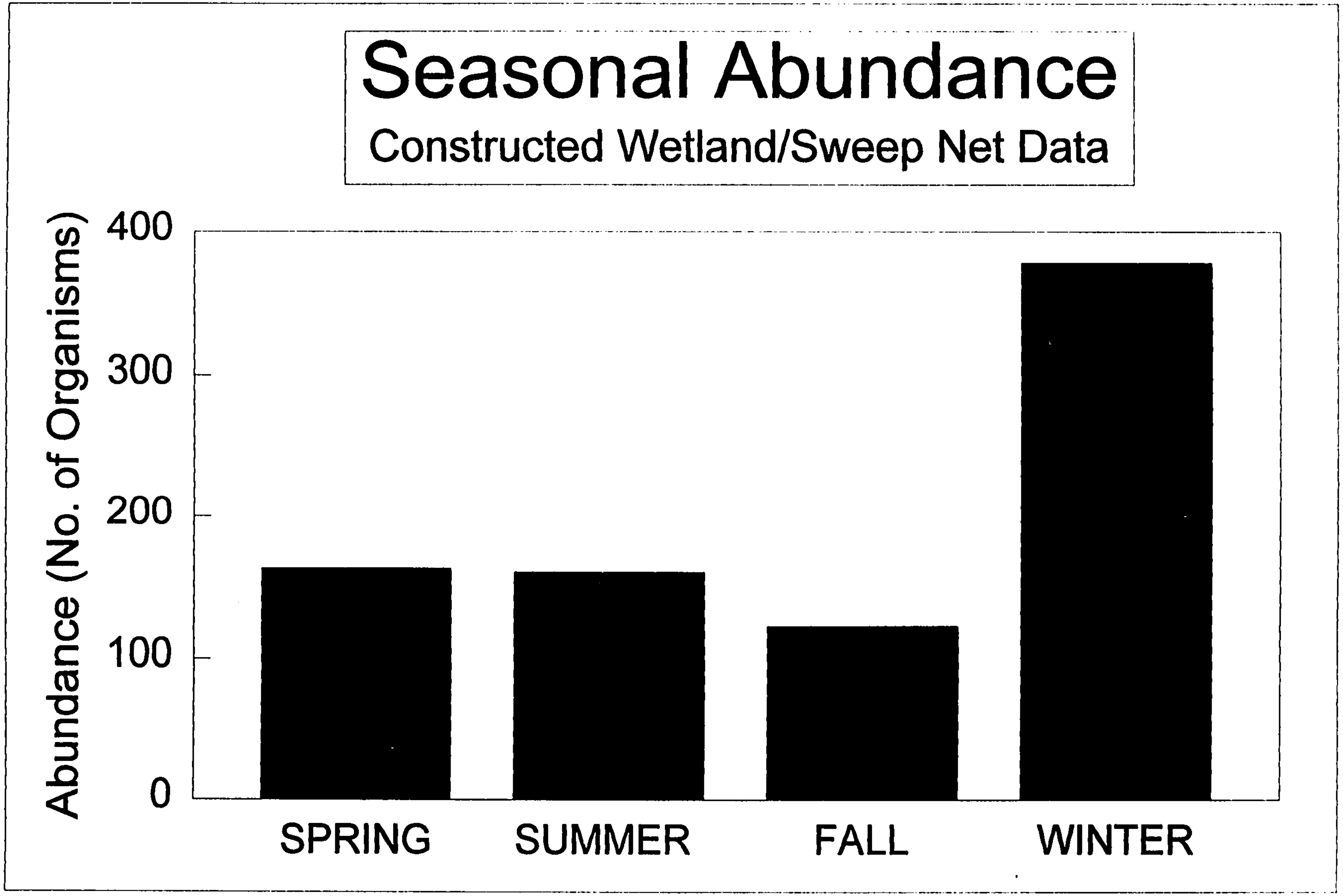
Influence of Hydrology

Although hydrological functions were not monitored during the current study, natural wetlands were observed to undergo seasonal water level fluctuations, primarily driven by rainfall. During the dry season (late fall), some of the natural wetlands were completely dry. During drydown, the density of existing fish and macroinvertebrate populations likely increased as wetland size decreased. As natural wetlands were reflooded with relatively small areas of inundation, organism densities peaked. This property of isolated, ephemeral wetlands renders excellent feeding grounds for the wood stork which depends on concentrated food resources during the breeding season. Water level fluctuation in natural wetlands may be the most important factor influencing seasonal abundance of macroinvertebrates. Total drydown was observed in the late fall, when organism densities were relatively low.

Influence of Food Quality and Quantity

Many of the species observed in natural wetlands are detritivores and are possibly responding to fall and winter pulses of decomposing plant material. Food quality and

Figure 50. Seasonal abundance of macroinvertebrates in constructed freshwater marshes in central Florida--Sweep net data.


Seasonal Abundance
Constructed Wetland/Sweep Net Data
Abundance (No. of Organisms)
400
300
200
100
0
SPRING
SUMMER
FALL
WINTER

quantity can affect aquatic insect growth rates significantly. Detritivores (Gallepp 1977; Colbo and Porter 1979), herbivores (Collins 1980), and predators (Macan 1977b; Fox and Murdoch 1978; Lawton et al. 1980) have been observed to grow faster with increasing food quantity. The increase in growth rate associated with improved food quality is most often related to microbial populations and the nitrogen content of detritus (Ward and Cummins 1979; Anderson and Cummins 1979).

Although water temperature declined during fall and winter, organic compounds consumed by bacteria were probably plentiful as macrophytes senesced. Cooler temperatures might improve dissolved oxygen retention, thereby allowing the more rapid process of aerobic decomposition. Therefore, it seems reasonable to expect a corresponding increase in bacterial production and the observed increase in invertebrate production during winter.

Influence of Temperature

The size of adults at emergence is a function of the length of the development period, and the growth rate during development. Temperature influences growth rate and duration of development prior to emergence. Growth rates are often positively correlated with temperature (Brittain 1976; Sweeney 1978; Humpesch 1979; Mackay 1979; Johannsen 1980). In contrast, a negative correlation exists between temperature and duration of development. Higher temperatures usually yield more rapid development rates (shorter life spans). The development period is lengthened under cooler temperatures.

Adults of multivoltine species emerging during the summer are often smaller in size than those of winter generations (LeSage and Harrison 1980; Sweeney and Vannote 1981). Since size of emerging adults has a positive correlation with fecundity (Clifford and Boerger 1974; Colbo and Porter 1979; Kondratieff and Voshell 1980; Sweeney and Vannote 1981), higher fecundity in winter is expected.

Comparisons between Core and Sweep Net Samples

General Background

Numerous sampling devices have been used to collect aquatic macroinvertebrates. The most commonly used samplers in lentic systems are grab samplers and coring devices (Downing 1984). In addition, box samplers (Macan 1949; Minto 1977) are often used to collect macroinvertebrates in submergent and emergent vegetation, and activity traps have been used in lakes and wetlands by some investigators, but they are limited to trapping relatively motile organisms, thus eliminating sessile forms from the sample (Whiteside and Lindegaard 1980; Murkin et al. 1983).

Hester-Dendy multiplate samplers are commonly used in lotic systems (Flannagan and Rosenberg 1982). Although multiplate samplers have been used to monitor wetland macroinvertebrate communities in freshwater marshes of

Florida (Evans and Sullivan 1984, 1986a; Erwin 1987, 1988), their use in wetland systems has not been fully tested. Evans (1987) reported limitations of their use in wetlands, including organism selectivity and their tendency to desiccate while incubating in shallow wetlands with fluctuating water levels.

Although sweep net sampling is less quantitative than other collection methods (Downing 1984), this method is used frequently because it is a simple, less time-consuming, cost-effective means of collecting aquatic macroinvertebrates. Sweep net samples are usually collected for a set time period or a consistent number of standardized sweeps, and results are reported as relative abundance or volumetric density (Downing 1984; Armitage 1977; Macan 1977a; Cheal et al. 1993; Danell and Sjoberg 1982). Macan (1977a) suggested that sweep nets can provide quantitative estimates of invertebrate population levels, and others have successfully used standardized sweeps to compare macroinvertebrate community structure in various types of wetland and aquatic systems (Evans 1989, Evans and Sullivan 1988; Erwin 1990; Friday 1987). Kaminski and Murkin (1981) investigated the use of sweep nets in wetlands and reported that sweep net collections yield data similar to those of box samplers.

The purpose of this aspect of the current study was to compare estimates of relative abundance and species richness obtained by using two sampling devices, a coring tube and a sweep net. This comparison provides a basis for determining which sampling method is more suitable for monitoring aquatic invertebrate community structure in natural and constructed wetlands of central Florida. Is it necessary to use both collection methods or is one of the methods sufficient for measuring success of wetland reclamation efforts?

Current Study Results

Total organism abundance

Although in general total organism abundance appeared to be higher in sweep samples (Tables B3 and B4), this difference was not significant (p=0.1534).

Abundance of major taxonomic groups

Chironomids, particularly the chironomines, tanypodines, and orthocladiines dominated the fauna collected by both sampling methods. Burrowers and some tube-dwellers such as oligochaetes, ceratopogonids, and tanytarsines occurred in significantly higher numbers in core samples than in sweep net samples (Tables 8, B7, and B8). The converse was true of active swimmers and organisms commonly associated with macrophytes. Active organisms included culicids, hemipterans, coleopterans, some ephemeropterans (*Callibaetis*), and decapods (*Palaemonetes*). Although gastropods are not active swimmers, they are often closely associated with vegetation in the water column (Brown and Lodge 1993).

Table 8. Comparison of Mean Abundance in Core and Sweep Net Samples

Taxonomic Group	Result	Level of Significance (P)	Mean Abundance	
			Core	Sweep Net
Naididae	C > SW	0.0009	9	4
Tubificidae	C > SW	0.0001	5	0
Lumbriculidae	C > SW	0.0076	2	1
Tanytarsini	C > SW	0.0028	5	2
Ceratopogonidae	C > SW	0.001	11	7
Decapoda	SW > C	0.0014	0	4
Odonata	SW > C	0.0001	5	27
Hemiptera	SW > C	0.0001	1	17
Culicidae	SW > C	0.0099	2	4
Gastropoda	SW > C	0.0011	1	9
Ephemeroptera	SW > C	0.0042	5	19
Coleoptera	SW > C	0.0001	9	14

C = Core sample abundance
SW = Sweep sample abundance

Similar results were reported by Cheal et al. (1993) for core and sweep net samples collected in five Australian wetlands, where amphipods, hemipterans, trichopterans, and odonates were consistently more common in sweep net samples and oligochaetes were more abundant in core samples. Other workers have observed that active swimmers are under-represented in benthic samples collected with dredges and corers (Macan 1949; Gerking 1957; Evans and Sullivan 1988).

Total taxa richness

There was no significant difference between total taxa richness within core and sweep net samples (p=0.7249), except within natural wetlands (p=0.0022) (Tables B3 and B4). Species richness of nektonic species was higher in natural wetlands than in constructed wetlands. This relationship is discussed in detail previously in this dissertation (natural vs. constructed wetland assemblages).

Taxa richness of major taxonomic groups

The taxa richness within many of the major taxonomic groups differed according to sampling method (Tables 9, B9, and B10). Decapods, culicids, odonates, coleopterans, hemipterans, Hirudinea, and gastropods were significantly richer in taxa in sweep samples than in core samples. Trombidiformes and trichopterans were conspicuously richer in taxa in sweep net samples, but not significantly so. Taxa richness of the major taxonomic groups in core samples was equal to or lower than that of sweep net samples.

Table 9. Comparison of Mean Taxa Richness in Core and Sweep Net Samples

Taxonomic Group	Result	Level of Significance (P)	Mean No. of Taxa	
			Core	Sweep Net
Hirudinea	SW > C	0.0061	0	1
Decapoda	SW > C	0.0001	0	1
Odonata	SW > C	0.0001	4	8
Hemiptera	SW > C	0.0001	1	8
Coleoptera	SW > C	0.0001	5	20
Gastropoda	SW > C	0.0029	2	3
Culicidae	SW > C	0.0001	2	4

C = Core sample abundance
SW = Sweep sample abundance

Discussion

Sweep net samples generally contained organisms that were actively swimming in the water column or clinging to submergent, emergent, and floating vegetation. Organisms on or within sediments occurred less frequently in sweep net samples. In contrast, core samples primarily consisted of organisms living on or in sediments, and organisms associated with vegetation and active swimmers were not well represented. Generally, the two methods sampled different vertical substrata, although sweep net samples can cover all substrata, including sediments. During the current study, an effort was made to include sediments in the sweep net samples to collect benthic invertebrates as well as nektonic invertebrates in the water column. However, some burrowing species (tubificid oligochaetes and bivalves) were not as well represented in sweep samples as in core samples. This is likely due to the difficulty in obtaining sediments with a sweep net in thickly vegetated areas.

Comparison based on organism abundance

Although a visual inspection of the data might lead one to suspect that more organisms were collected in sweep samples than in core samples, there is insufficient evidence to conclude this with certainty. If there is a difference, perhaps it is because the area and volume encompassed by sweeping a net through the vegetated water column is greater than that covered by the core samples.

Cheal et al. (1993) observed that in five Australian wetlands rare taxa were not as well represented in core samples as in sweep net samples. They attributed this to a smaller sampling area covered by core samplers. However, the rare taxonomic groups included coleopterans, odonates, water mites, and trichopterans. These organisms are primarily active swimmers (coleopterans and water mites) or are commonly associated with vegetation in the water column (odonates, water mites, and trichopterans) (Merritt and Cummins 1984), so they may have been rare in core samples due to behavior and habitat preference.

During the current study, coleopterans and odonates were not rare, but their abundance and taxa richness were significantly higher in sweep net samples than in core samples, probably as a result of their living habits. The current data do not support the statement that rare taxa are collected less frequently in core samples than in sweep net samples as suggested by Cheal et al. (1993). Differences in recorded organism abundance for the two collection methods appear to be related more to degree of motility and association with wetland plants than to organism rarity.

Differences in organism abundance between water column and benthic samples may also occur because surface area for attachment is greater in the vegetation than in the sediments. Brown and Lodge (1993) reported that when plant surface area is taken into account, the number of invertebrates per unit total surface area can be relatively low among plants. In light of the vast increase in surface area for attachment among macrophytes, significantly higher abundance per unit area of the bottom in the vegetated water column would be expected. As Brown and Lodge (1993) pointed out when considering the total available surface area, the most appropriate question may be as follows: "With all the apparent advantages macrophytes offer, why do invertebrates occur in lower densities among plants than at the sediment-water interface?"

Taxa richness

Core samples were probably lower in taxa richness because several major taxonomic groups, particularly nektonic macroinvertebrates, cannot be adequately sampled with a coring device. The inability of benthic samplers to collect nektonic invertebrates has also been observed and reported by other workers (Macan 1949; Gerking 1957).

Given the level of sampling effort performed during this study, in constructed wetlands, there was no significant difference between the number of taxa collected in core samples (mean = 34 taxa) and sweep net samples (mean = 30 taxa). In natural wetlands, the mean number of species collected per sampling event was higher for sweep net samples (51) than those collected using a corer (41). In spite of the influence of wetland type, mean taxa richness recorded for sweep net samples (39) was significantly higher than that recorded for core samples (36)(p=0.0022).

Results of the current study suggest that if sufficient resources are available, both sweep net and core samples should be collected. If only a single method is feasible, sweep net samples should be collected with great care to include at least the top sediment layer where most of the benthic organisms occur. Since this can be difficult to do in dense stands of emergent vegetation, it is best not to rely on sweep net sampling to adequately represent macroinvertebrate populations associated with sediments. Conversely, sweep net samples should not include sediments if the objective is demonstrate the influence of macrophytes on nektonic macroinvertebrates.

CHAPTER 4
SUMMARY AND CONCLUSIONS

Stability Relative to Natural Wetlands and Macroinvertebrate Community Variability

Within the age range of constructed wetlands studied, macroinvertebrate communities of the constructed wetlands did not attain stability relative to natural wetlands. Estimates of benthic macroinvertebrate population sizes were significantly more variable among constructed marshes than among natural marshes, probably due to varying environmental conditions in constructed wetlands. Variability was lower in natural wetlands in spite of their tendency to dry seasonally. This persistence is achieved, in part, by supporting fauna that are adapted to semi-terrestrial conditions.

Feeding Guilds

Abundance of organisms within feeding guilds established by Merritt and Cummins (1984) was similar in newly constructed wetlands and natural wetlands, except for scraper and shredder feeding guilds. Organisms that feed by scraping were more abundant in newly constructed wetlands than in older constructed and natural wetlands. Perhaps this can be attributed to an abundant food supply (epiphytic and epipelic algae) in constructed wetlands. Conversely, shredders may be less abundant in newly constructed wetlands due to a limited food supply (coarse organic material). As expected, abundance of collector-gatherers was similar among wetland types, perhaps due to rapid reproductive rates and an abundant food supply (organic particulate matter and algae). For unknown reasons collector-filterers were more abundant innatural marshes.

Predator-piercers (primarily beetles and hemipterans) colonized rapidly and were presumably able to make use of ample food resources (deposit feeders).

Macroinvertebrate Community Similarity

Within the range of wetland ages studied, constructed wetland benthic invertebrate communities were structurally more similar to one another than they were to natural wetland assemblages. Likewise, benthic macroinvertebrate communities of natural wetlands were more similar to one another than to those of constructed wetlands with respect to abundance, species richness, and diversity. With regard to macroinvertebrate community structure, older constructed marshes were more similar to natural marshes than newly constructed sites. This evidence supports the hypothesis that directional shifts in benthic macroinvertebrate communities occur as constructed wetlands age.

Relationships with Vegetation

Taxa richness of macroinvertebrate communities of constructed wetlands tended to be enhanced by the presence of vegetation cover, except where dense growth of filamentous algae or floating plants occurred. However, this study afforded little evidence of a strong direct relationship between living macrophytes and macroinvertebrates.

A significant negative correlation between total plant cover and organism abundance in natural wetlands (sweep data) is thought to be primarily due to dense filamentous algal growth occurring in natural wetlands where total plant cover was highest. There was a stronger negative correlation between sweep sample abundance and filamentous algae cover in natural wetlands during the wet season. In summer, macroinvertebrates in constructed wetlands exhibited a negative response to floating plant cover. This relationship is likely due to dissolved oxygen availability near the water-sediment interface and reduced plant surface for clinging organisms. Marshes supporting a high percent cover of floating plants tended to exhibit low dissolved oxygen values near the sediment water interface (Kiefer 1991). Chlorophyll _a_ concentration was also lower where floating plants were prevalent, indicating low phytoplankton populations (Kiefer 1991).

Wetland Design and Siltation

The relatively close similarity between benthic communities of shallow constructed wetlands with a gradual slope and natural wetlands, which are also characterized by shallow water depths and gentle slopes, provides evidence that wetland morphology may play an important role in determining benthic invertebrate community structure by influencing hydroperiod, sediment development, and plant community development.

Constructed wetlands with shallow water depths and gentle slopes may accumulate peat (production > decomposition) until the surface of the peat layer is near the water surface. At this stage in wetland development the peat surface elevation will likely attain equilibrium as peat decomposition rates approximate production rates (Mitsch and Gosselink 1986).

In constructed wetlands, the fraction of silt in sediments tended to be negatively correlated with wetland age. Perhaps siltation declined as wetland banks established rooted vegetation and stabilized with age. This relationship further implies that the constructed wetlands studied were in the process of achieving relative equilibrium. Sediment silt content was significantly higher in wetlands with steep slopes than wetlands with gentle slopes. The design of wetlands with gently sloping banks may promote macroinvertebrate production by reducing the amount of siltation, particularly during early wetland development when banks have not stabilized. Siltation in newly constructed wetlands was not severe enough to cause a significant reduction in total organism abundance. During the wet season, there were weak negative correlations between total macroinvertebrate taxa richness, diversity, and sediment silt content.

Organic Content of Sediments

There were no significant correlations between organic content of sediments and macroinvertebrate community structure. Perhaps macroinvertebrates did not respond to organic content because organic matter is not a limiting food resource in the wetlands studied. Since organic sediment analysis was not sensitive to particle size, it is also possible that the organic size fraction of greatest importance as food resource for macroinvertebrates, fine particulate organic matter (FPOM), was not quantified separately from total. Analysis of total organic content is not necessarily a good indicator of macroinvertebrate food availability.

Seasonal Distribution and Hydrology

In natural wetlands, abundance and taxa richness increased in winter and declined in spring. These changes are probably caused by a combination of factors such as hydrology, food availability, and temperature. Hydrology may be one of the most influential factors controlling seasonal abundance, as evidenced by a lack of standing water at some of the natural sites during the dry season (late fall). In the fall, natural wetlands decreased in size, thereby concentrating organisms, producing higher organism densities. In fall, when some natural wetlands went dry, the epifauna was temporarily eliminated. Following drydown, as water levels rose, macroinvertebrate abundance was highest. In constructed wetlands, organisms living in the water column followed a seasonal pattern of abundance similar to that of natural wetlands, but for unknown reasons, organisms associated with sediments exhibited no consistent seasonal patterns. Some unknown qualities of constructed wetland sediments may override seasonal effects on macroinvertebrate communities.

Sequence of Colonization

In general, macroinvertebrates are successful opportunists. The expected sequence of colonization based on ability to migrate and length of life cycles was not observed. Chironomids were immediately abundant as predicted; however, all major taxonomic groups were well represented within the first year of constructed marsh development. Evidently, any patterns of colonization occur very rapidly (within days or weeks), particularly for chironomids and oligochaetes. Perhaps monthly sampling is not a sufficient frequency to track events that occur on such a short time scale. It is also possible that variability was so great that any patterns are masked due to insufficient sample size. All major taxonomic groups of macroinvertebrates were effective opportunists in colonizing constructed marshes.

There was no significant difference in total organism abundance between newly constructed and older constructed wetlands. However, species richness was significantly higher in older constructed wetlands and natural wetlands in the wet season. Thus, organism abundance reached capacity before taxa richness. The same was true of species diversity during the dry season. These observations support the hypothesis that energy flow is first maximized through the successful colonization by opportunists and growth in system complexity occurs at a slower rate (Ulanowicz 1980).

Community Similarity and Ecological Development

The ecological development of newly constructed wetlands over time was accompanied by increasing similarity to natural wetlands, based on the following parameters:

1. macroinvertebrate community structure (Morisita's Index),
2. feeding guild structure,
3. macroindicators (abundance, taxa richness, and diversity),
4. degree of siltation, and
5. vegetation density.

The conditions of these parameters in constructed wetlands tend to converge on conditions in natural wetlands as constructed wetlands age. Even within the short range of ages studied (8 years), constructed wetlands showed signs of ecological development (macrophyte development, peat accumulation, silt reduction, shifts in aquatic macroinvertebrate species assemblages). Ecological development of constructed marshes may be accelerated by constructing shallow marshes (<40 cm) with gently sloping banks (<1.5 percent).

Hydrological characteristics and pH do not converge within the age range studied. These parameters may be responsible for some of the differences in macroinvertebrate community structure in the constructed and natural wetlands studied. Hydrological function of constructed marshes may never be similar to that of the natural marshes studied. A very long time period would be required for sufficient peat accumulation to occur in the constructed marshes to effectively shorten the hydroperiod.

Potential Applications

The usefulness of benthic invertebrates in the evaluation of wetland reclamation success may be somewhat limited by the difficulties encountered in collecting sufficient data for making valid statistical comparisons between wetlands. The time and resources required to collect a sufficient number of benthic invertebrate samples to allow conclusive statistical comparisons between constructed and natural wetlands may be prohibitive because invertebrate populations are highly variable, requiring collection of a large number of samples to obtain even modest statistical power.

Reduced sampling efforts may only be sufficient to detect the effects of major influencing factors (i.e., hydrology, siltation, vegetation, water quality). Therefore, even with a limited sampling effort, macroinvertebrate communities can be a useful semi-quantitative or qualitative indicator of wetland function.

Gastropods may prove to be an excellent indicator of constructed wetland condition. They were one of the first early opportunists to undergo dramatic population declines with increasing wetland age. Gastropods have the advantage of being easily collected and identified.

Hypothetically, as constructed wetlands accumulate peat over time, hydroperiod gradually shortens until equilibrium is reached and peat accumulation subsides. Species that are adapted to temporary waters or semi-terrestrial conditions may be useful indicators for tracking the influence of hydrological function on biota.

If sufficient resources are available, both sweep net and core samples should be collected. If only a single method is feasible, sweep net samples should be collected with great care to include at least the top sediment layer where most of the benthic organisms occur, unless the goal is to show the influence of vegetation on macroinvertebrates. It is best not to rely on sweep net sampling to represent macroinvertebrate populations associated with sediments because it is difficult to acquire sediments using the sweep method in dense stands of emergent vegetation.

Data reported by Kiefer (1991) and the results of the current study imply that monitoring water/sediment quality and aquatic macroinvertebrate populations of constructed sites prior to the third or fourth year after initial inundation is probably unnecessary and may be an inefficient use of resources.

Future Research Needs

This study used simultaneous sampling of wetlands of varying age as a representation of long-term wetland community development. Long-term studies within a limited number of constructed and natural wetlands would provide useful information for validating the approach taken for the current study.

If the concept of using macroinvertebrate indicator species to evaluate constructed wetlands is pursued, further work on the reliability of their use is warranted. An analysis of invertebrate biomass would allow hypotheses based on thermodynamics and information theory to be tested more directly.

Further evidence regarding the effect of pH on select invertebrate species needs to be based on controlled laboratory experiments and enclosure/exclosure experiments in the field.

Sediment analyses that account for organic particle size need to be performed in order to adequately assess detritivore food availability in constructed and natural wetlands.

Little is known of the role that periphyton and bacteria play in the development of communities in constructed wetlands. A detailed study of periphyton production in constructed wetlands of varying age would provide valuable insight to some of the questions generated by this study, particularly questions related to availability of invertebrate food resources.

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APPENDIX A
MACROINVERTEBRATE DATA

Table A1. Species Assemblages of Natural and Constructed Wetlands Based on Core Data

Wetland Age:	1.2	1.5	2	4	4.5	6	6.2	7	8	8	N	N	N	N	N	N	N	N	
Wetland Name:	P90	HP90	CS88	CS86	FG86	CS85	CS84	CS83	FG82	G81	R1	R2	R3	R4	R5	N1	N2	N3	GR
CONSTRUCTED WETLAND ASSEMBLAGE																			
Chaoborus punctipennis	0	99	160	62	25	62	86	0	49	0	25	0	0	0	0	0	0	0	0
Dero digitata	12	12	358	222	111	49	111	37	123	0	25	25	12	0	0	16	0	0	148
Dero nivea	123	25	1925	62	99	49	86	0	111	62	0	12	160	0	0	0	0	0	0
Erythemis simplicicollis	49	37	37	160	0	136	25	25	123	74	0	37	0	0	25	0	0	37	148
Goeldichironomus holoprasinus	160	49	148	12	37	0	12	0	25	12	0	62	0	0	62	0	0	247	49
Hyalella azteca	987	642	1703	2530	654	592	2579	8218	1493	1333	86	716	12	111	0	494	263	12	4640
Parachironomus hirtalatus	0	49	25	111	25	111	136	123	62	74	25	25	0	25	12	0	33	25	0
Polypedilum illinoense	62	1641	12	210	0	0	12	111	160	1061	0	370	12	12	12	0	33	173	99
TOTAL	1394	2554	4368	3369	950	1000	3048	8514	2147	2616	160	1246	197	148	111	510	329	494	5084
TRANSITIONAL ASSEMBLAGE																			
Ablabesmyia peleensis typeII	0	0	25	210	74	86	86	173	86	666	86	296	25	0	518	0	66	383	691
Celina sp.	62	0	12	247	123	271	25	49	210	37	308	136	49	111	74	181	66	111	642
Chironomus (Lobochironomus) sp.	383	25	49	1468	1037	49	346	222	1074	74	3949	531	1530	346	210	938	707	308	1925
Polypedilum tritum	12	0	12	975	99	25	481	111	62	0	481	197	111	1209	308	444	740	74	148
Tanytarsini Genus A-Roback	12	0	12	160	12	271	111	284	173	123	0	1012	62	0	432	0	66	346	0
Tubificidae sp. B (immature)	0	37	37	666	136	160	25	0	0	0	160	74	444	25	0	33	0	0	49
TOTAL	469	62	148	3727	1481	864	1074	839	1604	901	4985	2246	2221	1691	1542	1596	1645	1222	3455
NATURAL WETLAND ASSEMBLAGE																			
Ablabesmyia rhamphe gr.	0	0	0	0	0	0	0	0	0	0	333	25	173	49	0	99	66	0	395
Atrichopogon sp. A	0	0	0	12	0	12	12	0	12	12	210	185	25	74	136	132	99	197	0
Chaoborus albatus	0	0	0	0	0	0	0	0	0	74	148	25	49	12	62	33	148	12	0
Crangonyx floridanus	0	0	0	0	0	0	0	0	0	0	617	1197	12	568	210	378	280	12	197
Dicrotendipes leucoscelis	0	0	0	12	0	0	0	0	12	0	938	86	259	494	0	395	707	12	0
Fittkaumyia prob. serta	0	0	0	0	0	0	0	0	0	0	123	25	99	210	0	329	49	0	49
Kiefferulus dux	123	12	12	74	62	25	49	12	111	25	111	271	271	123	308	82	33	25	148
Labrundinia neopilosella	0	0	0	12	12	0	12	12	0	0	321	0	222	62	0	214	148	0	592
Laccophilus sp.	0	0	0	0	0	0	0	0	0	0	74	74	37	86	12	49	66	0	0
Larsia berneri	12	0	0	0	0	0	0	0	0	86	827	185	111	0	37	49	66	136	0
Larsia indistincta	160	173	0	0	0	0	0	0	0	420	592	469	62	0	469	16	148	123	0
Limnophyes sp.	0	0	0	0	0	0	0	0	0	0	99	49	25	432	62	214	313	25	0
Polypedilum trigonus	173	481	12	99	358	37	74	123	432	49	703	1333	296	580	333	444	790	592	740
Pseudosmittia sp.	0	0	0	0	0	0	0	0	0	0	0	25	136	0	0	33	214	99	0
TOTAL	469	666	25	210	432	74	148	148	568	666	5096	3949	1777	2690	1629	2468	3126	1234	2122

Table A2. Mean Number of Organisms Collected Within Major Taxonomic Groups—Core Data

CORE DATA																		
Wetland Age	1.2	1.5	1.5	2	4	4.5	6	6.2	7	8	8	N	N	N	N	N	N	N	
Wetland Name	P90	HP90	G90	CS88	CS86	FG86	CS85	CS84	CS83	FG82	G81	R1	R3	R4	R5	N1	N2	N3	Means
TAXONOMIC GROUP																			
Planariidae	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0
Nemertea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Naididae	5	1	3	60	20	14	7	15	1	24	4	3	7	0	1	0	1	3	9
Tubificidae	1	6	0	12	30	5	5	3	0	0	2	4	12	1	1	6	1	1	5
Lumbriculidae	0	0	2	1	4	3	11	3	3	2	0	2	1	3	0	1	3	0	2
Enchytraeidae	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hirudinea	0	0	1	0	0	1	2	0	0	1	0	0	0	0	1	0	0	0	0
Isopoda	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	49	33	0	5
Amphipoda	20	13	64	35	51	13	12	52	167	30	27	14	1	14	4	18	11	1	30
Decapoda	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Trombidiformes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ephemeroptera	2	1	6	3	22	10	1	7	4	5	1	7	12	2	2	2	2	1	5
Odonata	6	3	6	5	10	6	6	4	9	9	7	3	3	3	2	4	1	8	5
Hemiptera	2	2	1	1	2	1	1	1	3	1	1	4	1	1	2	0	0	1	1
Coleoptera	8	1	5	2	14	8	20	7	11	12	9	16	4	10	6	13	8	10	9
Chironomini	25	51	16	70	71	42	7	35	15	44	28	133	64	59	33	49	63	31	46
Orthocladiinae	0	1	0	0	1	0	0	1	0	0	0	15	15	9	1	5	11	3	3
Tanypodinae	24	27	11	8	28	55	21	13	12	35	78	106	37	14	59	28	17	57	35
Tanytarsini	1	2	15	2	4	9	6	3	6	5	11	0	2	1	22	0	3	10	5
Ceratopogonidae	17	6	12	4	10	20	15	9	4	8	7	20	4	4	36	9	10	7	11
Chaoboridae	0	2	0	3	1	1	1	2	0	1	2	4	1	0	1	1	3	0	1
Culicidae	0	0	0	1	4	1	5	1	4	2	1	3	2	2	2	6	2	2	2
Muscidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stratiomyidae	0	3	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0
Tipulidae	1	0	0	0	0	1	1	0	1	0	1	2	1	1	2	2	2	2	1
Other Diptera	0	0	1	1	1	1	0	0	0	1	0	1	1	3	1	1	1	1	1
Trichoptera	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Lepidoptera	0	0	0	0	0	0	1	1	2	1	1	0	0	0	0	0	1	0	0
Gastropoda	2	4	5	3	1	2	1	0	1	1	0	0	1	0	2	0	0	0	1
Pelecypoda	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0

Table A3. Mean Number of Organisms Collected Within Major Taxonomic Groups—Sweep Net Data

Wetland Age:	1.2	1.5	1.5	2	4	4.5	6	6.2	7	8	8	N	N	N	N	N	N	N	
Wetland Name:	P90	HP90	G90	CS88	CS86	FG86	CS85	CS84	CS83	FG82	G81	R1	R3	R4	R5	N1	N2	N3	Means
TAXONOMIC GROUP																			
Planariidae	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Nemertea	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	1	0
Naididae	1	0	0	18	15	5	6	4	1	13	1	14	3	0	0	1	1	1	4
Tubificidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Lumbriculidae	0	0	0	0	0	0	6	0	0	0	0	0	1	0	0	2	10	1	1
Enchytraeidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hirudinea	0	0	79	2	1	1	2	0	0	1	0	0	0	0	0	0	0	0	5
Isopoda	0	0	3	1	0	0	0	0	0	0	0	3	4	0	0	86	51	0	8
Amphipoda	38	7	0	234	66	42	2	39	86	31	23	12	0	129	2	741	59	1	84
Decapoda	10	13	0	1	0	3	0	6	6	5	0	1	8	18	0	3	0	0	4
Trombidiformes	0	0	0	0	7	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Ephemeroptera	9	0	5	9	63	37	7	27	3	24	2	49	25	16	25	19	23	0	19
Odonata	18	8	2	75	33	16	21	35	33	23	16	58	55	11	21	23	25	21	27
Hemiptera	35	11	11	18	9	12	14	13	15	12	4	20	62	17	5	18	21	9	17
Coleoptera	38	9	24	148	10	9	22	14	10	10	26	34	48	148	24	111	34	14	41
Chironomini	51	12	2	10	11	8	1	4	4	11	8	438	53	205	11	93	98	10	57
Orthocladiinae	1	0	1	0	0	0	0	0	1	0	0	38	2	5	1	2	9	0	3
Tanypodinae	50	3	1	6	39	38	10	9	17	38	7	279	70	34	30	76	54	33	44
Tanytarsini	4	1	0	0	1	2	1	1	1	2	3	0	0	1	6	1	2	7	2
Ceratopogonidae	6	0	1	2	9	17	1	1	2	8	4	22	2	11	7	7	18	3	7
Chaoboridae	0	0	3	0	0	0	0	0	0	0	0	13	1	0	0	0	1	0	1
Culicidae	2	1	0	3	4	4	11	8	6	3	2	7	2	0	8	8	2	4	4
Muscidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Stratiomyidae	4	6	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	3	1
Tipulidae	3	0	0	0	1	0	1	1	0	0	1	3	0	2	0	4	2	1	1
Other Diptera	1	0	3	0	1	0	0	0	0	0	0	2	2	1	1	3	5	1	1
Trichoptera	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0
Lepidoptera	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0
Gastropoda	13	12	7	60	2	7	3	2	2	10	1	0	0	1	29	0	0	9	9
Pelecypoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	284	81	141	586	272	202	105	162	186	189	95	997	343	599	169	1200	414	116	

Table A4. Mean Abundance of Organisms Within Major Feeding Guilds—Raw Core Data

Wetland Age:	1.2	1.5	1.5	2	4	4.5	6	6.2	7	8	8	N	N	N	N	N	N	N
Wetland Name:	P90	HP90	G90	CS88	CS86	FG86	CS85	CS84	CS83	FG82	G81	R1	R3	R4	R5	N1	N2	N3
FEEDING GUILD																		
Collector-Gatherers	49	69	80	124	168	76	43	106	184	85	61	90	76	73	43	102	99	33
Collector-Filterers	10	6	25	58	42	32	11	15	16	31	15	106	41	20	30	35	34	19
Scrapers	2	4	5	3	1	2	1	1	1	1	0	0	1	0	2	0	0	0
Shredders	1	0	0	1	0	1	1	1	3	1	1	2	1	2	3	2	3	2
Predator-Engulfers	41	39	30	20	49	69	43	24	25	50	92	127	44	22	94	42	31	72
Predator-Piercers	10	3	6	4	16	10	23	10	14	14	10	21	6	12	8	14	9	11
TOTAL	113	121	146	210	277	191	122	157	243	182	179	345	169	127	178	195	175	136

Table A5. Mean Abundance of Organisms Within Major Feeding Guilds—Sweep Net Data

Wetland Age:	1.2	1.5	1.5	2	4	4.5	6	6.2	7	8	8	N	N	N	N	N	N	N
Wetland Name:	P90	HP90	G90	CS88	CS86	FG86	CS85	CS84	CS83	FG82	G81	R1	R3	R4	R5	N1	N2	N3
FEEDING GUILD																		
Collector-Filterers	7	5	1	7	10	9	10	9	6	9	7	419	20	37	18	68	57	12
Collector-Gatherers	107	32	12	267	153	100	21	79	100	80	31	155	82	338	36	887	201	15
Predator-Engulfers	73	12	7	84	79	63	32	44	52	67	24	364	129	56	55	108	99	56
Predator-Piercers	73	20	114	168	27	23	39	27	26	23	30	55	111	166	30	129	55	24
Scrapers	14	12	7	60	2	7	3	2	3	10	1	0	0	1	29	0	0	9
Shredders	3	0	0	0	1	0	1	1	0	1	2	4	1	3	1	5	2	1
Total	277	81	141	586	272	201	105	162	186	189	94	997	343	599	169	1196	414	116

APPENDIX B
STATISTICAL TABLES

Table B-1. Regression tables showing relationships between aquatic macrophytes and aquatic m
constructed marshes of central Florida

Wetland Type	Season	Sampling Method	Dependent Variable	Sources of Variation	Degrees of Freedom	Mean Square	F Value	p Val
Constructed	Dry	Core	Logabun	Emergent	1	1.08	4.56	0.
				Error	9	0.24	----	----
Natural	Wet	Sweep	Logabun	Algae	1	3.28	26.77	0.
				Error	5	0.12	----	----
Natural	Dry	Sweep	Logabun	Total	1	3.61	12.23	0.
				Error	5	0.30	----	----
Constructed	Wet	Sweep	Taxa	pH	1	209.46	5.71	0.
				Error	9	36.71	----	----
Constructed	Dry	Core	Taxa	Total	?			
				Error	?			
Constructed			Logabun	Years	1	1.73	10.43	0.
			Abla pel	Error	9	0.17	----	----
Natural			Logabun	pH	1	4.22	20.19	0.
			Belo test	Error	5	0.21	----	----
Natural			Logabun	Total	1	10.96	10.57	0.
			Lobochiro	Error	5	1.04	----	----
Natural			Logabun	Emergent	1	0.99	8.28	0.0
			Desmo gran	Error	5	0.60	----	----
Natural			Logabun	Algae	1	9.34	28.33	0.
			Dicro leuco	Error	5	0.33	----	----
Natural			Logabun	pH	1	3.95	7.24	0.
			Kief dux	Error	5	0.55	----	----
Natural			Logabun	Algae	1	2.10	180.57	0.
			Labrun neo	Error	5	0.06	----	----
			Logabun	Floating	1	1.61	4.67	0.
Natural			Lacco gent	Emergent	1	3.15	9.12	0.
				Error	4	0.34	----	----
Natural			Logabun	Algae	1	1.78	13.24	0.01
			Lacco sp.	Error	5	0.67	----	----
Constructed		Core	Logabun	Emergent	1	1.94	8.73	0.
			Lobochiro	Slope	1	1.69	7.63	0.
				Error	8	0.22	----	----
Constructed		Core	Logabun	Slope	1	0.72	6.12	0.
			Kieffer dux	Error	9	0.12	----	----
Constructed		Core	Logabun	Years	1	0.35	4.04	0.
			Manson tit	Submergent	1	0.85	9.90	0.
				Error	9	0.09	----	----
Constructed		Core	Logabun	Total	1	0.04	9.95	0.
			Natarsia sp.	Years	1	0.03	9.99	0.
				Error	8	0.003	----	----
Natural		Core	Logabun	Algae	1	7.47	35.32	0.
			Dicro leuc	Error	5	0.21	----	----
Natural		Core	Logabun	Algae	1	3.25	18.66	0.
			Labrund neo	Error	5	0.17	----	----
Natural		Core	Logabun	Submerge	1	0.29	21.96	0.

hytes and aquatic macroinvertebrates, constructed wetland design, and wetland age in natural and

Mean uare	F Value	p Value	Linear Regression Equation						
1.08	4.56	0.06	Logabun	=	4.55	+	0.013	*	Emergent
0.24	----	------							
3.28	26.77	0.00	Logabun	=	5.63	-	0.05	*	Algae
0.12	----	------							
3.61	12.23	0.02	Logabun	=	8.78	-	0.02	*	Total
0.30	----	------							
9.46	5.71	0.04	Taxa	=	-4.63	+	4.49	*	pH
6.71	----	------							
1.73	10.43	0.01	Logabun	=	0.16	-	0.1	*	Years
0.17	----	------	Abla pel						
4.22	20.19	0.01	Logabun	=	47.15	-	4.2	*	pH
0.21	----	------	Belo test						
0.96	10.57	0.02	Logabun	=	7.08	-	0.034	*	Total
1.04	----	------	Lobochiro						
0.99	8.28	0.035	Logabun	=	0.017	-	0.974	*	Emergent
0.60	----	------	Desmo gran						
9.34	28.33	0.00	Logabun	=	2.56	-	0.08	*	Algae
0.33	----	------	Dicro leuco						
3.95	7.24	0.04	Logabun	=	8.08	-	1.25	*	pH
0.55	----	------	Kief dux						
2.10	180.57	0.00	Logabun	=	1.22	-	0.038	*	Algae
0.06	----	------	Labrun neo						
1.61	4.67	0.10	Logabun	=	-1.65	+	0.03	*	Emergent
3.15	9.12	0.04	Lacco gent			-	0.03	*	Floating
0.34	----	------							
1.78	13.24	0.0149	Logabun	=	-0.035	+	1.12	*	Algae
0.67	----	------	Lacco sp.						
1.94	8.73	0.02	Logabun	=	0.13	+	1.01	*	Slope
1.69	7.63	0.02	Lobochiro			+	0.02	*	Emergent
0.22	----	------							
0.72	6.12	0.04	Logabun	=	0.296	+	0.513	*	Slope
0.12	----	------	Kieffer dux						
0.35	4.04	0.08	Logabun	=	-0.03	+	0.01	*	Submergent
0.85	9.90	0.01	Manson tit			+	0.07	*	Years
0.09	----	------							
0.04	9.95	0.01	Logabun	=	-0.15	+	0.03	*	Years
0.03	9.99	0.01	Natarsia sp.			+	0.00	*	Total
.003	----	------							
7.47	35.32	0.00	Logabun	=	2.42	-	0.071	*	Algae
0.21	----	------	Dicro leuc						
3.25	18.66	0.01	Logabun	=	1.51	-	0.047	*	Algae
0.17	----	------	Labrund neo						
0.29	21.96	0.02	Logabun	=	-2.19	-	0.02	*	Submerge

Table B-1. Regression tables showing relationships between aquatic macrophytes and aquat constructed marshes of central Florida

Wetland Type	Season	Sampling Method	Dependent Variable	Sources of Variation	Degrees of Freedom	Mean Square	F Value
			Natarsia sp.	Total	1	0.44	33.24
				pH	1	0.1	7.59
				Error	3	0.01	----
Constructed			Algae	Slope	1	506.83	8.09
				Years	1	370.74	5.92
				Error	8	501.31	----
Constructed			Emergent	Slope	1	3321.25	17.32
				Years	1	2541.46	13.25
				Error	8	191.77	----

s and aquatic macroinvertebrates, constructed wetland design, and wetland age in natural and

F Value	p Value	Linear Regression Equation						
33.24	0.01	Natarsia sp.			+	0.01	*	Total
7.59	0.07				+	0.33		pH
----	------							
8.09	0.02	Algae	=	28.14	-	13.75	*	Slope
5.92	0.04				-	2.3	*	Years
----	------							
17.32	0.00	Emergent	=	40.42	-	35.2	*	Slope
13.25	0.01				+	6.02	*	Years
----	------							

Table B-2. Regression tables showing relationships between sediment quality (particle size in natural and constructed marshes of central Florida

Wetland Type	Season	Sampling Method	Dependent Variable	Sources of Variation	Degrees of Freedom	Mean Square
Constructed	Dry	Core	Log	% Organic Matter	1	1.73
			Abundance	Error	7	0.18
Constructed	Wet	Core	Taxa	% Silt Content	1	297.82
			Richness	Error	7	61.36
Constructed	Dry	Core	Taxa	% Organic Matter	1	391.25
			Richness	Error	7	77.28
Constructed	Dry	Sweep	Taxa	% Organic Matter	1	607.78
			Richness	Error	6	453.69
Constructed	Wet	Core	Shannon	% Silt	1	2.14
			Diversity	Error	7	2.62
Constructed	Wet	Sweep	Shannon	% Silt	1	0.92
			Diversity	Error	7	0.22
Constructed	Dry	Sweep	Shannon	% Silt	1	1.34
			Diversity	Error	6	1.14
Regression Table - Individual Taxa						
Constructed		Core	Log Abund.	% Silt	1	5.71
			Chiro. Lobo.	Error	7	0.69
Constructed		Core	Log Abund.	% Silt	1	0.74
			Kief. dux	Error	7	0.61
Constructed		Sweep	Logabun	%Silt	1	5.71
			Lobochiro	Error	7	0.69
Constructed		Core	Logabun	%Silt	1	0.74
			Kieffer dux	Error	7	0.61
Constructed		Core	Logabun	%Silt	1	5.71
			Lobochiro	Error	7	0.69
Constructed		Core	Logabun	%Silt	1	0.74
			Kieffer dux	Error	7	0.61
Constructed			Organic	Wetland Slope	1	0.01
				Years	1	0.00
				Error	6	0.01
Constructed			Silt	Wetland Slope	1	7.52
				Years	1	3.61
				Error	6	4.05
Constructed			% Silt	Wetland Slope	1	7.52
				Wetland Age	1	3.61
				Error	6	0.68

(particle size) and aquatic macroinvertebrates, constructed wetland design, and wetland age

of om	Mean Square	F Value	p Value	Linear Regression Equation						
1	1.73	9.83	0.016	Log	=	5.77	-	9.03	*	% Organic Matter
7	0.18	----	------	Abundance						
1	297.82	4.85	0.063	Taxa	=	47.15	-	4.2	*	% Silt Content
7	61.36	----	------	Richness						
1	391.25	5.06	0.059	Taxa	=	47.06	-	135.9	*	% Organic Matter
7	77.28	----	------	Richness						
1	607.78	8.04	0.030	Taxa	=	50.72	-	171.1	*	% Organic Matter
6	453.69	----	------	Richness						
1	2.14	5.73	0.048	SW	=	4.67	-	0.36	*	% Silt
7	2.62	----	------	Diversity						
1	0.92	4.09	0.083	SW	=	4.50	-	0.23	*	% Silt
7	0.22	----	------	Diversity						
1	1.34	7.06	0.038	SW	=	4.53	-	0.29	*	% Silt
6	1.14	----	------	Diversity						
1	5.71	8.30	0.024	Log	=	3.69	-	0.58	*	% Silt
7	0.69	----	------	Abundance						
1	0.74	8.42	0.023	Log	=	3.69	-	0.58	*	% Silt
7	0.61	----	------	Abundance						
1	5.71	8.30	0.02	Logabun	=	3.69	-	0.582	*	%Silt
7	0.69	----	------							
1	0.74	8.42	0.02	Logabun	=	1.29	-	0.21	*	%Silt
7	0.61	----	------							
1	5.71	8.30	0.02	Logabun	=	3.69	-	0.582	*	%Silt
7	0.69	----	------							
1	0.74	8.42	0.02	Logabun	=	1.29	-	0.21	*	%Silt
7	0.61	----	------							
1	0.01	3.32	0.12	Organic	=	0.07	+	0.054	*	Wetland Slope
1	0.00	1.01	0.35				-	0.01	*	Years
6	0.01	----	------							
1	7.52	11.13	0.02	Silt	=	3.41	+	1.86	*	Wetland Slope
1	3.61	5.34	0.06				-	0.27	*	Years
6	4.05	----	------							
1	7.52	11.13	0.016	% Silt	=	3.41	-	1.86	*	Wetland Slope
1	3.61	5.34	0.060							
6	0.68	----	------							

Table B3. ANOVA tables showing relationships between select variables and total log baundance, taxa richness, and Shannon-Weiner species diversity of aquatic macroinvertebrates in natural and constructed marshes of central Florida

Sources of Variation	Degrees of Freedom	Mean Square	F Value	p Value
Class	4	0.98	1.07	0.41
Site within Class	13	0.92	----	-----
Sampling Method	1	0.66	2.12	0.15
Class*Method	4	0.66	2.11	0.10
Season	1	2.35	7.53	0.01
Method*Season	1	0.25	0.81	0.37
Class*Season	4	0.92	2.93	0.03
Class*Method*Season	4	0.91	2.91	0.03
Error	38	0.31	----	-----
Wetland Age (new vs. old	1 wet		0.10	0.76
Slope (steep vs. gentle)	1 wet		0.86	0.36
Interaction	1 wet		1.65	0.21
Natural vs. constructed	1 wet		0.00	0.97
Wetland Age (new vs. old	1 dry		2.50	0.13
Slope (steep vs. gentle)	1 dry		0.82	0.37
Interaction	1 dry		0.09	0.76
Natural vs. constructed	1 dry		7.76	0.01

ANOVA Table - Total taxa richness of aquatic macroinvertebrates collected from natural and constructed marshes in central Florida

Class				
Site within Class	13	292.56	----	-----
Sampling Method	1	8.13	0.13	0.72
Class*Method	4	199.91	3.09	0.03
Season	1	783.11	12.12	0.00
Method*Season	1	24.46	0.38	0.54
Class*Season	4	122.84	1.90	0.13
Class*Method*Season	4	59.05	0.91	0.47
Error	38	64.63	----	-----
Wetland Age (new vs. old	1 wet		4.95	0.04
Slope (steep vs. gentle)	1 wet		0.08	0.78
Interaction	1 wet		0.00	0.98
Natural vs. new	1 wet		6.19	0.02
Natural vs. old	1 dry		0.09	0.77
Wetland Age (new vs. old	1 dry		1.55	0.23
Slope (steep vs. gentle)	1 dry		1.30	0.27
Interaction	1 dry		0.25	0.62
Natural vs. constructed	1 dry		17.69	0.00

ANOVA Table - Shannon-Weiner diversity of aquatic macroinvertebrates collected from natural and constructed marshes in central Florida

Class	4	1.64	3.38	0.04
Site within Class	13	0.49	----	-----

Table B3. ANOVA tables showing relationships between select variables and total log baundance, taxa richness, and Shannon-Weiner species diversity of aquatic macroinvertebrates in natural and constructed marshes of central Florida

Sources of Variation	Degrees of Freedom	Mean Square	F Value	p Value
Sampling Method	1	0.47	3.10	0.09
Class*Method	4	0.05	0.31	0.87
Season	1	0.02	0.15	0.70
Method*Season	1	0.67	4.39	0.04
Class*Season	4	0.47	3.09	0.03
Class*Method*Season	4	0.32	2.11	0.10
Error	38	0.15	----	-----
Wetland Age (new vs. old	1 wet		0.33	0.57
Slope (steep vs. gentle)	1 wet		3.97	0.06
Interaction	1 wet		0.55	0.46
Natural vs. constructed	1 wet		10.47	0.00
Wetland Age (new vs. old	1 dry		7.50	0.01
Slope (steep vs. gentle)	1 dry		0.01	0.91
Interaction	1 dry		0.00	0.98
Natural vs. new	1 dry		10.01	0.00
Natural vs. old	1 dry		0.21	0.65

Table B4. Tables of means showing relationships between select variables and total log abundance, taxa richness, and Shannon-Weiner species diversity of aquatic macroinvertebrates in natural and constructed marhes of central Florida

Class	Sampling Method	Season	Log Abundance Least Square Mean	Standard Error Least Square Mean
Table of Means - Total log abundance of aquatic macroinvertebrates from natural and constructed marshes in central Florida				
Natural	Core	Wet	4.80	0.21
Natural	Core	Dry	5.57	0.21
Natural	Sweep	Wet	5.20	0.21
Natural	Sweep	Dry	6.45	0.21
New/Steep	Core	Wet	5.41	0.40
New/Steep	Core	Dry	4.21	0.40
New/Steep	Sweep	Wet	5.24	0.40
New/Steep	Sweep	Dry	5.51	0.40
New/Gentle	Core	Wet	4.05	0.40
New/Gentle	Core	Dry	5.53	0.40
New/Gentle	Sweep	Wet	5.05	0.40
New/Gentle	Sweep	Dry	4.61	0.40
Old/Steep	Core	Wet	5.26	0.32
Old/Steep	Core	Dry	5.44	0.32
Old/Steep	Sweep	Wet	4.70	0.32
Old/Steep	Sweep	Dry	5.18	0.32
Old/Gentle	Core	Wet	5.24	0.28
Old/Gentle	Core	Dry	5.36	0.28
Old/Gentle	Sweep	Wet	4.97	0.28
Old/Gentle	Sweep	Dry	6.10	0.34
Table of Means - Total taxa richness of aquatic macroinvertebrates from natural and constructed marshes in central Florida				
Natural	Core	Wet	36.50	3.04
Natural	Core	Dry	44.93	3.04
Natural	Sweep	Wet	41.00	3.04
Natural	Sweep	Dry	60.43	3.04
New/Steep	Core	Wet	26.50	5.68
New/Steep	Core	Dry	23.50	5.68
New/Steep	Sweep	Wet	26.58	5.68
New/Steep	Sweep	Dry	24.25	5.68
New/Gentle	Core	Wet	21.00	5.68
New/Gentle	Core	Dry	32.75	5.68
New/Gentle	Sweep	Wet	29.75	5.68
New/Gentle	Sweep	Dry	28.75	5.68
Old/Steep	Core	Wet	34.00	4.64
Old/Steep	Core	Dry	42.83	4.64
Old/Steep	Sweep	Wet	22.22	4.64
Old/Steep	Sweep	Dry	37.50	4.64

Table B4. Tables of means showing relationships between select variables and total log abundance, taxa richness,. and Shannon-Weiner species diversity of aquatic macroinvertebrates in natural and constructed marhes of central Florida

Class	Sampling Method	Season	Log Abundance Least Square Mean	Standard Error Least Square Mean
Old/Gentle	Core	Wet	37.75	4.02
Old/Gentle	Core	Dry	42.25	4.02
Old/Gentle	Sweep	Wet	33.42	4.02
Old/Gentle	Sweep	Dry	45.66	4.83

Table of Means - Shannon-Weiner diversity of aquatic macroinvertebrate from natural and constructed marshes in central Florida

Class	Sampling Method	Season	Log Abundance Least Square Mean	Standard Error Least Square Mean
Natural	Core	Wet	4.29	0.15
Natural	Core	Dry	4.07	0.15
Natural	Sweep	Wet	4.11	0.15
Natural	Sweep	Dry	4.11	0.15
New/Steep	Core	Wet	3.16	0.28
New/Steep	Core	Dry	3.79	0.28
New/Steep	Sweep	Wet	3.50	0.28
New/Steep	Sweep	Dry	2.82	0.28
New/Gentle	Core	Wet	3.65	0.28
New/Gentle	Core	Dry	3.62	0.28
New/Gentle	Sweep	Wet	3.64	0.28
New/Gentle	Sweep	Dry	2.95	0.28
Old/Steep	Core	Wet	3.39	0.23
Old/Steep	Core	Dry	3.02	0.23
Old/Steep	Sweep	Wet	3.18	0.23
Old/Steep	Sweep	Dry	4.00	0.23
Old/Gentle	Core	Wet	3.86	0.20
Old/Gentle	Core	Dry	4.15	0.20
Old/Gentle	Sweep	Wet	4.10	0.20
Old/Gentle	Sweep	Dry	3.78	0.24

Table B5. ANOVA tables showing relationships between select variables and log abundance of major feeding guilds groups of aquatic macroinvertebrates in natural and constructed marhes of central Florida

Sources of Variation	Degrees of Freedom	Mean Square	F Value	p Value
ANOVA Table - Log abundance of collector-filterers collected from natural and constructed marshes in central Florida				
Class	4	3.31	4.27	0.02
Site within Class	13	0.78	-----	-----
Sampling Method	1	4.52	13.06	0.00
Error	13	0.35	-----	-----
Class*Method	4	0.93	2.70	0.08
Wetland Age (new vs. old)	1	0.68	0.88	0.37
Slope (steep vs. gentle)	1	0.00	0.00	0.95
Interaction	1	0.85	1.09	0.32
Natural vs. constructed	1	12.50	16.09	0.00
ANOVA Table - Log abundance of collector-gatherers collected from natural and constructed marshes in central Florida				
Class	4	0.63	0.56	0.69
Site within Class	13	1.12	-----	-----
Sampling Method	1	0.12	0.28	0.60
Error	13	0.41	-----	-----
Class*Method	4	0.52	1.26	0.33
Wetland Age (new vs. old)	1	0.08	0.07	0.80
Slope (steep vs. gentle)	1	0.01	0.01	0.94
Interaction	1	1.92	1.71	0.21
Natural vs. constructed	1	0.53	0.47	0.50
ANOVA Table - Log abundance of predator-engulfers collected from natural and constructed marshes in central Florida				
Class	4	1.07	2.22	0.12
Site within Class	13	0.48	-----	-----
Sampling Method	1	0.03	0.09	0.77
Error	13	0.40	-----	-----
Class*Method	4	0.35	0.88	0.50
Wetland Age (new vs. old)	1	0.98	2.03	0.18
Slope (steep vs. gentle)	1	0.07	0.13	0.72
Interaction	1	0.14	0.28	0.60
Natural vs. constructed	1	3.59	7.42	0.02
ANOVA Table - Log abundance of scrapers collected from natural and constructed marshes in central Florida				
Class	4	3.44	4.91	0.01
Site within Class	13	0.70	-----	-----
Sampling Method	1	7.44	18.82	0.00

Table B5. ANOVA tables showing relationships between select variables and log abundance of major feeding guilds groups of aquatic macroinvertebrates in natural and constructed marhes of central Florida

Sources of Variation	Degrees of Freedom	Mean Square	F Value	p Value
Error	13	0.25	-----	-----
Class*Method	4	7.30	0.62	0.65
Wetland Age (new vs. old)	1	0.00	10.42	0.01
Slope (steep vs. gentle)	1	1.26	0.00	0.10
Interaction	1	0.14	1.80	0.20
Natural vs. new	1	12.13	17.31	0.01
Natural vs. old	1	0.81	1.15	0.30
ANOVA Table - Log abundance of shredders collected from natural and constructed marshes in central Florida				
Class	4	0.79	5.67	0.01
Site within Class	13	0.14	-----	-----
Sampling Method	1	0.00	0.00	0.99
Error	13	0.15		-----
Class*Method	4	0.13	0.90	0.49
Wetland Age (new vs. old)	1	0.20	1.43	0.25
Slope (steep vs. gentle)	1	0.00	0.00	0.96
Interaction	1	0.44	3.20	0.01
Natural vs. constructed	1	2.56	18.44	0.00
ANOVA Table - Log abundance of predator-piercers collected from natural and constructed marshes in central Florida				
Class	4	1.44	1.44	0.28
Site within Class	13	0.30	-----	-----
Sampling Method	1	19.38	80.40	0.00
Error	13	0.24	-----	-----
Class*Method	4	1.18	4.90	0.01
Wetland Age (new vs. old)	1 core		7.58	0.01
Slope (steep vs. gentle)	1 core		0.79	0.38
Interaction	1 core		2.13	0.16
Natural vs. new	1 core		0.89	0.04
Natural vs. old	1 core		0.56	0.46
Wetland Age (new vs. old)	1 sweep		8.29	0.01
Slope (steep vs. gentle)	1 sweep		0.12	0.73
Interaction	1 sweep		1.02	0.32
Natural vs. new	1 sweep		0.10	0.75
Natural vs. old	1 sweep		8.99	0.01

Table B-6. Tables of means tables showing relationships between select variables and log abundance of major feeding guilds of aquatic macroinvertebrates in natural and constructed marhes of central Florida

Class	Sampling Method	Log collector-filterers Least Square Mean	Standard Error Least Square Mean
Table of Means - Log abundance of collector-filterers from natural and constructed marshes in central Florida			
Natural	Core	3.57	0.22
Natural	Sweep	3.79	0.22
New/Steep	Core	2.99	0.42
New/Steep	Sweep	1.92	0.42
New/Gentle	Core	2.82	0.42
New/Gentle	Sweep	1.32	0.42
Old/Steep	Core	2.70	0.34
Old/Steep	Sweep	2.14	0.34
Old/Gentle	Core	3.37	0.29
Old/Gentle	Sweep	2.33	0.29
Table of Means - Log abundance of collector-gatherers from natural and constructed marshes in central Florida			
Natural	Core	4.24	0.24
Natural	Sweep	4.82	0.24
New/Steep	Core	4.54	0.45
New/Steep	Sweep	4.54	0.45
New/Gentle	Core	4.15	0.45
New/Gentle	Sweep	3.63	0.45
Old/Steep	Core	4.38	0.37
Old/Steep	Sweep	3.72	0.37
Old/Gentle	Core	4.65	0.32
Old/Gentle	Sweep	4.61	0.32
Table of Means - Log abundance of predator-engulfers from natural and constructed marshes in central Florida			
Natural	Core	3.98	0.24
Natural	Sweep	4.59	0.24
New/Steep	Core	3.37	0.44
New/Steep	Sweep	3.49	0.44
New/Gentle	Core	3.58	0.44
New/Gentle	Sweep	3.17	0.44
Old/Steep	Core	3.86	0.36
Old/Steep	Sweep	3.56	0.36
Old/Gentle	Core	3.83	0.31
Old/Gentle	Sweep	4.14	0.31

Table B-6. Tables of means tables showing relationships between select variables and log abundance of major feeding guilds of aquatic macroinvertebrates in natural and constructed marhes of central Florida

Class	Sampling Method	Log collector-filterers Least Square Mean	Standard Error Least Square Mean
Table of Means - Log abundance of scrapers from natural and constructed marshes in central Florida			
		Mean	Mean
Natural	Core	0.24	0.24
Natural	Sweep	1.04	0.24
New/Steep	Core	1.43	0.44
New/Steep	Sweep	3.34	0.44
New/Gentle	Core	1.49	0.44
New/Gentle	Sweep	2.38	0.44
Old/Steep	Core	0.42	0.36
Old/Steep	Sweep	1.04	0.36
Old/Gentle	Core	0.76	0.31
Old/Gentle	Sweep	1.70	0.31
Table of Means - Log abundance of shredders from natural and constructed marshes in central Florida			
Natural	Core	1.02	0.15
Natural	Sweep	1.10	0.15
New/Steep	Core	0.39	0.27
New/Steep	Sweep	0.11	0.27
New/Gentle	Core	0.28	0.27
New/Gentle	Sweep	0.84	0.27
Old/Steep	Core	0.88	0.22
Old/Steep	Sweep	0.61	0.22
Old/Gentle	Core	0.50	0.19
Old/Gentle	Sweep	0.41	0.19
Table of Means - Log abundance of predator-piercers from natural and constructed marshes in central Florida			
Natural	Core	2.46	0.19
Natural	Sweep	4.20	0.19
New/Steep	Core	1.38	0.35
New/Steep	Sweep	4.08	0.35
New/Gentle	Core	2.15	0.35
New/Gentle	Sweep	4.52	0.35
Old/Steep	Core	2.76	0.28
Old/Steep	Sweep	3.47	0.28
Old/Gentle	Core	2.58	0.25
Old/Gentle	Sweep	3.25	0.25

Table B-7. ANOVA tables showing relationships between select variables and log abundance of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marhes of central Florida

Sources of Variation	Degrees of Freedom	Mean Square	F Value	p Value
ANOVA Table - Log abundance of planariidae collected from natural and constructed marshes in central Florida				
Class	4	0.08	1.19	0.36
Site within Class	13	0.07	----	-----
Sampling Method	1	0.01	0.15	0.72
Error	13	0.04	----	-----
Class*Method	4	0.03	0.69	0.03
Wetland Age (new vs. old)	1	0.07	0.99	0.34
Slope (steep vs. gentle)	1	0.05	0.80	0.39
Interaction	1	0.05	0.80	0.39
Natural vs. constructed	1	0.05	0.72	0.41
Natural vs. new	1	0.00	0.03	0.87
Natural vs. old	1	0.12	1.85	0.20
ANOVA Table - Log abundance of naididae collected from natural and constructed marshes in central Florida				
Class	4	4.07	2.59	0.09
Site within Class	13	1.57	----	-----
Sampling Method	1	3.38	18.15	0.00
Error	13	0.19	0.19	-----
Class*Method	4	0.30	1.62	0.23
Wetland Age (new vs. old)	1	1.04	0.66	0.43
Slope (steep vs. gentle)	1	0.20	0.13	0.73
Interaction	1	6.58	4.19	0.06
Natural vs. constructed	1	4.89	3.11	0.10
ANOVA Table - Log abundance of tubificidae collected from natural and constructed marshes in central Florida				
Class	4	0.58	1.07	0.41
Site within Class	13	0.55	----	-----
Sampling Method	1	10.93	28.59	0.00
Error	13	0.38	----	-----
Class*Method	4	0.55	1.45	0.27
Wetland Age (new vs. old)	1	0.00	0.00	0.96
Slope (steep vs. gentle)	1	0.37	0.67	0.43
Interaction	1	2.28	4.16	0.06
Natural vs. constructed	1	0.00	0.00	0.95

Table B-7. ANOVA tables showing relationships between select variables and log abundance of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marhes of central Florida

Sources of Variation	Degrees of Freedom	Mean Square	F Value	p Value
ANOVA Table - Log abundance of lumbriculidae collected from natural and constructed marshes in central Florida				
Class	4	0.66	0.94	0.47
Site within Class	13	0.70	----	-----
Sampling Method	1	1.79	9.94	0.01
Error	13	0.18	----	-----
Class*Method	4	0.42	2.34	0.11
Wetland Age (new vs. old)	1	2.15	3.06	0.10
Slope (steep vs. gentle)	1	0.05	0.08	0.79
Interaction	1	0.27	0.38	0.55
Natural vs. constructed	1	0.46	0.65	0.43
ANOVA Table - Log abundance of isopoda collected from natural and constructed marshes in central Florida				
Class	4	4.54	1.49	0.26
Site within Class	13	3.05	----	-----
Sampling Method	1	0.33	1.84	0.20
Error	13	0.18	----	-----
Class*Method	4	0.02	0.45	0.77
Wetland Age (new vs. old)	1	0.22	0.07	0.79
Slope (steep vs. gentle)	1	0.06	0.02	0.89
Interaction	1	0.06	0.02	0.89
Natural vs. constructed	1	16.58	5.44	0.04
ANOVA Table - Log abundance of amphipoda collected from natural and constructed marshes in central Florida				
Class	4	2.56	0.65	0.64
Site within Class	13	3.95	-----	-----
Sampling Method	1	0.15	0.12	0.73
Error	13	1.23	-----	-----
Class*Method	4	1.88	1.53	0.25
Wetland Age (new vs. old)	1	0.77	0.19	0.67
Slope (steep vs. gentle)	1	0.15	0.04	0.85
Interaction	1	1.44	0.36	0.56
Natural vs. constructed	1	6.60	1.67	0.22
ANOVA Table - Log abundance of decapoda collected from natural and constructed marshes in central Florida				
Class	4	0.18	0.27	0.89
Site within Class	13	0.65	-----	-----
Sampling Method	1	9.77	16.21	0.00

Table B-7. ANOVA tables showing relationships between select variables and log abundance of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marhes of central Florida

Sources of Variation	Degrees of Freedom	Mean Square	F Value	p Value
Error	13	0.60	-----	-----
Class*Method	4	0.17	0.28	0.89
Wetland Age (new vs. old)	1	0.22	0.33	0.57
Slope (steep vs. gentle)	1	0.01	0.02	0.89
Interaction	1	0.45	0.69	0.42
Natural vs. constructed	1	0.00	0.01	0.94

ANOVA Table - Log abundance of decapoda collected from natural and constructed marshes in central Florida

Class	4	0.43	1.32	0.32
Site within Class	13	0.32	-----	-----
Sampling Method	1	10.53	35.67	0.00
Error	13	0.75	-----	-----
Class*Method	4	0.75	2.53	0.09
Wetland Age (new vs. old)	1	1.02	3.15	0.10
Slope (steep vs. gentle)	1	0.28	0.86	0.37
Interaction	1	0.34	1.06	0.32
Natural vs. constructed	1	0.05	0.16	0.69

ANOVA Table - Log abundance of hemiptera collected from natural and constructed marshes in central Florida

Class	4	0.07	0.23	0.92
Site within Class	13	0.30	-----	-----
Sampling Method	1	26.57	97.67	0.00
Error	13	0.272	-----	-----
Class*Method	4	0.23	0.84	0.53
Wetland Age (new vs. old)	1	0.23	0.78	0.39
Slope (steep vs. gentle)	1	0.01	0.04	0.84
Interaction	1	0.02	0.08	0.78
Natural vs. constructed	1	0.00	0.00	0.98

ANOVA Table - Log abundance of orthocladiinae collected from natural and constructed marshes in central Florida

Class	4	5.34	6.48	0.00
Site within Class	13	0.82	-----	-----
Sampling Method	1	0.01	0.05	0.83
Error	13	0.20	-----	-----
Class*Method	4	0.34	1.70	0.21
Wetland Age (new vs. old)	1	0.04	0.05	0.83
Slope (steep vs. gentle)	1	0.01	0.01	0.93

Table B-7. ANOVA tables showing relationships between select variables and log abundance of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marhes of central Florida

Sources of Variation	Degrees of Freedom	Mean Square	F Value	p Value
Interaction	1	0.00	0.00	0.99
Natural vs. constructed	1	20.32	24.68	0.00

ANOVA Table - Log abundance of tanypodinae collected from natural and constructed marshes in central Florida

Class	4	3.10	3.58	0.04
Site within Class	13	0.87	-----	-----
Sampling Method	1	1.20	2.66	0.13
Error	13	0.45	-----	-----
Class*Method	4	0.79	1.74	0.20
Wetland Age (new vs. old)	1	2.57	2.97	0.11
Slope (steep vs. gentle)	1	1.01	1.17	0.30
Interaction	1	0.01	0.01	0.93
Natural vs. constructed	1	10.22	11.79	0.00

ANOVA Table - Log abundance of tanytarsinae collected from natural and constructed marshes in central Florida

Class	4	0.49	0.52	0.72
Site within Class	13	0.94	-----	-----
Sampling Method	1	4.82	13.55	0.00
Error	13	0.36	-----	-----
Class*Method	4	0.29	0.82	0.53
Wetland Age (new vs. old)	1	1.02	1.09	0.32
Slope (steep vs. gentle)	1	0.17	0.18	0.68
Interaction	1	0.87	0.93	0.35
Natural vs. constructed	1	0.03	0.04	0.85

ANOVA Table - Log abundance of ceratopogonidae collected from natural and constructed marshes in central Florida

Class	4	1.36	2.16	0.13
Site within Class	13	0.63	-----	-----
Sampling Method	1	5.40	17.63	0.00
Error	13	0.31	-----	-----
Class*Method	4	0.48	1.58	0.24
Wetland Age (new vs. old)	1	0.63	1.00	0.34
Slope (steep vs. gentle)	1	2.80	4.44	0.06
Interaction	1	0.03	0.05	0.82
Natural vs. constructed	1	2.33	3.70	0.08

Table B-7. ANOVA tables showing relationships between select variables and log abundance of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marhes of central Florida

Sources of Variation	Degrees of Freedom	Mean Square	F Value	p Value
ANOVA Table - Log abundance of culicidae collected from natural and constructed marshes in central Florida				
Class	4	1.34	0.05	0.05
Site within Class	13	0.43	-----	-----
Sampling Method	1	1.74	0.01	0.01
Error	13	0.19	-----	-----
Class*Method	4	0.08	0.79	0.79
Wetland Age (new vs. old)	1	4.67	0.01	0.01
Slope (steep vs. gentle)	1	0.18	0.54	0.54
Interaction	1	0.00	0.99	0.99
Natural vs. new	1	3.78	8.74	0.01
Natural vs. old	1	0.07	0.16	0.6977
ANOVA Table - Log abundance of stratiomyidae collected from natural and constructed marshes in central Florida				
Class	4	0.56	1.74	0.20
Site within Class	13	0.32	-----	-----
Sampling Method	1	0.14	1.30	0.28
Error	13	0.11	-----	-----
Class*Method	4	0.06	0.54	0.71
Wetland Age (new vs. old)	1	1.51	4.70	0.05
Slope (steep vs. gentle)	1	0.11	0.35	0.56
Interaction	1	0.05	0.15	0.71
Natural vs. new	1	1.87	5.84	0.03
Natural vs. old	1	0.03	0.08	0.78
ANOVA Table - Log abundance of tipulidae collected from natural and constructed marshes in central Florida				
Class	4	0.81	4.82	0.01
Site within Class	13	0.17	-----	-----
Sampling Method	1	0.02	0.13	0.72
Error	13	0.13	-----	-----
Class*Method	4	0.06	4.82	0.75
Wetland Age (new vs. old)	1	0.05	0.31	0.59
Slope (steep vs. gentle)	1	0.01	0.08	0.78
Interaction	1	0.47	2.80	0.12
Natural vs. constructed	1	2.67	15.82	0.00

Table B-7. ANOVA tables showing relationships between select variables and log abundance of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marhes of central Florida

Sources of Variation	Degrees of Freedom	Mean Square	F Value	p Value
ANOVA Table - Log abundance of other diptera collected from natural and constructed marshes in central Florida				
Class	4	0.90	8.48	0.00
Site within Class	13	0.11	-----	-----
Sampling Method	1	0.10	0.79	0.39
Error	13	0.15	-----	-----
Class*Method	4	0.60	1.17	0.37
Wetland Age (new vs. old)	1	0.08	0.78	0.39
Slope (steep vs. gentle)	1	0.39	3.64	0.08
Interaction	1	0.00	0.03	0.86
Natural vs. constructed	1	2.97	28.03	0.00
ANOVA Table - Log abundance of trichoptera collected from natural and constructed marshes in central Florida				
Class	4	0.17	3.04	0.06
Site within Class	13	0.10	-----	-----
Sampling Method	1	0.10	1.64	0.22
Error	13	0.06	-----	-----
Class*Method	4	0.07	1.15	0.38
Wetland Age (new vs. old)	1	0.17	3.17	0.10
Slope (steep vs. gentle)	1	0.17	3.17	0.10
Interaction	1	0.08	1.54	0.24
Natural vs. constructed	1	0.21	3.91	0.07
ANOVA Table - Log abundance of lepidoptera collected from natural and constructed marshes in central Florida				
Class	4	0.10	3.79	0.03
Site within Class	13	0.03	-----	-----
Sampling Method	1	0.10	0.10	0.76
Error	13	0.06	-----	-----
Class*Method	4	0.15	2.43	0.10
Wetland Age (new vs. old)	1	0.25	9.52	0.01
Slope (steep vs. gentle)	1	0.03	1.08	0.32
Interaction	1	0.03	1.08	0.32
Natural vs. new	1	0.30	11.06	0.01
Natural vs. old	1	0.00	0.07	0.79
ANOVA Table - Log abundance of gastropoda collected from natural and constructed marshes in central Florida				
Class	4	3.44	4.55	0.02
Site within Class	13	0.76	-----	-----

Table B-7. ANOVA tables showing relationships between select variables and log abundance of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marhes of central Florida

Sources of Variation	Degrees of Freedom	Mean Square	F Value	p Value
Sampling Method	1	7.49	17.56	0.00
Error	13	0.43	-----	-----
Class*Method	4	0.32	0.75	0.57
Wetland Age (new vs. old)	1	7.37	9.73	0.01
Slope (steep vs. gentle)	1	0.00	0.00	0.98
Interaction	1	1.43	0.02	0.25
Natural vs. new	1	12.33	16.28	0.00
Natural vs. old	1	0.84	1.11	0.31

ANOVA Table - Log abundance of hirudinea collected (with outlier) from natural and constructed marshes in central Florida

Sources of Variation	Degrees of Freedom	Mean Square	F Value	p Value
Class	4	1.16	2.15	0.13
Site within Class	13	0.54	-----	-----
Sampling Method	1	1.96	6.61	0.02
Error	13	0.30	-----	-----
Class*Method	4	1.01	3.40	0.04
Wetland Age (new vs. old)	1 core		0.4	0.53
Slope (steep vs. gentle)	1 core		0.02	0.89
Interaction	1 core		0.4	0.53
Natural vs. constructed	1 core		0.29	0.59
Wetland Age (new vs. old)	1 sweep		6.51	0.02
Slope (steep vs. gentle)	1 sweep		5.23	0.03
Interaction	1 sweep		4.57	0.04
Natural vs. constructed	1 sweep		7.23	0.01

ANOVA Table - Log abundance of hirudinea collected (without outlier from natural and constructed marshes in central Florida

Sources of Variation	Degrees of Freedom	Mean Square	F Value	p Value
Class	4	0.19	1.31	0.32
Site within Class	13	0.14	--------	--------
Sampling Method	1	0.12	4.39	0.06
Error	13	0.03	--------	--------
Class*Method	4	0.09	3.36	0.05
Wetland Age (new vs. old)	1 core		1.91	0.18
Slope (steep vs. gentle)	1 core		0.09	0.77
Interaction	1 core		1.91	0.18
Natural vs. constructed	1 core		1.40	0.25
Wetland Age (new vs. old)	1 sweep		0.11	0.74
Slope (steep vs. gentle)	1 sweep		0.04	0.84
Interaction	1 sweep		0.25	0.62
Natural vs. constructed	1 sweep		6.05	0.02

Table B-7. ANOVA tables showing relationships between select variables and log abundance of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marhes of central Florida

Sources of Variation	Degrees of Freedom		Mean Square	F Value	p Value
ANOVA Table - Log abundance of ephemeroptera collected from natural and constructed marshes in central Florida					
Class	4		3.47	4.55	0.02
Site within Class	13		1.06	-----	-----
Sampling Method	1		3.89	17.56	0.00
Error	13		0.33	-----	-----
Class*Method	4		3.89	0.75	0.57
Wetland Age (new vs. old)	1		2.11	9.73	0.01
Slope (steep vs. gentle)	1		6.73	0.00	0.98
Interaction	1		1.58	0.02	0.25
Natural vs. deep slope	1		4.19	3.96	0.07
Natural vs. gentle slope	1		0.53	0.50	0.49
ANOVA Table - Log abundance of coleoptera collected from natural and constructed marshes in central Florida					
Class	4		0.79	1.58	0.24
Site within Class	13		0.5	--------	--------
Sampling Method	1		11.03	37.80	0.00
Error	13		0.29	--------	--------
Class*Method	4		1.61	5.53	0.01
Wetland Age (new vs. old)	1	core		7.28	0.01
Slope (steep vs. gentle)	1	core		1.22	0.28
Interaction	1	core		2.64	0.12
Natural vs. new	1	core		5.03	0.03
Natural vs. old	1	core		0.30	0.59
Wetland Age (new vs. old)	1	sweep		4.57	0.04
Slope (steep vs. gentle)	1	sweep		0.70	0.41
Interaction	1	sweep		0.13	0.72
Natural vs. new	1	sweep		0.46	0.50
Natural vs. old	1	sweep		10.86	0.00
ANOVA Table - Log abundance of chironomini collected from natural and constructed marshes in central Florida					
Class	4		4.96	4.09	0.02
Site within Class	13		1.21	--------	--------
Sampling Method	1		7.29	20.67	0.00
Error	13		4.58	--------	--------
Class*Method	4		1.49	4.24	0.02
Wetland Age (new vs. old)	1	core		0.24	0.63
Slope (steep vs. gentle)	1	core		0.00	0.97
Interaction	1	core		3.86	0.06
Natural vs. constructed	1	core		1.88	0.19

Table B-7. ANOVA tables showing relationships between select variables and log abundance of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marhes of central Florida

Sources of Variation	Degrees of Freedom	Mean Square	F Value	p Value
Wetland Age (new vs. old)	1 sweep		1.43	0.25
Slope (steep vs. gentle)	1 sweep		0.45	0.51
Interaction	1 sweep		0.40	0.53
Natural vs. constructed	1 sweep		22.37	0.00
ANOVA Table - Log abundance of chaoboridae collected from natural and constructed marshes in central Florida				
Class	4	0.27	0.54	0.18
Site within Class	13	0.51	--------	--------
Sampling Method	1	1.27	8.67	0.01
Error	13	1.90	--------	--------
Class*Method	4	0.53	3.66	0.03
Wetland Age (new vs. old)	1 core		0.01	0.91
Slope (steep vs. gentle)	1 core		1.96	0.18
Interaction	1 core		3.35	0.08
Natural vs. constructed	1 core		0.11	0.25
Wetland Age (new vs. old)	1 sweep		0.59	0.45
Slope (steep vs. gentle)	1 sweep		0.59	0.45
Interaction	1 sweep		0.95	0.34
Natural vs. constructed	1 sweep		3.03	0.10

Table B-8. Tables of means showing relationships between select variables and log abundance of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marshes of central Florida

Class	Sampling Method	Log abundance Least Square Mean	Standard Error Least Square Mean
Table of Means - Log abundance of planariidae from natural and constructed marshes in central Florida			
Natural	Core	0.07	0.08
Natural	Sweep	0.00	0.08
New/Steep	Core	0.00	0.14
New/Steep	Sweep	0.11	0.14
New/Gentle	Core	0.00	0.14
New/Gentle	Sweep	0.11	0.14
Old/Steep	Core	0.00	0.11
Old/Steep	Sweep	0.13	0.11
Old/Gentle	Core	0.34	0.10
Old/Gentle	Sweep	0.20	0.10
Table of Means - Log abundance of naididae from natural and constructed marshes in central Florida			
Natural	Core	0.93	0.16
Natural	Sweep	0.83	0.16
New/Steep	Core	2.33	0.31
New/Steep	Sweep	1.46	0.31
New/Gentle	Core	1.50	0.31
New/Gentle	Sweep	0.41	0.31
Old/Steep	Core	1.50	0.25
Old/Steep	Sweep	0.91	0.25
Old/Gentle	Core	2.93	0.22
Old/Gentle	Sweep	2.17	0.22
Table of Means - Log abundance of tubificidae from natural and constructed marshes in central Florida			
Natural	Core	0.12	0.23
Natural	Sweep	0.07	0.23
New/Steep	Core	2.20	0.44
New/Steep	Sweep	0.00	0.44
New/Gentle	Core	0.31	0.44
New/Gentle	Sweep	0.00	0.44
Old/Steep	Core	0.89	0.36
Old/Steep	Sweep	0.00	0.36
Old/Gentle	Core	1.63	0.31
Old/Gentle	Sweep	0.06	0.31

Table B-8. Tables of means showing relationships between select variables and log abundance of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marshes of central Florida

Class	Sampling Method	Log abundance Least Square Mean	Standard Error Least Square Mean
Table of Means - Log abundance of lumbriculidae from natural and constructed marshes in central Florida			
Natural	Core	0.76	0.16
Natural	Sweep	0.69	0.16
New/Steep	Core	0.20	0.30
New/Steep	Sweep	0.00	0.30
New/Gentle	Core	0.46	0.30
New/Gentle	Sweep	0.00	0.30
Old/Steep	Core	1.27	0.25
Old/Steep	Sweep	0.70	0.25
Old/Gentle	Core	1.24	0.21
Old/Gentle	Sweep	0.06	0.21
Table of Means - Log abundance of isopoda from natural and constructed marshes in central Florida			
Natural	Core	1.40	0.16
Natural	Sweep	1.64	0.16
New/Steep	Core	0.00	0.30
New/Steep	Sweep	0.20	0.30
New/Gentle	Core	0.00	0.30
New/Gentle	Sweep	0.63	0.30
Old/Steep	Core	0.00	0.25
Old/Steep	Sweep	0.00	0.25
Old/Gentle	Core	0.00	0.21
Old/Gentle	Sweep	0.00	0.21
Table of Means - Log abundance of amphipoda from natural and constructed marshes in central Florida			
Natural	Core	1.90	0.42
Natural	Sweep	2.84	0.42
New/Steep	Core	3.10	0.78
New/Steep	Sweep	3.74	0.78
New/Gentle	Core	3.61	0.78
New/Gentle	Sweep	1.83	0.78
Old/Steep	Core	3.67	0.64
Old/Steep	Sweep	2.88	0.64
Old/Gentle	Core	3.51	0.55
Old/Gentle	Sweep	3.77	0.55

Table B-8. Tables of means showing relationships between select variables and log abundance of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marshes of central Florida

Class	Sampling Method	Log abundance Least Square Mean	Standard Error Least Square Mean
Table of Means - Log abundance of decapoda from natural and constructed marshes in central Florida			
Natural	Core	0.10	0.29
Natural	Sweep	1.11	0.29
New/Steep	Core	0.00	0.55
New/Steep	Sweep	1.71	0.55
New/Gentle	Core	0.00	0.55
New/Gentle	Sweep	1.21	0.55
Old/Steep	Core	0.00	0.45
Old/Steep	Sweep	0.70	0.45
Old/Gentle	Core	0.10	0.39
Old/Gentle	Sweep	1.29	0.39
Table of Means - Log abundance of odonata from natural and constructed marshes in central Florida			
Natural	Core	1.36	0.21
Natural	Sweep	3.31	0.21
New/Steep	Core	1.60	0.38
New/Steep	Sweep	3.30	0.38
New/Gentle	Core	1.87	0.38
New/Gentle	Sweep	2.01	0.38
Old/Steep	Core	2.12	0.31
Old/Steep	Sweep	3.14	0.31
Old/Gentle	Core	2.03	0.27
Old/Gentle	Sweep	3.27	0.27
Table of Means - Log abundance of hemiptera from natural and constructed marshes in central Florida			
Natural	Core	0.60	0.20
Natural	Sweep	2.89	0.20
New/Steep	Core	0.85	0.37
New/Steep	Sweep	2.72	0.37
New/Gentle	Core	0.80	0.37
New/Gentle	Sweep	3.01	0.37
Old/Steep	Core	0.92	0.30
Old/Steep	Sweep	2.36	0.30
Old/Gentle	Core	0.73	0.26
Old/Gentle	Sweep	2.51	0.26

Table B-8. Tables of means showing relationships between select variables and log abundance of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marshes of central Florida

Class	Sampling Method	Log abundance Least Square Mean	Standard Error Least Square Mean
Table of Means - Log abundance of orthocladiinae from natural and constructed marshes in central Florida			
Natural	Core	2.05	0.17
Natural	Sweep	1.45	0.17
New/Steep	Core	0.31	0.31
New/Steep	Sweep	0.11	0.31
New/Gentle	Core	0.00	0.31
New/Gentle	Sweep	0.48	0.31
Old/Steep	Core	0.00	0.26
Old/Steep	Sweep	0.23	0.26
Old/Gentle	Core	0.20	0.22
Old/Gentle	Sweep	0.11	0.22
Table of Means - Log abundance of tanypodinae from natural and constructed marshes in central Florida			
Natural	Core	3.63	0.25
Natural	Sweep	4.11	0.25
New/Steep	Core	2.73	0.48
New/Steep	Sweep	1.67	0.48
New/Gentle	Core	2.84	0.48
New/Gentle	Sweep	2.37	0.48
Old/Steep	Core	3.32	0.39
Old/Steep	Sweep	2.42	0.39
Old/Gentle	Core	3.40	0.34
Old/Gentle	Sweep	3.31	0.34
Table of Means - Log abundance of tanytarsini from natural and constructed marshes in central Florida			
Natural	Core	1.23	0.23
Natural	Sweep	0.93	0.23
New/Steep	Core	1.05	0.42
New/Steep	Sweep	0.20	0.42
New/Gentle	Core	1.58	0.42
New/Gentle	Sweep	0.86	0.42
Old/Steep	Core	2.11	0.34
Old/Steep	Sweep	0.87	0.34
Old/Gentle	Core	1.75	0.30
Old/Gentle	Sweep	0.77	0.30

Table B-8. Tables of means showing relationships between select variables and log abundance of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marshes of central Florida

Class	Sampling Method	Log abundance Least Square Mean	Standard Error Least Square Mean
Table of Means - Log abundance of ceratopogonidae from natural and constructed marshes in central Florida			
Natural	Core	2.37	0.21
Natural	Sweep	2.17	0.21
New/Steep	Core	1.72	0.39
New/Steep	Sweep	0.57	0.39
New/Gentle	Core	2.71	0.39
New/Gentle	Sweep	1.23	0.39
Old/Steep	Core	2.09	0.32
Old/Steep	Sweep	1.07	0.32
Old/Gentle	Core	2.48	0.28
Old/Gentle	Sweep	2.01	0.28
Table of Means - Log abundance of culicidae from natural and constructed marshes in central Florida			
Natural	Core	1.26	0.17
Natural	Sweep	1.46	0.17
New/Steep	Core	0.28	0.31
New/Steep	Sweep	0.90	0.31
New/Gentle	Core	0.11	0.31
New/Gentle	Sweep	0.70	0.31
Old/Steep	Core	1.35	0.25
Old/Steep	Sweep	1.76	0.25
Old/Gentle	Core	1.04	0.22
Old/Gentle	Sweep	1.68	0.22
Table of Means - Log abundance of muscidae from natural and constructed marshes in central Florida			
Natural	Core	0.06	0.06
Natural	Sweep	0.10	0.06
New/Steep	Core	0.00	0.11
New/Steep	Sweep	0.00	0.11
New/Gentle	Core	0.11	0.11
New/Gentle	Sweep	0.00	0.11
Old/Steep	Core	0.07	0.09
Old/Steep	Sweep	0.00	0.09
Old/Gentle	Core	0.00	0.08
Old/Gentle	Sweep	0.00	0.08

Table B-8. Tables of means showing relationships between select variables and log abundance of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marshes of central Florida

Class	Sampling Method	Log abundance Least Square Mean	Standard Error Least Square Mean
Table of Means - Log abundance of stratiomyidae from natural and constructed marshes in central Florida			
Natural	Core	0.16	0.12
Natural	Sweep	0.18	0.12
New/Steep	Core	0.86	0.23
New/Steep	Sweep	0.94	0.23
New/Gentle	Core	0.39	0.23
New/Gentle	Sweep	0.92	0.23
Old/Steep	Core	0.21	0.19
Old/Steep	Sweep	0.31	0.19
Old/Gentle	Core	0.21	0.16
Old/Gentle	Sweep	0.20	0.16
Table of Means - Log abundance of tipulidae from natural and constructed marshes in central Florida			
Natural	Core	0.95	0.14
Natural	Sweep	0.87	0.14
New/Steep	Core	0.22	0.26
New/Steep	Sweep	0.00	0.26
New/Gentle	Core	0.28	0.26
New/Gentle	Sweep	0.66	0.26
Old/Steep	Core	0.50	0.21
Old/Steep	Sweep	0.54	0.21
Old/Gentle	Core	0.20	0.18
Old/Gentle	Sweep	0.34	0.18
Table of Means - Log abundance of other diptera from natural and constructed marshes in central Florida			
Natural	Core	0.78	0.14
Natural	Sweep	1.02	0.14
New/Steep	Core	0.20	0.26
New/Steep	Sweep	0.22	0.26
New/Gentle	Core	0.20	0.26
New/Gentle	Sweep	0.83	0.26
Old/Steep	Core	0.15	0.21
Old/Steep	Sweep	0.07	0.21
Old/Gentle	Core	0.47	0.18
Old/Gentle	Sweep	0.25	0.18

Table B-8. Tables of means showing relationships between select variables and log abundance of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marshes of central Florida

Class	Sampling Method	Log abundance Least Square Mean	Standard Error Least Square Mean
Table of Means - Log abundance of trichoptera from natural and constructed marshes in central Florida			
Natural	Core	0.19	0.09
Natural	Sweep	0.37	0.09
New/Steep	Core	0.11	0.17
New/Steep	Sweep	0.00	0.17
New/Gentle	Core	0.11	0.17
New/Gentle	Sweep	0.63	0.17
Old/Steep	Core	0.00	0.14
Old/Steep	Sweep	0.00	0.14
Old/Gentle	Core	0.06	0.12
Old/Gentle	Sweep	0.06	0.12
Table of Means - Log abundance of lepidoptera from natural and constructed marshes in central Florida			
Natural	Core	0.17	0.09
Natural	Sweep	0.42	0.09
New/Steep	Core	0.00	0.18
New/Steep	Sweep	0.11	0.18
New/Gentle	Core	0.00	0.18
New/Gentle	Sweep	0.11	0.18
Old/Steep	Core	0.58	0.14
Old/Steep	Sweep	0.14	0.14
Old/Gentle	Core	0.30	0.13
Old/Gentle	Sweep	0.11	0.13
Table of Means - Log abundance of gastropoda from natural and constructed marshes in central Florida			
Natural	Core	0.24	0.25
Natural	Sweep	0.95	0.25
New/Steep	Core	0.14	0.46
New/Steep	Sweep	3.34	0.46
New/Gentle	Core	0.15	0.46
New/Gentle	Sweep	2.35	0.46
Old/Steep	Core	0.42	0.37
Old/Steep	Sweep	1.02	0.37
Old/Gentle	Core	0.67	0.33
Old/Gentle	Sweep	1.68	0.33

Table B-8. Tables of means showing relationships between select variables and log abundance of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marshes of central Florida

Class	Sampling Method	Log abundance Least Square Mean	Standard Error Least Square Mean
Table of Means - Log abundance of hirudinea (with outlier) from natural and constructed marshes in central Florida			
Natural	Core	0.06	0.21
Natural	Sweep	0.03	0.21
New/Steep	Core	0.00	0.38
New/Steep	Sweep	0.51	0.38
New/Gentle	Core	0.20	0.38
New/Gentle	Sweep	2.30	0.38
Old/Steep	Core	0.51	0.31
Old/Steep	Sweep	0.34	0.31
Old/Gentle	Core	0.20	0.27
Old/Gentle	Sweep	0.40	0.27
Table of Means - Log abundance of hirudinea (without outlier) from natural and constructed marshes in central Florida			
Natural	Core	0.06	0.06
Natural	Sweep	0.03	0.06
New/Steep	Core	0.00	0.12
New/Steep	Sweep	0.51	0.12
New/Gentle	Core	0.20	0.12
New/Gentle	Sweep	0.43	0.20
Old/Steep	Core	0.51	0.09
Old/Steep	Sweep	0.34	0.09
Old/Gentle	Core	0.20	0.08
Old/Gentle	Sweep	0.40	0.08
Table of Means - Log abundance of ephemeroptera from natural and constructed marshes in central Florida			
Natural	Core	1.36	0.22
Natural	Sweep	2.78	0.22
New/Steep	Core	1.10	0.40
New/Steep	Sweep	1.24	0.40
New/Gentle	Core	1.52	0.40
New/Gentle	Sweep	2.00	0.40
Old/Steep	Core	1.06	0.33
Old/Steep	Sweep	1.45	0.33
Old/Gentle	Core	2.35	0.29
Old/Gentle	Sweep	3.59	0.29

Table B-8. Tables of means showing relationships between select variables and log abundance of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marshes of central Florida

Class	Sampling Method	Log abundance Least Square Mean	Standard Error Least Square Mean
Table of Means - Log abundance of coleoptera from natural and constructed marshes in central Florida			
Natural	Core	2.30	0.20
Natural	Sweep	3.80	0.38
New/Steep	Core	0.87	0.38
New/Steep	Sweep	3.63	0.38
New/Gentle	Core	1.95	0.38
New/Gentle	Sweep	3.44	0.38
Old/Steep	Core	2.58	0.31
Old/Steep	Sweep	2.93	0.31
Old/Gentle	Core	2.38	0.27
Old/Gentle	Sweep	2.45	0.27
Table of Means - Log abundance of chironomini from natural and constructed marshes in central Florida			
Natural	Core	4.03	0.22
Natural	Sweep	4.20	0.22
New/Steep	Core	4.11	0.42
New/Steep	Sweep	2.46	0.42
New/Gentle	Core	3.04	0.42
New/Gentle	Sweep	2.48	0.42
Old/Steep	Core	2.74	0.34
Old/Steep	Sweep	1.45	0.34
Old/Gentle	Core	3.86	0.30
Old/Gentle	Sweep	2.17	0.30
Table of Means - Log abundance of chaoboridae from natural and constructed marshes in central Florida			
Natural	Core	0.76	0.14
Natural	Sweep	0.66	0.14
New/Steep	Core	1.27	0.27
New/Steep	Sweep	0.00	0.27
New/Gentle	Core	0.11	0.27
New/Gentle	Sweep	0.63	0.27
Old/Steep	Core	0.58	0.22
Old/Steep	Sweep	0.07	0.22
Old/Gentle	Core	0.73	0.19
Old/Gentle	Sweep	0.00	0.19

Table B-9. ANOVA tables showing relationships between select variables and taxa richness of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marshes of central Florida

Sources of Variation	Degrees of Freedom	Mean Square	F Value	p Value
ANOVA Table - Taxa richness of naididae collected from natural and constructed marshes in central Florida				
Class	4	30.89	4.15	0.02
Site within Class	13	7.44	----	-----
Sampling Method	1	3.45	1.55	0.24
Error	13	2.23	----	-----
Class*Method	4	1.69	0.76	0.57
Wetland Age (new vs. old)	1	29.51	3.97	0.07
Slope (steep vs. gentle)	1	3.51	0.47	0.50
Interaction	1	27.51	3.70	0.08
Natural vs. constructed	1	27.51	4.11	0.06
ANOVA Table - Taxa richness of lumbriculidae collected from natural and constructed marshes in central Florida				
Class	4	1.38	1.84	0.18
Site within Class	13	0.75	----	-----
Sampling Method	1	1.86	4.33	0.06
Error	13	0.43	----	-----
Class*Method	4	0.42	0.97	0.46
Wetland Age (new vs. old)	1	2.39	3.19	0.10
Slope (steep vs. gentle)	1	0.02	0.03	0.87
Interaction	1	0.02	0.03	0.87
Natural vs. constructed	1	3.96	5.29	0.04
ANOVA Table - Taxa richness of hirudinea collected from natural and constructed marshes in central Florida				
Class	4	1.72	1.20	0.18
Site within Class	13	1.44	----	-----
Sampling Method	1	3.84	10.68	0.06
Error	13	0.36	----	-----
Class*Method	4	0.89	2.46	0.46
Wetland Age (new vs. old)	1	0.08	0.05	0.82
Slope (steep vs. gentle)	1	0.08	0.05	0.82
Interaction	1	0.08	0.05	0.82
Natural vs. constructed	1	6.20	4.32	0.06
ANOVA Table - Taxa richness of decapoda collected from natural and constructed marshes in central Florida				
Class	4	0.20	0.47	0.75
Site within Class	13	0.41	----	-----
Sampling Method	1	8.99	30.30	0.00

Table B-9. ANOVA tables showing relationships between select variables and taxa richness of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marshes of central Florida

Sources of Variation	Degrees of Freedom	Mean Square	F Value	p Value
Error	13	0.30	----	-----
Class*Method	4	0.40	1.36	0.30
Wetland Age (new vs. old)	1	0.08	0.19	0.67
Slope (steep vs. gentle)	1	0.08	0.19	0.67
Interaction	1	0.71	1.72	0.21
Natural vs. constructed	1	0.01	0.01	0.91

ANOVA Table - Taxa richness of ephemeroptera collected from natural and constructed marshes in central Florida

Class	4	0.31	0.59	0.68
Site within Class	13	0.54	----	-----
Sampling Method	1	0.03	0.12	0.73
Error	13	0.23	----	-----
Class*Method	4	0.22	0.95	0.47
Wetland Age (new vs. old)	1	0.71	1.33	0.27
Slope (steep vs. gentle)	1	0.08	0.15	0.71
Interaction	1	0.08	0.15	0.71
Natural vs. constructed	1	0.24	0.44	0.52

ANOVA Table - Taxa richness of odonata collected from natural and constructed marshes in central Florida

Class	4	0.88	0.26	0.90
Site within Class	13	3.36	0.82	-----
Sampling Method	1	118.34	28.91	0.00
Error	13	4.09	----	-----
Class*Method	4	2.73	0.67	0.63
Wetland Age (new vs. old)	1	0.00	0.00	1.00
Slope (steep vs. gentle)	1	1.26	0.38	0.55
Interaction	1	1.26	0.38	0.55
Natural vs. constructed	1	0.17	0.05	0.83

ANOVA Table - Taxa richness of hemiptera collected from natural and constructed marshes in central Florida

Class	4	2.30	0.75	0.58
Site within Class	13	3.08	-----	-----
Sampling Method	1	273.89	81.15	0.00
Error	13	3.38	----	-----
Class*Method	4	4.57	1.35	0.30
Wetland Age (new vs. old)	1	1.37	0.44	0.52
Slope (steep vs. gentle)	1	4.05	1.32	0.27
Interaction	1	0.79	0.26	0.62
Natural vs. constructed	1	1.86	0.60	0.45

Table B-9. ANOVA tables showing relationships between select variables and taxa richness of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marshes of central Florida

Sources of Variation	Degrees of Freedom	Mean Square	F Value	p Value
ANOVA Table - Taxa richness of coleoptera collected from natural and constructed marshes in central Florida				
Class	4	51.53	3.72	0.03
Site within Class	13	13.85	-----	-----
Sampling Method	1	1483.75	134.32	0.00
Error	13	11.05	----	-----
Class*Method	4	11.97	1.08	0.40
Wetland Age (new vs. old)	1	21.06	1.52	0.24
Slope (steep vs. gentle)	1	37.06	2.68	0.13
Interaction	1	32.64	2.36	0.15
Natural vs. constructed	1	144.21	10.41	0.01
ANOVA Table - Taxa richness of chironomini collected from natural and constructed marshes in central Florida				
Class	4	20.91	2.27	0.12
Site within Class	13	9.20	-----	-----
Sampling Method	1	1483.75	0.57	0.26
Error	13	3.57	----	----
Class*Method	4	4.41	0.70	0.60
Wetland Age (new vs. old)	1	12.34	1.34	0.27
Slope (steep vs. gentle)	1	18.97	2.06	0.17
Interaction	1	36.49	3.97	0.07
Natural vs. constructed	1	1.36	0.15	0.71
ANOVA Table - Taxa richness of orthocladiinae collected from natural and constructed marshes in central Florida				
Class	4	4.97	6.37	0.00
Site within Class	13	0.78	-----	-----
Sampling Method	1	0.42	0.65	0.44
Error	13	0.65	----	----
Class*Method	4	0.89	1.38	0.29
Wetland Age (new vs. old)	1	0.11	0.14	0.72
Slope (steep vs. gentle)	1	0.00	0.00	0.96
Interaction	1	0.00	0.00	0.96
Natural vs. constructed	1	18.65	23.91	0.00
ANOVA Table - Taxa richness of tanypodinae collected from natural and constructed marshes in central Florida				
Class	4	38.56	5.70	0.01
Site within Class	13	6.77	-----	-----

Table B-9. ANOVA tables showing relationships between select variables and taxa richness of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marshes of central Florida

Sources of Variation	Degrees of Freedom	Mean Square	F Value	p Value
Sampling Method	1	2.40	1.14	0.30
Error	13	2.10	----	----
Class*Method	4	1.63	0.77	0.56
Wetland Age (new vs. old)	1	16.22	2.40	0.15
Slope (steep vs. gentle)	1	2.54	0.37	0.55
Interaction	1	4.64	0.69	0.42
Natural vs. constructed	1	142.98	21.12	0.00
ANOVA Table - Taxa richness of tanytarsini collected from natural and constructed marshes in central Florida				
Class	4	0.75	0.25	0.91
Site within Class	13	3.02	-----	-----
Sampling Method	1	0.20	0.19	0.67
Error	13	1.02	-----	----
Class*Method	4	0.44	0.43	0.78
Wetland Age (new vs. old)	1	2.39	0.79	0.39
Slope (steep vs. gentle)	1	0.18	0.06	0.81
Interaction	1	0.49	0.16	0.69
Natural vs. constructed	1	0.30	0.10	0.76
ANOVA Table - Taxa richness of ceratopogonidae collected from natural and constructed marshes in central Florida				
Class	4	10.52	5.27	0.01
Site within Class	13	1.99	-----	-----
Sampling Method	1	0.13	0.12	0.74
Error	13	1.10	-----	-----
Class*Method	4	1.17	1.06	0.42
Wetland Age (new vs. old)	1	1.97	0.99	0.34
Slope (steep vs. gentle)	1	0.08	0.04	0.85
Interaction	1	3.87	1.94	0.19
Natural vs. constructed	1	37.03	18.57	0.00
ANOVA Table - Taxa richness of chaoboridae collected from natural and constructed marshes in central Florida				
Class	4	0.39	2.10	0.14
Site within Class	13	0.19	-----	-----
Sampling Method	1	2.21	13.11	0.00
Error	13	0.17	-----	-----
Class*Method	4	0.26	1.53	0.25
Wetland Age (new vs. old)	1	0.00	0.00	1.00
Slope (steep vs. gentle)	1	0.00	0.00	1.00
Interaction	1	0.00	0.00	1.00

Table B-9. ANOVA tables showing relationships between select variables and taxa richness of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marshes of central Florida

Sources of Variation	Degrees of Freedom	Mean Square	F Value	p Value
Natural vs. constructed	1	1.52	8.13	0.01
ANOVA Table - Taxa richness of culicidae collected from natural and constructed marshes in central Florida				
Class	4	4.89	2.39	0.10
Site within Class	13	2.05	-----	-----
Sampling Method	1	45.52	35.67	0.00
Error	13	1.28	-----	-----
Class*Method	4	1.55	1.22	0.35
Wetland Age (new vs. old)	1	18.97	9.27	0.01
Slope (steep vs. gentle)	1	0.49	0.24	0.63
Interaction	1	0.18	0.09	0.77
Natural vs. new	1	6.65	3.25	0.09
Natural vs. old	1	4.37	2.14	0.17
ANOVA Table - Taxa richness of tipulidae collected from natural and constructed marshes in central Florida				
Class	4	3.22	3.80	0.03
Site within Class	13	0.85	-----	-----
Sampling Method	1	0.85	1.48	0.24
Error	13	0.57	-----	-----
Class*Method	4	0.63	1.10	0.40
Wetland Age (new vs. old)	1	2.54	2.99	0.11
Slope (steep vs. gentle)	1	0.22	0.26	0.62
Interaction	1	1.06	1.25	0.28
Natural vs. constructed	1	9.87	11.65	0.00
ANOVA Table - Taxa richness of other diptera collected from natural and constructed marshes in central Florida				
Class	4	7.11	8.14	0.00
Site within Class	13	0.87	-----	-----
Sampling Method	1	0.32	0.23	0.64
Error	13	1.39	-----	-----
Class*Method	4	0.55	0.40	0.81
Wetland Age (new vs. old)	1	0.08	0.09	0.77
Slope (steep vs. gentle)	1	0.71	0.81	0.38
Interaction	1	0.71	0.81	0.38
Natural vs. constructed	1	26.11	29.89	0.00
ANOVA Table - Taxa richness of lepidoptera collected from natural and constructed marshes in central Florida				

Table B-9. ANOVA tables showing relationships between select variables and taxa richness of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marshes of central Florida

Sources of Variation	Degrees of Freedom	Mean Square	F Value	p Value
Class	4	0.88	1.75	0.41
Site within Class	13	0.50	-----	-----
Sampling Method	1	0.17	0.20	0.66
Error	13	0.82	-----	-----
Class*Method	4	1.55	1.88	0.17
Wetland Age (new vs. old)	1	2.84	5.68	0.03
Slope (steep vs. gentle)	1	0.00	0.00	1.00
Interaction	1	0.00	0.00	1.00
Natural vs. new	1	2.86	5.73	0.03
Natural vs. old	1	0.00	0.00	1.00
ANOVA Table - Taxa richness of gastropoda collected from natural and constructed marshes in central Florida				
Class	4	27.31	9.29	0.00
Site within Class	13	2.94	-----	-----
Sampling Method	1	16.87	13.35	0.00
Error	13	1.26	-----	-----
Class*Method	4	3.43	2.71	0.08
Wetland Age (new vs. old)	1	18.97	6.45	0.02
Slope (steep vs. gentle)	1	5.70	1.94	0.19
Interaction	1	12.34	4.19	0.06
Natural vs. new	1	80.01	27.20	0.00
Natural vs. old	1	28.46	9.68	0.01

Table B-10. Tables of means showing relationships between select variables and taxa richness of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marshes of central Florida

Class	Sampling Method	Log naididae Least Square Mean	Standard Error Least Square Mean
Table of Means - Taxa richness of naididae from natural and constructed marshes in central Florida			
Natural	Core	1.43	0.56
Natural	Sweep	2.14	0.56
New/Steep	Core	4	1.06
New/Steep	Sweep	2.5	1.06
New/Gentle	Core	2.5	1.06
New/Gentle	Sweep	1	1.06
Old/Steep	Core	3.67	0.86
Old/Steep	Sweep	3	0.86
Old/Gentle	Core	6.75	0.75
Old/Gentle	Sweep	6.25	0.75
Table of Means - Taxa richness of lumbriculidae from natural and constructed marshes in central Florida			
Natural	Core	1.43	0.25
Natural	Sweep	1.14	0.25
New/Steep	Core	0.5	0.46
New/Steep	Sweep	0	0.46
New/Gentle	Core	0.5	0.46
New/Gentle	Sweep	0	0.46
Old/Steep	Core	1	0.38
Old/Steep	Sweep	1	0.38
Old/Gentle	Core	1.5	0.33
Old/Gentle	Sweep	0.25	0.33
Table of Means - Taxa richness of hirudinea from natural and constructed marshes in central Florida			
Natural	Core	0	0.23
Natural	Sweep	0.14	0.23
New/Steep	Core	0	0.42
New/Steep	Sweep	2	0.42
New/Gentle	Core	0.5	0.42
New/Gentle	Sweep	1	0.42
Old/Steep	Core	1	0.35
Old/Steep	Sweep	1	0.35
Old/Gentle	Core	0.5	0.3
Old/Gentle	Sweep	1.5	0.3
Table of Means - Taxa richness of decapoda from natural and constructed marshes in central Florida			

Table B-10. Tables of means showing relationships between select variables and taxa richness of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marshes of central Florida

Class	Sampling Method	Log naididae Least Square Mean	Standard Error Least Square Mean
Natural	Core	0.43	0.21
Natural	Sweep	1	0.21
New/Steep	Core	0	0.39
New/Steep	Sweep	2	0.39
New/Gentle	Core	0	0.39
New/Gentle	Sweep	1	0.39
Old/Steep	Core	0	0.31
Old/Steep	Sweep	1	0.31
Old/Gentle	Core	0.25	0.27
Old/Gentle	Sweep	1.25	0.27

Table of Means - Taxa richness of epheroptera from natural and constructed marshes in central Florida

Natural	Core	1.57	0.18
Natural	Sweep	1.71	0.18
New/Steep	Core	1.5	0.34
New/Steep	Sweep	1.5	0.34
New/Gentle	Core	2	0.34
New/Gentle	Sweep	1.5	0.34
Old/Steep	Core	1.67	0.28
Old/Steep	Sweep	2.33	0.28
Old/Gentle	Core	2	0.24
Old/Gentle	Sweep	2	0.24

Table of Means - Taxa richness of odonata from natural and constructed marshes in central Florida

Natural	Core	3	0.76
Natural	Sweep	8.71	0.76
New/Steep	Core	4	1.43
New/Steep	Sweep	8	1.43
New/Gentle	Core	4	1.43
New/Gentle	Sweep	8	1.43
Old/Steep	Core	5	1.17
Old/Steep	Sweep	8	1.17
Old/Gentle	Core	3.75	1.01
Old/Gentle	Sweep	7.25	1.01

Table of Means - Taxa richness of hemiptera from natural and constructed marshes in central Florida

Natural	Core	0.71	0.69

Table B-10. Tables of means showing relationships between select variables and taxa richness of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marshes of central Florida

Class	Sampling Method	Log naididae Least Square Mean	Standard Error Least Square Mean
Natural	Sweep	8.71	0.69
New/Steep	Core	1.5	1.3
New/Steep	Sweep	7	1.3
New/Gentle	Core	1.5	1.3
New/Gentle	Sweep	8	1.3
Old/Steep	Core	1.33	1.06
Old/Steep	Sweep	5.33	1.06
Old/Gentle	Core	1.25	0.92
Old/Gentle	Sweep	8	0.92

Table of Means - Taxa richness of coleoptera
from natural and constructed marshes in central Florida

Natural	Core	6.29	1.26
Natural	Sweep	23.86	1.26
New/Steep	Core	1.5	2.35
New/Steep	Sweep	13	2.35
New/Gentle	Core	5	2.35
New/Gentle	Sweep	20	2.35
Old/Steep	Core	4.33	1.92
Old/Steep	Sweep	19.33	1.92
Old/Gentle	Core	5.75	1.66
Old/Gentle	Sweep	18.25	1.66

Table of Means - Taxa richness of chironomini
from natural and constructed marshes in central Florida

Natural	Core	8.29	0.95
Natural	Sweep	10.71	0.95
New/Steep	Core	9.5	1.77
New/Steep	Sweep	11	1.77
New/Gentle	Core	9	1.77
New/Gentle	Sweep	10	1.77
Old/Steep	Core	6.33	1.45
Old/Steep	Sweep	5.67	1.45
Old/Gentle	Core	11	1.25
Old/Gentle	Sweep	10.25	1.25

Table of Means - Taxa richness of orthocladiinae
from natural and constructed marshes in central Florida

Natural	Core	2.29	0.3
Natural	Sweep	1.57	0.3
New/Steep	Core	0.5	0.57

Table B-10. Tables of means showing relationships between select variables and taxa richness of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marshes of central Florida

Class	Sampling Method	Log naididae Least Square Mean	Standard Error Least Square Mean
New/Steep	Sweep	0.5	0.57
New/Gentle	Core	0	0.57
New/Gentle	Sweep	1	0.57
Old/Steep	Core	0	0.46
Old/Steep	Sweep	0.67	0.46
Old/Gentle	Core	0.25	0.4
Old/Gentle	Sweep	0.5	0.4

Table of Means - Taxa richness of tanypodinae from natural and constructed marshes in central Florida

Natural	Core	8.57	0.55
Natural	Sweep	9.29	0.55
New/Steep	Core	3.5	1.02
New/Steep	Sweep	4.5	1.02
New/Gentle	Core	4	1.02
New/Gentle	Sweep	3.5	1.02
Old/Steep	Core	5	0.84
Old/Steep	Sweep	4.67	0.84
Old/Gentle	Core	5.5	0.72
Old/Gentle	Sweep	7.5	0.72

Table of Means - Taxa richness of ceratopogonidae from natural and constructed marshes in central Florida

Natural	Core	4.43	0.4
Natural	Sweep	5.43	0.4
New/Steep	Core	2.5	0.74
New/Steep	Sweep	1.5	0.74
New/Gentle	Core	2.5	0.74
New/Gentle	Sweep	3.5	0.74
Old/Steep	Core	3.67	0.61
Old/Steep	Sweep	3.33	0.61
Old/Gentle	Core	2.75	0.53
Old/Gentle	Sweep	2.75	0.53

Table of Means - Taxa richness of chaoboridae from natural and constructed marshes in central Florida

Natural	Core	1.14	0.16
Natural	Sweep	0.71	0.16
New/Steep	Core	1	0.29
New/Steep	Sweep	0	0.29
New/Gentle	Core	0.5	0.29

Table B-10. Tables of means showing relationships between select variables and taxa richness of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marshes of central Florida

Class	Sampling Method	Log naididae Least Square Mean	Standard Error Least Square Mean
New/Gentle	Sweep	0.5	0.29
Old/Steep	Core	0.67	0.24
Old/Steep	Sweep	0.33	0.24
Old/Gentle	Core	1	0.21
Old/Gentle	Sweep	2.75	0.21

Table of Means - Taxa richness of culicidae from natural and constructed marshes in central Florida

Natural	Core	2	0.43
Natural	Sweep	3.29	0.43
New/Steep	Core	0.5	0.8
New/Steep	Sweep	3	0.8
New/Gentle	Core	0	0.8
New/Gentle	Sweep	2.5	0.8
Old/Steep	Core	2	0.65
Old/Steep	Sweep	5	0.65
Old/Gentle	Core	1.75	0.56
Old/Gentle	Sweep	5	0.56

Table of Means - Taxa richness of tipulidae from natural and constructed marshes in central Florida

Natural	Core	2.43	0.29
Natural	Sweep	1.71	0.29
New/Steep	Core	1	0.54
New/Steep	Sweep	0	0.54
New/Gentle	Core	1	0.54
New/Gentle	Sweep	0.5	0.54
Old/Steep	Core	1.67	0.44
Old/Steep	Sweep	1.67	0.44
Old/Gentle	Core	0.75	0.38
Old/Gentle	Sweep	1.25	0.38

Table of Means - Taxa richness of lepidoptera from natural and constructed marshes in central Florida

Natural	Core	0.71	0.34
Natural	Sweep	1.29	0.34
New/Steep	Core	0	0.64
New/Steep	Sweep	0.5	0.64
New/Gentle	Core	0	0.64
New/Gentle	Sweep	0.5	0.64
Old/Steep	Core	1.67	0.52

Table B-10. Tables of means showing relationships between select variables and taxa richness of major taxonomic groups of aquatic macroinvertebrates in natural and constructed marshes of central Florida

Class	Sampling Method	Log naididae Least Square Mean	Standard Error Least Square Mean
Old/Steep	Sweep	0.33	0.52
Old/Gentle	Core	1.5	0.45
Old/Gentle	Sweep	0.5	0.45

Table of Means - Taxa richness of gastropoda from natural and constructed marshes in central Florida

Class	Sampling Method	Log naididae Least Square Mean	Standard Error Least Square Mean
Natural	Core	0.43	0.42
Natural	Sweep	1.14	0.42
New/Steep	Core	4	0.79
New/Steep	Sweep	6	0.79
New/Gentle	Core	3.5	0.79
New/Gentle	Sweep	5.5	0.79
Old/Steep	Core	1.67	0.65
Old/Steep	Sweep	1.33	0.65
Old/Gentle	Core	2.5	0.56
Old/Gentle	Sweep	5.75	0.56

BIOGRAPHICAL SKETCH

David Lynn Evans was born in Crossville, Tennessee, on May 15, 1954. He graduated from Westtown School in Westchester, Pennsylvania, in 1972 and entered Earlham College in Richmond, Indiana. While at Earlham, he served as Curator of Ichthyology at the Joseph Moore Museum. In 1976, he received a B.A. in biology from Earlham. He taught ecology, biology, and introductory chemistry at Oakwood School in Poughkeepsie, New York, in 1977. He entered graduate school at Tennessee Technological University in 1978, where he held a teaching assistantship for 2 years and conducted a research project surveying benthic macroinvertebrates, aquatic macrophytes, algae, and water chemistry in a spring-fed limestone quarry. He completed an M.S. in fisheries management in 1980.

Mr. Evans has been employed as an environmental scientist at Water and Air Research, Inc., in Gainesville, Florida, since 1981, where he currently serves as senior scientist and director. He has authored or coauthored over 70 technical reports and papers for clients, regulatory agencies, and professional journals. His project management responsibilities included a 4-year research project involving construction design, management, and evaluation of a constructed freshwater marsh.

Mr. Evans is a founder, past president, and past executive committee chairman of the Florida Association of Benthologists. He is also certified as a wetland scientist by the Society of Wetland Scientists.

In 1987, he entered the University of Florida, pursuing a Ph.D. in environmental engineering sciences. Research conducted by Mr. Evans in pursuit of this degree included design and performance of a 3-year study of natural and constructed wetlands.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy

Thomas L. Crisman, Chairperson
Professor of Environmental
Engineering Sciences

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy

George R. Best
Scientist of Environmental
Engineering Sciences

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy

Wiley M. Kitchens

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Associate Professor of Wildlife
Ecology and Conservation

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy

Clay L. Montague

Clay L. Montague
Associate Professor of Environmental
Engineering Sciences

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy

Frank G. Nordlie
Professor of Zoology

This dissertation was submitted to the Graduate Faculty of the College of Engineering and to the Graduate School and was accepted as partial fulfillment of the requirements of the degree of Doctor of Philosophy.

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