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Harrier Meadow Wetlands Mitigation Site
Fifth Annual Monitoring Report
2003

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APPENDIX K:

Avian Survey at the Harrier Meadow Wetlands Mitigation Site

Avian Survey at the Harrier Meadow Wetlands Mitigation Site

Alison Seigel

Introduction

Prior to restoration, Harrier Meadow was relatively homogeneous habitat dominated by the invasive species, *Phragmites australis* and *Lythrum salicaria.* The marsh contained isolated patches of native vegetation and only small areas of open water. A principal goal of the restoration was to increase wildlife utilization of the marsh, specifically waterfowl and shorebirds, by increasing habitat diversity. Completed in 1998, the restoration created scrub/shrub habitat and tidal, open water and low/high marsh areas and reduced the areal cover of the invasive species. Three shallow impoundments with connecting channels were created as part of the restoration.

Avian monitoring was an essential component of the overall monitoring program at Harrier Meadow. The marshes in the Meadowlands are surrounded by a highly urbanized landscape and therefore have the potential to provide valuable habitat for numerous bird species, both migratory and resident. Moreover, birds serve as indicators of habitat value and development. A comprehensive avian monitoring program can therefore be a valuable tool in assessing the effect of restoration on the avian community in the marsh and in evaluating the progress of the restored marsh over time. The avian monitoring program used at Harrier Meadow included pre-restoration monitoring and multi-year post-restoration monitoring, enabling a direct comparison of the avian community in the marsh before and after restoration to detect interannual and intra-annual trends. This type of comparison is only possible when both pre and post-restoration data is available.

Methods

Avian monitoring at Harrier Meadow was conducted using the point count method. All birds seen and heard within a predetermined survey area, during a five minute observation period were recorded with the exception of birds flying over the survey area. Foraging raptors and aerial insectivores were however included. Surveys were conducted between sunrise and 10 am. Birds were not surveyed on rainy or windy days. One survey consisted of observations made at all point count stations on one date. The location of the survey stations are presented in Figure 1.

In this analysis, pre-restoration monitoring years at Harrier Meadow include 1996 and 1997. Post-restoration monitoring years include 2000 through 2003. Monitoring was carried out weekly across all seasons with the exception of winter, when surveys were conducted every third week. Survey dates are categorized into seasons. Summer/breeding included June, July, and August; fall migration included September and October; winter included November, December, January, and February; and spring migration included March, April, and May.

Results

Trends in avian community composition at Harrier Meadow are presented both on the annual level (combines all four seasons) and the seasonal level. In order to make valid annual comparisons of the bird community, only years which received even sampling effort across all seasons (1997, 2001, and 2002) were included. For example, avian surveys conducted in 1999 were not included in annual comparisons as winter was not sampled during that year. Data from the summer/breeding season are presented here because this season was sampled consistently for two years prior to restoration and four years after restoration, providing higher temporal resolution in the interannual avian community trends. Moreover, birds are tightly coupled to local resources available in the marsh during the summer/breeding season.

The influence of restoration on the avian community is readily apparent when comparing pre and post-restoration cumulative avian species richness between years (Figure 2). Pre-restoration annual species richness was 42 species which increased by 55% to 65 species in 2001. Species richness decreased to 58 species in 2002, but remained 38% above pre-restoration species richness.

Avian response to restoration was also evident during the breeding season. Prior to restoration, species richness was 22 species. During all post-restoration monitoring years species richness remained higher than pre-restoration richness, nearly doubling it in 2001 (Figure 3). Average avian abundance per survey during the summer/breeding season also increased after restoration, ranging from a minimum of 34 (SE = 6) individuals per survey in 1997 to a maximum of around 900 (SE = 690) individuals per survey in 2002 (Figure 4).

Bird species representing seven guilds (waterfowl, waders, shorebirds, raptors, rails, gulls/terns, and landbirds) were observed at Harrier Meadow and avian guild structure changed markedly in response to restoration (Figure 5). Prior to restoration, avian relative abundance was dominated by landbirds (0.87) such as Red-winged Blackbird (*Agelaius phoeniceus*) and Marsh Wren (*Cistothorus palustris*). A very small proportion (0.13) of the overall avian abundance was represented by the remaining guilds. After restoration, the proportion of landbirds decreased dramatically (0.17 in 2001 and 0.09 in 2002), while the proportion of waterfowl, gulls/terns, and shorebirds increased correspondingly (0.83 in 2001 and 0.91 in 2002) Although rails and raptors were observed, their abundances were very low and were therefore, not included in the graphical representation.

Guild structure during the summer/breeding season showed a similar response to restoration (Figure 6). Ninety percent of the pre-restoration avian community was comprised of landbirds with post-restoration avian abundance becoming more evenly distributed across waterfowl, waders, shorebirds, and gulls/terns. The relatively large proportion of shorebirds in 2002 was most likely due to an early wave of shorebird migration.

The species-level response to restoration can be seen in Table 1. This table includes a list of species observed at Harrier Meadow prior to restoration and lists of the species that were both lost and gained after restoration. In order to make valid conclusions, the analyses in this summary report were based on a subset of the total data collected during avian monitoring. The pre and post-restoration species list, however, was based on all avian surveys conducted at Harrier Meadow to present an all-inclusive comparison of pre and post-restoration species richness.

Discussion

Avian community composition at Harrier Meadow changed considerably in response to the creation of new habitat types through restoration. The pre-restoration avian abundance in the marsh was dominated by a few species within a single guild, indicative of a homogeneous habitat with few avian ecological niches. After new habitat types were created through restoration, a larger proportion of avian abundance was comprised of species in wetland-associated guilds such as waterfowl and gulls/terns.

The use of an appropriate avian monitoring strategy was essential in detecting the avian response to restoration at Harrier Meadow. Pre-restoration monitoring is an important part of the overall monitoring strategy as it provides the baseline data necessary to detect post-restoration change in avian community composition. Post-restoration habitat development in marshes has been shown to be dynamic with high interannual variability. As a result, it is extremely important to carry out long-term, post-restoration monitoring to determine if the restored marsh is following the intended successional trajectory.

Table 1. Avian Survey Species List for Harrier Meadow

Pre restoration	Absent after restoration	Gained through restoration
American Black Duck	American Wigeon	American Redstart
American Goldfinch	Eastern Meadowlark	Black-Bellied Plover
American Kestrel	Eastern Towhee	Black-Capped Chickadee
American Robin	Fox Sparrow	Bank Swallow
American Wigeon	Hermit Thrush	Black Skimmer
American Tree Sparrow	House Finch	Bobolink
Baltimore Oriole	Northern Waterthrush	Brant
Barn Swallow	Saltmarsh Sharp-Tailed Sparrow	Brown Thrasher
Black-Crowned Night Heron	Seaside Sparrow	Bufflehead
Belted Kingfisher	Solitary Sandpiper	Canvasback
Brown-Headed Cowbird	Yellow-Crowned Night Heron	Caspian Tern
Blue Jay		Cedar Waxwing
Blue-Winged Teal		Common Merganser
Canada Goose		Common Snipe
Calidris spp.		Double-Crested Cormorant
Common Grackle		Dark-Eyed Junco
Common Moorhen		Dunlin
Corvus Spp		Eastern Kingbird
Common Snipe		Field Sparrow
Common Yellowthroat		Forster's Tern
Downy Woodpecker		Great Horned Owl
Eastern Meadowlark		Green Heron
Eastern Phoebe		Hooded Merganser
Eastern Towhee		House Sparrow
European Starling		Laughing Gull
Fox Sparrow		Lesser Scaup
Gadwall		Merlin
Great Black-Backed Gull		Mute Swan
Great Blue Heron		Northern Goshawk
Glossy Ibis		Northern Harrier
Gray Catbird		Northern Pintail
Great Egret		Northern Shoveler
Green-Winged Teal		Northern Rough-Winged Swallow
Herring Gull		Pied-Billed Grebe
Hermit Thrush		Ruby-Crowned Kinglet
House Finch		Ring-Necked Duck
Indigo Bunting		Rock Dove
Killdeer		Ruddy Duck
Mallard		Savannah Sparrow
Marsh Wren		Semipalmated Plover
Mourning Dove		Snow Goose
Northern Cardinal		Tri-Colored Heron
Northern Flicker		Tree Swallow
Northern Mockingbird		Turkey Vulture
Northern Waterthrush		Wilson's Phalarope
Osprey		
Palm Warbler		
Peregrine Falcon		
Prairie Warbler		
Ring-Billed Gull		
Ring-Necked Pheasant		

Table 1. Avian Survey Species List for Harrier Meadow

Pre restoration

Red-Tailed Hawk
Red-Winged Blackbird
Savannah Sparrow
Seaside Sparrow
Snowy Egret
Sora
Solitary Sandpiper
Song Sparrow
Spotted Sandpiper
Saltmarsh Sharp-Tailed Sparrow
Swamp Sparrow
Tringa spp.
Virginia Rail
White-Crowned Sparrow
Willow Flycatcher
Wood Duck
White-Throated Sparrow
Yellow-Crowned Night Heron
Yellow Warbler
Yellow-Rumped Warbler

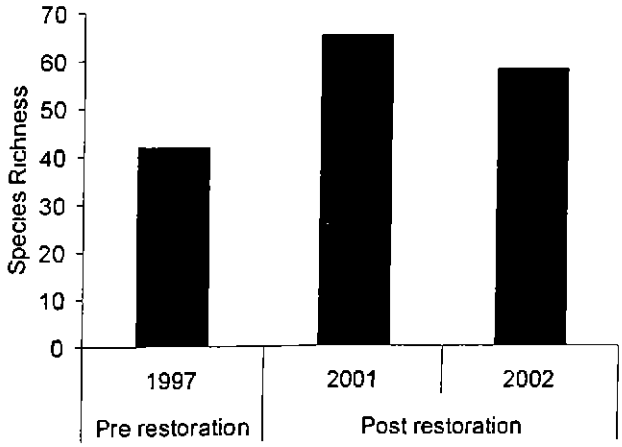


Figure 2. Cumulative annual avian species richness at Harrier Meadow before and after restoration

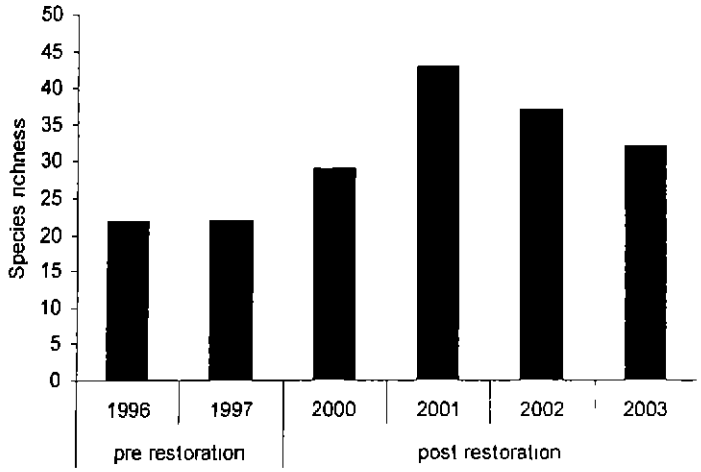


Figure 3. Cumulative avian species richness during the summer/breeding season before and after restoration

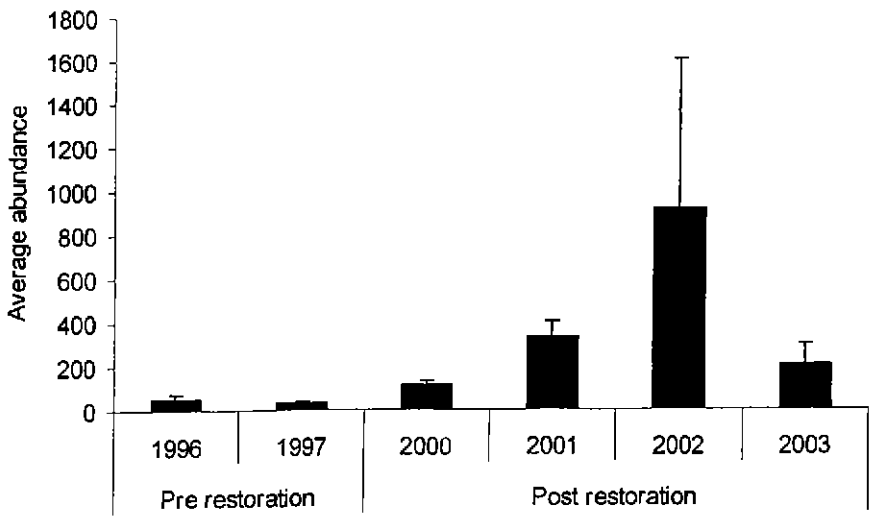


Figure 4. Average avian abundance per survey at Harrier Meadow during summer/breeding season

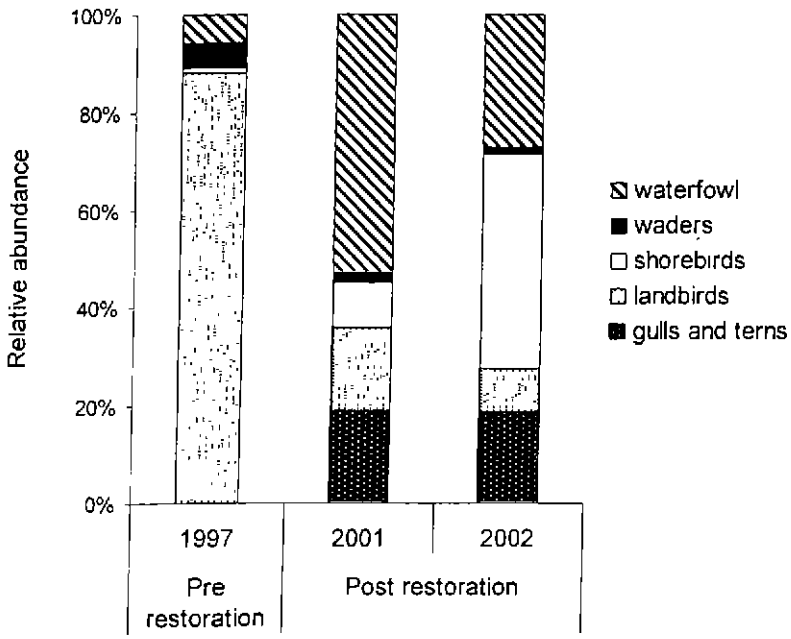


Figure 5. Annual relative abundances of five guilds at Harrier Meadow. Raptors and rails were observed in low numbers and are not visible in this graph.

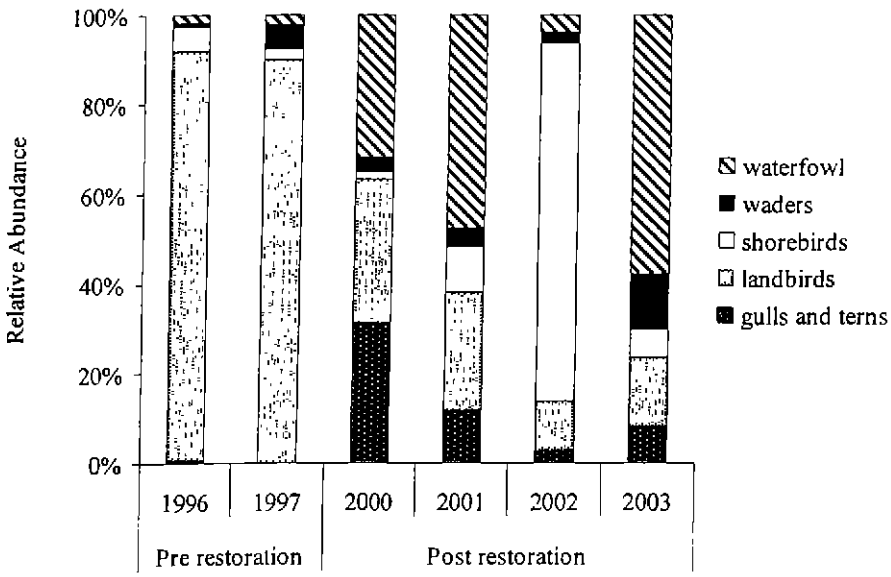


Figure 6. Relative abundance of 5 guilds during the summer/breeding season at Harrier Meadow. Rails and raptors were observed in low numbers and are not visible in this graph.



Figure 1

Avian Point-Count Sampling Locations at Harrier Meadow Wetland Mitigation Site

NEW JERSEY MEADOWLANDS COMMISSION

avian point-count sampling locations

site boundaries

200 0 200 400 600 Feet

N

map prepared November 7, 2003

APPENDIX L:

Monitoring of Fish at the Harrier Meadow Wetland Mitigation Site

Monitoring of Fish at the Harrier Meadow Wetlands Mitigation Site

Ross M. Feltes, Ph.D.

Introduction

Enhancement of Harrier Meadow included the construction of three shallow impoundments with connecting channels. Water-control structures are present to allow for manipulation of water levels and the control of tidal flow. Water is retained in the impoundments even at low tide. The extent of open water in the enhanced portion of the Site (areas that are always flooded) was from 11.6 to 18.5 acres at the time of preparation of vegetation maps in 2000, 2001 and 2002. This is approximately one-third of the mitigation area. Two of the proposed goals of the Wetland Enhancement Plan for this site were greater fishery access and "increased cover and breeding functions on the marsh for a variety of estuarine-associated species including waterfowl and shorebirds". Some of the specifically listed target avian species are piscivorous.

Tidal salt marshes are often claimed as a valuable link between the estuaries and coastal fisheries (Weinstein et al. 2000). Salt marshes can support large numbers of estuarine fish and their offspring (Weinstein et al. 1979). They can act as nurseries for commercially important species or for the forage fish that they feed upon in the larger estuary. Marsh habitat is also a relatively safe haven from many other fish acting as predators (Shenker and Dean 1979). Young fish benefit from the rich source of detritus in marshes as secondary consumers, feeding largely on invertebrates. Fish are important in the transfer of material between the marsh surface and subtidal waters (Kneib 1997). The use of tidal marsh habitats by fishes has been used as an important indicator of mitigation success (Matthews and Minello 1994, James-Pirri et al. 2001).

Methods

Fish were collected at the Harrier Meadow Wetlands Mitigation Site to determine species composition, relative numbers, and size of the captured specimens. Specimens were taken using a 6.1 m x 1.2 m seine of 3.2 mm mesh with a bag; and baited killitraps, 25cm x 38 cm with 2.5 cm openings. Up to three seine hauls were made to collect at least 50 specimens of the most numerous taxa, *Menidia* spp. (silverside) and *Fundulus heteroclitus* (mummichog). Tidal flow in the impoundments was not significant during most collection periods. Traps were set at stations in the tidally flushed unrestored areas of the Site at lower tide levels, and were retrieved approximately 24 hours after being set. Temperature and salinity were measured. Identification of specimens was made at the Site when possible. These specimens were measured and then returned to the water. Usually, up to 50 specimens of a species were measured. Specimens of a species in excess of 50 were counted, but not typically measured. *Menidia beryllina* and *Fundulus heteroclitus* often mature at approximately 30 mm (Hardy 1978; Martin and Drewry 1978). The length of specimens less than 30 mm was not routinely measured, but were

counted as specimens of a given taxon and simply noted as less than 30 mm. Unidentified specimens, or previously uncollected species, were preserved for examination in the lab. Listings for *Menidia* sp. represent specimens, often juveniles, which were largely *M. beryllina*, but may have included *M.* menidia. In 2001, 2002, and 2003 at least the initial 50 specimens of *Menidia* captured were identified to species in the lab.

In 1999, the first year of monitoring at Harrier Meadow, three locations were sampled. These stations were in each of the three major impoundments. Collections were expanded to eight stations in 2000. Fish from the large impoundments in the restored area of the Site (stations 1 through 3) were primarily taken using a seine. Killitraps were the primary method of capture in the unrestored area of the Site (stations 4 through 8). The locations of sampling stations are shown in Figure 1. Few specimens were obtained in traps at stations 6 and 7 in 2000, and sampling at these stations duplicated the effort made at the adjacent station 8. Sampling at stations 6 and 7 was not repeated in 2001 or 2002, but these locations were seined in 2003. Stations 4 through 8 are influenced by tides through breaches in the earthen berm along the southeast perimeter of the Site.

The length of specimens was measured from the anterior of the snout to the posterior of the caudal fin at the midpoint along the margin. For species with rounded caudal fins this would be total length. For species with emarginated or forked caudal fins this would be fork length.

Confirmation of the presumption of gravid female specimens taken in collections was done by dissection in the lab.

Results

Tables 1 through 4 lists the species caught, the number of specimens of each species, and the mean length of those specimens taken in each sampling.

Five species were taken in the first year of the fish survey for Harrier Meadow, conducted May through September 1999 (Table 1). *Fundulus heteroclitus* (mummichog) and *Menidia* sp. (silversides) made up approximately 51% and 49% of the catch for the entire year, respectively. Large numbers of small specimens of these taxa were collected in the impoundments (stations 1, 2 and 3) in July and August. A single specimen of *Gasterosteus aculeatus* (three-spine stickleback) was taken in May and a few *Morone americana* (white perch) were taken in July and August.

The same species taken in 1999 were found again in collections made May through September of 2000 (Table 2). *Menidia* was considerably more abundant than the other taxa at 77% of the year's catch, except in August when *Fundulus* dominated the samples. *Fundulus* made up 23% of the year's catch. Large numbers of young of the year *Menidia* were collected at stations 2 and 3 from June through September. This resulted in a

significantly larger number of fish being collected in 2000 than the other years. The collections made with traps at stations 6 and 7 were insignificant.

Nine species were taken in the 2001 collections (Table 3). The most abundant taxon at this site was *Menidia*, 53% of the year's catch, and *F. heteroclitus*, 22%. Large numbers of *G. aculeatus* were present in May at station 3, making up11% of the annual catch. In June many juvenile *Menidia* were collected at stations 2 and 3 and young *M. americana* at station 2. *Morone americana* made up 10% of the year's sampling. A few *M. americana* were collected in 1999 and 2000, but as with *G. aculeatus* a significant presence of young was not observed until 2001.

Five species were present in the collections for 2002 (Table 4). *Menidia* sp., 53% of year's catch, and *F. heteroclitus,* 46%, dominated the samples. *Gasterosteus aculeatus* were taken again in May of 2002. They made up less than 2% of the total catch for the year.

Collections made in 2003 include *Anguilla rostrata* (American eel), *Cyprinus carpio* (common carp), *Fundulus heteroclitus, F. majalis* (striped killifish), *Gambusia affinis* (western mosquitofish), *Gasterosteus aculeatus, Lepomis gibbosus* (pumpkinseed), *Menidia beryllina, M. menidia*, and *Morone americana*. These collections were again dominated by *M. beryllina* and *F. heteroclitus*. *Fundulus majalis* was taken only in the unrestored portion of the Site in 2003.

Thirteen species of fishes were collected at Harrier Meadow in this monitoring effort from 1999 through 2003 (Table 5). *Menidia* were the most abundant fish taken each year, except in 1999, comprising between 49% and 77% of all specimens. In 2001 the ratio of *M. beryllina* : *M. menidia* was 65% : 35% and in 2002 the ratio was 92% : 8%. The largest number of specimens of *M. beryllina* with a length greater than 30 mm was collected in September of 2001 and 2002. Most of the larger *M. menidia* appeared in the collections from September in 2001, and July in 2002. Many more adult *M. beryllina* were taken from stations 2 and 3 than station 1. This was true for small *Menidia* in 2000, when *Menidia* was particularly abundant, but not other years. *Fundulus heteroclitus* was the most abundant in the total catch in 1999 and ranked second in the following years, contributing between 22% and 51%. Collections from all three impoundments included large numbers of *F. heteroclitus*, without any one yielding notably more than the others. Figure 2 shows the relative abundance of *F. heteroclitus* and *Menidia* for each collection. The abundance of *F. heteroclitus* and *Menidia* in collections does not correlate with particular months of the year.

Figure 3 illustrates the mean length of primarily mature specimens of *F. heteroclitus* and *Menidia* measured in each collection. These were generally specimens over 30 mm.

Specimens less than 30 mm in length comprise up to 66% of the total catch during a year. Most of the small juvenile fish were *Menidia*, primarily *M. beryllina*. They were at least half of the less than 30 mm long fish taken each year and in 2000 were 98% of the small specimens. In 2000 young *Menidia* were collected May through September, but were

taken in large numbers in the June collections in each survey year. Specimens of *Menidia* with a length less than 30 mm made up between 40% and 77% of the total *Menidia* collected. Young *Fundulus* were collected June through September in 2000, but were taken in the June collections in each year. Specimens of *Fundulus* less than 30 mm in length made up between 7% and 34% of the total *Fundulus* collected. The month with the greatest presence of small *Menidia* and *Fundulus* varied between June and July in different years. The greatest number of specimens of *Menidia* and *Fundulus* with lengths greater than 30 mm often appeared in September collections.

Gravid female specimens of *F. heteroclitus* and *M. beryllina* with well-developed eggs were confirmed in impoundment collections from May and June 2001, May 2002, and May and June 2003. *Gambusia affinis* containing large embryos were collected in August 2003 from station 1. Some large *M. americana* released milt while being handled after capture in the impoundments. Adult *C. carpio* (common carp) were observed exhibiting courting behavior during 2002 and 2003.

In addition to the fish species collected, there was incidental capture of benthic invertebrate species. *Palaemonetes pugio* (grass shrimp) were common in seine hauls. Harrier Meadow has a large population of *Callinectes sapidus* (blue crab) in the impoundments and creeks. These congregate at the water-control structures. The average carapace width of the specimens collected at Harrier Meadow increased through the years of 1999, 2000, and 2001. More and larger *C. sapidus* were collected at Harrier Meadow in 2001 than during that period at Mill Creek Marsh. *Rhithropanopeus harrisii* (white-finger mud crab) were occasionally found at Harrier Meadow.

Table 6 summarizes the data on salinity and temperature taken at the time of fish collections. Salinity in the impoundments ranged from 5 to 18 ppt and thus is considered mesohaline. Temperature was recorded from 16 to 38° C. There is not a correlation between the months over the years of sampling and levels of salinity. The salinity readings for 2002 were relatively high for each month compared to other years. The water temperature was low during the May 2002 monitoring. There was much variation in recorded water temperature between stations within some months, with a maximum range of 11degrees. No pattern was determined for the differences in salinity and temperature between the three impoundments. The salinities and temperatures recorded at the stations in the unrestored portion of the Site did not vary consistently relative to the large impoundments except from July through September, 2002, the salinity at station 8 was notably less than the other stations.

Discussion

The difference in diversity and the number of specimens collected between the restored area of the Site (stations 1 through 3) and the unrestored area (stations 4 through 8) represents differences not only in habitat, but also is an artifact of the success of seining compared to killitraps. Different gear for collecting may capture different taxa, but rarely provides comparable quantitative results. The diversity and number of specimens taken

in traps placed either in tidal creeks and pools in the unrestored area or in the constructed impoundments was low compared to seining. Seining in the creeks and pools of the unrestored area collected varying numbers of specimens, depending on the station, but included catches with numbers at least as large as those in the impoundments.

The size of the collections was significantly influenced by the presence of large numbers of juvenile specimens. Since specimens less than 30 mm in length were not routinely measured they are not reflected in Figure 3 that shows the mean length of measured specimens. Few or no specimens were collected from station 1 in impoundment 1 during July and August of 2000 and 2001. Heavy algal blooms made seining difficult there. Low collection numbers for those periods does not reflect population numbers in the impoundment.

Sampling with seines was done in depths generally less than 1 meter and traps were set in shallower water. The different species being taken together by seining probably were typically somewhat spatially separated in the water column. *Gasterosteus aculeatus* and *Anguilla rostrata* reside near the bottom, while *Anchoa mitchilli* tend to occupy midwater, and *Menidia beryllina* is at the surface. Deep channels run through the impoundments. Species in addition to those collected may exist in these deeper channels at the Site. Many species of fishes, if present, would not regularly leave the deeper waters and thus would not be collected by the methods used.

Open water at Harrier Meadow is drained by Kingsland Creek, which flows into the Hackensack River. There is potential for a greater diversity of fish at Harrier Meadow, but this may be impeded by the lack of substantial flow through the water-control structures. In collections from sites on the Hackensack River and its major tributaries conducted from February 1987 through January 1988 Kraus and Bragin (1989) report a total of 37 species of fishes. *Fundulus heteroclitus* made up 91% of the total collections, *M. menidia* 2.5%, *M. beryllina* 1.4% and *M. americana* 1.3%. These were the same dominant species taken at Harrier Meadow, though *M. beryllina* had a much greater relative abundance at the enhanced site. *Fundulus heteroclitus* was the most abundant species in collections taken closest to the Harrier Meadow site for the Hackensack River and tributaries study. The specific habitat and collecting methods differed between the Krasus and Bragin (1989) survey and the study at Harrier Meadow. *Fundulus heteroclitus*, *M. beryllina,* and *M. americana*, *L. gibbosus*, *A. rostrata* and *C. carpio* were considered as resident species in the Krasus and Bragin (1989) survey. Permanent residents of tidal salt marshes are often small (150 mm) (Kneib 1997). *Cyprinus carpio* is certainly an exception to this generalization, but it is an exotic and primarily a freshwater species. Fifty species of fish have been listed for the greater Hudson-Raritan estuary (Kiviat and MacDonald 2002).

Dionne et al. (1999) compared fish communities at created, restored, and reference salt marshes in Maine. *Fundulus* dominated the collections. After one year the density of *Fundulus* was higher in the reference marsh, but after four years the fish densities in the reference and created marshes were the same. The mean size of specimens was similar between collections from the two types of marshes as well. Conflicting results exist for

the relative diversity and abundance between natural and restored tidal marshes. In a study at a salt marsh in Connecticut Warren et al. (2002) found the abundance of *Fundulus* to be as high in a restored marsh as a reference marsh one year after restoration and suggests a typical fish species assemblage occurred at the restored site eight years after restoration. Collections of *Fundulus* made by Moy and Levin (1991) consistently yielded more fish from natural marshes than a planted marsh. A study in marshes along the Texas coast (Minello and Zimmerman 1992) showed newly established marshes created with dredged materials were occupied by fish at the same densities as natural marshes. In North Carolina, Meyer et al. (1993) found that two years after planting an established marsh had a mean density of fish half that of a natural reference marsh. The discrepancy in results between studies may be contributed to by the use of dissimilar collection gear, regional distinctions in the structure of coastal marshes, and temporal differences. Many published studies on fish in tidal marshes of eastern North America are at sites where salinity is higher, polyhaline, with a salinity ranging from 18-30 ppt.

Menidia beryllina was the most abundant species in the collections. *Menidia* often rivals *Fundulus* in abundance among fish inhabiting tidal areas in eastern North America (Conover and Ross 1982, Minton 1999). Several published studies on collections of salt marsh fish from eastern North America list *M. menidia* as one of the most numerous species (Minton 1999), but the salinities at those study sites were higher than Harrier Meadow. *Menidia beryllina* tends to prefer lower salinities than *M. menidia*, though is found along the entire salinity gradient (Murdy et al. 1997). Seasonal dominance in collections by *M. beryllina* has been reported in salt marshes of Chesapeake Bay with salinities of 5-10 ppt (Meyer et al. 2001). *Menidia* exhibit active schooling behavior. The wide variation in catch size between sampling periods may be strongly affected by the schooling nature of some species of fish and encountering one of these schools while seining.

Menidia menidia is ubiquitous in tidal areas along the eastern North American coast, often occurring in large schools. It is migratory, entering the shallows in spring and leaving for deeper water in late fall. The specimens taken at Harrier were not resident and thus presumably entered through the water-control structures. *M. menidia* has a life span seldom exceeding one year (Conover and Ross 1982; Minton 1999). All of the specimens taken at Harrier appear to be young-of-the year.

Fundulus heteroclitus is particularly stress and pollution tolerant. It is the dominant species in most collections from tidal marshes along the eastern coast of North America. It is a major prey item for wading birds, aerial searching birds, piscivorous ducks as well as larger fishes. The diet of nesting herons and egrets may contain up to 95% killifishes (Abraham 1985). The role of *F. heteroclitus* in transferring material from the marsh surface, where it primarily feeds, to deeper waters has been documented (Allen et al. 1994). Without tidal flooding fishes do not have access to the marsh surface habitat at Harrier. The limited access to marsh surface without tidal flushing at Harrier would reduce breeding habitat. *Fundulus luciae* occurs sporadically in salt marshes from Long Island to Georgia. It is common in pools of tidal marshes in New Jersey (Smith 1985). This species has not been identified in the collections for this study or in Kraus and

Bragin (1989) for the Hackensack. It is easily misidentified as small *F. heteroclitus*, but examination of all preserved specimens that were potentially *F. luciae* did not reveal any.

Morone americana prefers salinities less than 18 ppt and frequently inhabit impoundments. This habitat did not exist prior to construction. Young reside along shore margins such as where the monitoring collections were made. Larger *M. americana* are piscivorous predators in the marsh (Murdy el al. 1997).

Though a few specimens of *Gasterosteus aculeatus* appeared in collections made at this site in 2000, none were taken in 1999. The presence of this species would be expected in such a tidal habitat, and it was common at this site in standing water in marsh areas prior to construction (A. Krivenko, personal comm.). All of the collections of *G. aculeatus* occurred in May or June. *G. aculeatus* uses the marsh environment during a spring breeding season, but moves back into deeper water by summer.

The spring collections of fish in this study were still dominated by survivors of one growing season. *Fundulus heteroclitus* breeds in New Jersey from April to late August with a peak in late May (Hardy 1978). Very few *F. heteroclitus* reach a third year (Abraham 1985). *Menidia beryllina* attains mature size by the end of the first growing season and reproduces the following year. Studies report this species reproducing from mid-May through August in Delaware and June through July in Massachusetts. Few individuals survive beyond 16 months (Martin and Drewry 1978).

The presence of large numbers of juvenile fish demonstrates the use of the impoundments and associated channels as nursery areas for *F. heteroclitus*, *M. beryllina*, *M. menidia*, and *M. americana*. Based on the reproductive state of some specimens, or observed behavior, at least *F. heteroclitus*, *M. beryllina*, *M. americana*, *G. affinis*, and *C. carpio* are presumed to breed at the Site.

Palaemonetes pugio often dominate the catch of invertebrates taken in collections of fish in salt marshes along the east coast of North America (Shenker and Dean 1979). There were large numbers of this crustacean at Harrier Meadow.

The amount of flow through the water-control structures obviously affects tidal exchange, the size of the impoundments, and access by fish. Water flow through the water-control structures did not allow for significant tidal exchange through most of the monitoring period. Water levels dropped notably in 2002. There was little rain that year and the salinities in the impoundments for June through September of 2002 were relatively high. They would still be within the tolerance of the estuarine fish species, but may discourage any primary freshwater species. The water levels increased somewhat in 2003, though this may be due to heavy rainfall and not tidal flow. The salinities readings for 2003 were low.

Conclusions

The species found to be present at Harrier Meadow, and the dominance of the collections by *Menidia beryllina* and *Fundulus heteroclitus*, are consistent with published surveys of salt marsh habitats along eastern North America. Thirteen species of fishes were collected at the Site in this monitoring effort from 1999 through 2003. The diversity would probably be greater if there was tidal flow through the water-control structures. Collections were not made to quantify the density of fish, but the total abundance of fish was large. In spite of the restricted flow between the impoundments and the adjacent tidal areas there was an extensive range of specimen sizes and pulses of large numbers of juveniles that indicates the Site is acting as a nursery for fish. Several species are breeding in the impoundments at the Site. Some of the species present in the impoundments are migrants and presumably are passing through the water-control structures.

Literature Cited

Abraham, B. J. 1985. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Mid-Atlantic) mummichog and striped killifish. U.S. Fish and Wildlife Service, Washington.

Allen, E. A., P. E. Fell, M. A. Peck, J. A. Gieg, C. R.Guthke and M. D. Newkirk. 1994. gut contents of common mummichogs, *Fundulus heteroclitus* L., in a restored impounded marsh and in natural reference marshes. Estuaries. 17(2):462-471.

Conover, D.O. and M.R. Ross. 1982. Patterns in seasonal abundance, growth, and biomass of the Atlantic silverside, *Menidia menidia* , in a New England estuary. Estuaries 5:275-286.

Dionne, M. F. T. Short and d. M. Burdick. 1999. Fish utilization of restored, created, and reference salt-marsh habitat in the Gulf of Maine. American Fisheries Society Symposium 22:384-404.

James-Pirri, K. B. Raposa and J. G. Catena. 2001. Diet composition of mummichogs, *Fundulus heteroclitus*, from restoring and unrestricted regions of a New England (U.S.A.) salt marsh. Estuarine, Coastal and Shelf Science 53:205-213.

Hardy, J. D., Jr. 1978. Development of fishes of the mid-Atlantic Bight: an atlas of egg, larval and juvenile stages. Volume 2. Anguillidae through Syngnathidae. FWS/OBS-78/12. U. S. Fish and Wildlife Service, Office of Biological Services.

Kiviat, E. and K. MacDonald. 2002. Hackensack Meadowlands, New Jersey, biodiversity: A review and synthesis. Hudsonia, Annandale, New York. http://www.meadowlandspartnership.org/images/hm%20alert%20-%20kiviat%20report.pdf and http://www.meadowlandspartnership.org/images/hm%20alert%20-%20combined%20tables.pdf .

Kneib, R. T. 1997. The role of tidal marshes in the ecology of estuarine nekton. Oceanography and Marine Biology: An Annual Review 35:163-220.

Kraus, M. L. and A. B. Bragin 1989. Inventory of fisheries resources of the Hackensack River within the jurisdictional boundary of the Hackensack Meadowlands Development Commission from Kearny, Hudson County, to Ridgefield, Bergen County, New Jersey. Hackensack Meadowlands Development Commission, Lyndhurst, NJ.

Martin, F. D. and G. E. Drewry. 1978. Development of fishes of the mid-Atlantic Bight: an atlas of egg, larval and juvenile stages. Volume 6. Stromateidae through Ogcocephalidae. FWS/OBS-78/12. U. S. Fish and Wildlife Service, Office of Biological Services.

Matthews, G.A. and T.J. Minello. 1994. Technology and success in restoration, creation and enhancement of *Spartina alterniflora* marshes in the United States. NOAA Coastal Ocean Program Decision Analysis Series No. 2. 2 volumes. U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, Coastal Ocean Office, Washington, DC.

Meyer D. L., M. S. Fonseca, D. R. Colby, W. J. Kenworthy, and G. W. Thayer. 1993. An examination of created marsh and seagrass utilization by living marine resources. Pages 1858-1863 *in* O. Magoon, W. S. Wilson, H. Converse, and L. T. Tobin. Coastal Zone '93, vol. 2. Proceedings of the 8th Symposium on Coastal and Ocean Management. American Society of Civil Engineers, NY.

Meyer, D. L., J. M. Johnson and J. W. Gill. 2001. Comparison of nekton use of *Phragmites australis* and *Spartina alterniflora* marshes in the Chesapeake Bay, USA. Marine Ecology Progress Series. 209:71-84.

Minello, T. J. and R. J. Zimmerman. 1992. Utilization of natural and transplanted Texas Salt marshes by fish and decapod crustaceans. Marine Ecology Progress Series 90:273-285.

Minton, M. D. 1999. Coastal wetland restoration and its potential impact on fishery resources in the Northeastern United States. American Fisheries Symposium 22:405-420.

Moy, L. D. and L. A. Levin. 1991. Are *Spartina* marshes a replaceable resource: A functional approach to evaluation of marsh creation efforts. Estuaries 13:1-16.

Murdy, E. O., R. S. Birdsong, and J. A. Musick et al. 1997. Fishes of Chesapeake Bay. Smithsonian Institution Press, Washington.

Shenker, J. M. and J. M. Dean. 1979. The utilization of an intertidal salt marsh creek by larval and juvenile fishes: abundance, diversity and temporal variation. Estuaries. 2(3):154-163.

Smith, C. L. 1985. The inland fishes of New York State. New York State Department of Environmental Conservation, Albany, NY.

Warren R. S., P. E. Fell, R. Rozsa, A. H. Brawley, A. C. Orsted, E. T. Olson, V. Swamy, W. A. Niering. 2002. Salt marsh restoration in Connecticut: 20 years of science and management. Restoration Ecology. 10 (3):497-513.

Weinstein, M. P., S. Y. Litvin, K. L. Bosley, C. M. Fuller and S. C. Wainright. 2000. The role of tidal salt marsh as an energy source for marine transient and resident finfishes: A stable isotope approach. Transactions American Fisheries Society 129:797-810.

Table 1. Fish Sampling Results at Harrier Meadow, 1999.

Date	Location	Species	Count	Mean Length (mm)
May 5	Station 1	*Fundulus heteroclitus*	5	60
May 5	Station 1	*Gasterosteus aculeatus*	1	64
May 5	Station 1	*Menidia menidia*	2	88
May 5	Station 1	*Fundulus heteroclitus*	3	64
June 1	Station 1	*Fundulus heteroclitus*	9	60
June 1	Station 2	*Fundulus heteroclitus*	14	66
June 1	Station 3	*Fundulus heteroclitus*	26	72
June 1	Station 3	*Menidia beryllina*	8	58
July 1	Station 1	*Fundulus heteroclitus*	60	26
July 1	Station 1	*Menidia* sp.	19	28
July 1	Station 2	*Fundulus heteroclitus*	51	31
July 1	Station 2	*Menidia* sp.	59	29
July 1	Station 3	*Fundulus heteroclitus*	100	29
July 1	Station 3	*Menidia* sp.	100	35
July 15	Station 1	*Fundulus heteroclitus*	50	34
July 15	Station 1	*Menidia* sp.	50	24
July 15	Station 2	*Fundulus heteroclitus*	50	37
July 15	Station 2	*Menidia* sp.	25	39
July 15	Station 3	*Fundulus heteroclitus*	30	36
July 15	Station 3	*Menidia* sp.	12	41
July 30	Station 1	*Fundulus heteroclitus*	35	38
July 30	Station 1	*Menidia* sp.	50	32
July 30	Station 2	*Fundulus heteroclitus*	50	42
July 30	Station 2	*Menidia* sp.	50	39
July 30	Station 2	*Morone americana*	1	< 30
July 30	Station 3	*Fundulus heteroclitus*	43	40
July 30	Station 3	*Menidia* sp.	50	33
July 30	Station 3	*Morone americana*	2	92
August 31	Station 1	*Fundulus heteroclitus*	26	38
August 31	Station 1	*Menidia* sp.	50	29
August 31	Station 2	*Fundulus heteroclitus*	19	49
August 31	Station 2	*Menidia* sp.	52	51
August 31	Station 2	*Morone americana*	1	126
August 31	Station 3	*Fundulus heteroclitus*	11	41
August 31	Station 3	*Menidia* sp.	50	33
September 27	Station 1	*Fundulus heteroclitus*	43	55
September 27	Station 1	*Menidia* sp.	50	44
September 27	Station 2	*Fundulus heteroclitus*	49	51
September 27	Station 2	*Menidia* sp.	3	44
September 27	Station 3	*Fundulus heteroclitus*	47	53
September 27	Station 3	*Menidia* sp.	51	43

Table 2. Fish Sampling Results at Harrier Meadow, 2000.

Date	Location	Species	Count	Mean Length (mm)
May 16	Station 1	*Menidia* sp.	33	59
May 16	Station 1	*Menidia* sp.	6	< 30
May 16	Station 1	*Morone americana*	1	180
May 16	Station 2	*Fundulus heteroclitus*	1	66
May 16	Station 2	*Menidia* sp.	152	< 30
May 16	Station 3	*Menidia* sp.	56	61
May 16	Station 3	*Menidia* sp.	1	< 30
June 13	Station 1	*Fundulus heteroclitus*	3	66
June 13	Station 2	*Fundulus heteroclitus*	3	< 30
June 13	Station 2	*Menidia* sp.	30	62
June 13	Station 2	*Menidia* sp.	204	< 30
June 13	Station 2	*Gasterosteus aculeatus*	3	< 30
June 13	Station 3	*Fundulus heteroclitus*	1	< 30
June 13	Station 3	*Fundulus heteroclitus*	1	64
June 13	Station 3	*Gasterosteus aculeatus*	1	< 30
June 13	Station 3	*Menidia* sp.	41	60
June 13	Station 3	*Menidia* sp.	> 200	< 30
June 13	Station 3	*Menidia* sp.	37	> 30
June 13	Station 4	*Menidia* sp.	1	< 30
June 13	Station 5	none		
June 13	Station 6	none		
June 13	Station 7	none		
July 11	Station 1	none		
July 10	Station 2	*Fundulus heteroclitus*	1	< 30
July 10	Station 2	*Menidia* sp.	10	52
July 10	Station 2	*Menidia* sp	> 400 est.	< 30
July 10	Station 3	*Fundulus heteroclitus*	2	58
July 10	Station 3	*Fundulus heteroclitus*	10	< 30
July 10	Station 3	*Menidia* sp.	30	51
July 10	Station 3	*Menidia* sp.	> 300 est.	< 30
July 11	Station 4	*Fundulus heteroclitus*	5	< 30
July 11	Station 5	*Fundulus heteroclitus*	5	< 30
July 11	Station 5	*Menidia* sp.	20	< 30
July 11	Station 8	*Fundulus heteroclitus*	20	< 30
July 11	Station 8	*Menidia* sp.	30	< 30
August 8	Station 1	none		
August 7	Station 2	*Fundulus heteroclitus*	12	49
August 7	Station 2	*Fundulus heteroclitus*	3	<30
August 7	Station 2	*Menidia* sp.	78	53
August 7	Station 2	*Menidia* sp.	>355	< 30
August 8	Station 3	*Fundulus heteroclitus*	84	48
August 8	Station 3	*Fundulus heteroclitus*	> 400 est.	> 30
August 8	Station 3	*Menidia* sp.	11	48
August 8	Station 4	*Fundulus heteroclitus*	1	39

Table 2. Fish Sampling Results at Harrier Meadow, 2000.

Date	Location	Species	Count	Mean Length (mm)
August 8	Station 5	*Fundulus heteroclitus*	3	36
August 8	Station 5	*Menidia* sp.	2	36
August 8	Station 5	*Menidia* sp.	2	< 30
August 8	Station 6	*Fundulus heteroclitus*	3	38
August 8	Station 6	*Menidia* sp.	2	< 30
September 29	Station 1	*Fundulus heteroclitus*	1	51
September 29	Station 1	*Menidia* sp.	1	37
September 25	Station 2	*Fundulus heteroclitus*	54	47
September 25	Station 2	*Fundulus heteroclitus*	30	>30
September 25	Station 2	*Menidia* sp.	50	54
September 25	Station 2	*Menidia* sp.	20	>30
September 25	Station 3	*Fundulus heteroclitus*	32	49
September 25	Station 3	*Menidia* sp.	38	55
September 25	Station 3	*Menidia* sp.	> 550 est.	< 30
September 28	Station 4	none		
September 29	Station 5	*Fundulus heteroclitus*	10	48
September 29	Station 5	*Menidia* sp.	6	43
September 29	Station 8	*Fundulus heteroclitus*	61	70
September 29	Station 8	*Fundulus heteroclitus*	40	>30
September 29	Station 8	*Fundulus heteroclitus*	5	< 30

Table 3. Fish Sampling Results at Harrier Meadow, 2001.

Date	Location	Species	Count	Mean Length (mm)
May 17	Station 1	*Fundulus heteroclitus*	49	59
May 17	Station 1	*Gasterosteus aculeatus*	17	< 30
May 17	Station 1	*Menidia sp.*	2	59
May 17	Station 2	*Fundulus heteroclitus*	22	62
May 17	Station 2	*Gasterosteus aculeatus*	31	< 30
May 17	Station 2	*Morone americana*	1	< 30
May 17	Station 3	*Fundulus heteroclitus*	41	56
May 17	Station 3	*Gasterosteus aculeatus*	> 100	< 30
May 17	Station 3	*Gobiosoma bosc*	1	43
May 17	Station 3	*Menidia beryllina*	29	52
May 17	Station 3	*Menidia* sp.	1	< 30
May 18	Station 4	none		
May 18	Station 5	none		
May 18	Station 8	none		
June 20	Station 1	*Fundulus heteroclitus*	2	< 30
June 20	Station 1	*Menidia sp.*	5	< 30
June 19	Station 2	*Dorosoma cepedianum*	13	32
June 19	Station 2	*Fundulus heteroclitus*	1	54
June 19	Station 2	*Fundulus heteroclitus*	5	< 30
June 19	Station 2	*Gasterosteus aculeatus*	1	< 30
June 19	Station 2	*Menidia beryllina*	1	72
June 19	Station 2	*Menidia sp.*	> 100	< 30
June 19	Station 2	*Morone americana*	14	38
June 19	Station 2	*Menidia sp.*	4	69
June 19	Station 2	*Morone americana*	> 100	< 30
June 19	Station 3	*Fundulus heteroclitus*	2	70
June 19	Station 3	*Menidia menidia*	2	36
June 19	Station 3	*Menidia sp.*	> 100	< 30
June 19	Station 3	*Morone americana*	1	38
June 20	Station 4	*Fundulus heteroclitus*	1	< 30
June 20	Station 8	*Fundulus heteroclitus*	18	< 30
June 20	Station 8	*Lepomis gibbosus*	1	54
July 18	Station 1	*Fundulus heteroclitus*	15	71
July 18	Station 2	*Fundulus heteroclitus*	3	49
July 18	Station 2	*Menidia beryllina*	25	53
July 18	Station 2	*Menidia* sp.	>100	<30
July 18	Station 2	*Morone americana*	1	45
July 18	Station 3	*Fundulus heteroclitus*	1	47
July 18	Station 3	*Menidia beryllina*	7	48
July 18	Station 3	*Morone americana*	6	53
July 18	Station 4	none		
July 18	Station 5	none		
July 18	Station 8	*Fundulus heteroclitus*	1	< 30
July 18	Station 8	*Menidia* sp.	1	< 30

Table 3. Fish Sampling Results at Harrier Meadow, 2001.

August 15	Station 1	none		
August 15	Station 2	*Fundulus heteroclitus*	16	32
August 15	Station 2	*Menidia beryllina*	50	36
August 15	Station 2	*Menidia menidia*	36	45
August 15	Station 3	*Fundulus heteroclitus*	32	49
August 15	Station 3	*Menidia beryllina*	50	32
August 15	Station 3	*Menidia menidia*	4	37
August 15	Station 3	*Menidia menidia*	4	< 30
August 15	Station 4	*Fundulus heteroclitus*	3	< 30
August 15	Station 5	none		
August 15	Station 8	none		
September 24	Station 1	*Fundulus heteroclitus*	41	55
September 24	Station 1	*Menidia beryllina*	49	42
September 24	Station 1	*Morone americana*	11	69
September 24	Station 1	*Lepomis gibbosus*	1	82
September 24	Station 2	*Fundulus heteroclitus*	12	73
September 24	Station 2	*Morone americana*	2	78
September 24	Station 2	*Menidia beryllina*	50	41
September 24	Station 2	*Menidia menidia*	73	58
September 24	Station 3	*Fundulus heteroclitus*	20	55
September 24	Station 3	*Anchoa mitchilli*	4	< 30
September 24	Station 3	*Morone americana*	3	91
September 24	Station 3	*Menidia beryllina*	50	38
September 24	Station 3	*Menidia menidia*	50	58
September 24	Station 4	*Fundulus heteroclitus*	19	51
September 24	Station 5	*Fundulus heteroclitus*	8	45
September 24	Station 8	*Fundulus heteroclitus*	4	59

Table 4. Fish Sampling Results at Harrier Meadow, 2002.

Date	Location	Species	Count	Mean Length (mm)
May 21	Station 1	*Fundulus heteroclitus*	37	53
May 21	Station 1	*Gasterosteus aculeatus*	14	17
May 21	Station 1	*Menidia beryllina*	25	52
May 21	Station 2	*Fundulus heteroclitus*	47	57
May 21	Station 2	*Gasterosteus aculeatus*	1	14
May 21	Station 2	*Menidia beryllina*	7	57
May 21	Station 3	*Gasterosteus aculeatus*	33	24
May 21	Station 3	*Menidia beryllina*	50	56
May 21	Station 3	*Menidia beryllina*	86	> 30
May 21	Station 4	none		
May 21	Station 5	none		
May 21	Station 8	none		
June 26	Station 1	*Fundulus heteroclitus*	1	75
June 26	Station 1	*Fundulus heteroclitus*	>100	< 30
June 26	Station 1	*Menidia sp.*	>100	< 30
June 26	Station 2	*Menidia beryllina*	49	58
June 26	Station 2	*Menidia menidia*	3	71
June 26	Station 3	*Fundulus heteroclitus*	4	40
June 26	Station 3	*Fundulus heteroclitus*	102	< 30
June 26	Station 3	*Menidia beryllina*	70	28
June 26	Station 3	*Menidia beryllina*	340	<30
June 26	Station 3	*Menidia menidia*	3	30
June 26	Station 4	*Fundulus heteroclitus*	1	40
June 26	Station 4	*Fundulus heteroclitus*	6	< 30
June 26	Station 4	*Menidia beryllina*	1	57
June 26	Station 4	*Menidia menidia*	1	49
June 26	Station 5	none		
June 26	Station 8	none		
July 30	Station 1	*Fundulus heteroclitus*	50	53
July 30	Station 1	*Menidia beryllina*	2	56
July 30	Station 2	*Fundulus heteroclitus*	50	52
July 30	Station 2	*Fundulus heteroclitus*	>100	< 30
July 30	Station 2	*Menidia beryllina*	22	51
July 30	Station 2	*Menidia* sp.	100	>30
July 30	Station 2	*Menidia menidia*	3	48
July 30	Station 3	*Fundulus heteroclitus*	50	46
July 30	Station 3	*Menidia menidia*	50	50
July 30	Station 3	*Menidia menidia*	29	>30
July 30	Station 4	none		
July 30	Station 5	none		
July 31	Station 8	*Fundulus heteroclitus*	51	57
July 31	Station 8	*Fundulus heteroclitus*	17	>30

Table 4. Fish Sampling Results at Harrier Meadow, 2002.

August 19	Station 1	*Fundulus heteroclitus*	50	37
August 19	Station 1	*Menidia beryllina*	1	33
August 19	Station 2	*Fundulus heteroclitus*	50	35
August 19	Station 2	*Fundulus heteroclitus*	25	>30
August 19	Station 2	*Fundulus heteroclitus*	50	<30
August 19	Station 2	*Menidia beryllina*	51	35
August 19	Station 2	*Menidia beryllina*	80	>30
August 19	Station 2	*Menidia menidia*	1	33
August 19	Station 2	*Menidia* sp.	2	43.5
August 19	Station 2	*Menidia majalis*	1	50
August 19	Station 3	*Fundulus heteroclitus*	51	37
August 19	Station 3	*Menidia beryllina*	7	33
August 20	Station 4	none		
August 20	Station 5	none		
August 20	Station 8	*Fundulus heteroclitus*	5	49
September 23	Station 1	*Fundulus heteroclitus*	50	64
September 23	Station 1	*Fundulus heteroclitus*	>150	>30
September 23	Station 1	*Menidia beryllina*	8	37
September 23	Station 2	*Fundulus heteroclitus*	50	67
September 23	Station 2	*Menidia beryllina*	50	35
September 23	Station 2	*Menidia beryllina*	50	>30
September 23	Station 2	*Menidia beryllina*	35	<30
September 23	Station 3	*Fundulus heteroclitus*	50	55
September 23	Station 3	*Menidia beryllina*	50	34
September 23	Station 3	*Menidia beryllina*	14	>30
September 23	Station 3	*Menidia* sp.	39	<30
September 23	Station 3	*Menidia menidia*	1	36
September 24	Station 4	none		
September 24	Station 5	*Fundulus heteroclitus*	1	33
September 24	Station 8	*Fundulus heteroclitus*	10	48
September 24	Station 8	*Menidia beryllina*	6	39

Table 5. Fishes Collected at Harrier Meadow 1999-2003

Family	Species	Common name
Anguillidae	*Anguilla rostrata*	American eel
Clupeidae	*Dorosoma cepedianum*	gizzard shad
Engraulidae	*Anchoa mitchilli*	bay anchovy
Cyprinidae	*Cyprinus carpio*	common carp
Cyprinidontidae	*Fundulus heteroclitus*	mummichog
Cyprinidontidae	*Fundulus majalis*	striped killifish
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish
Atherinidae	*Menidia beryllina*	inland silverside
Atherinidae	*Menidia menidia*	Atlantic silverside
Gasterosteidae	*Gasterosteus aculeatus*	threespine stickleback
Moronidae	*Morone americana*	white perch
Centrarchidae	*Lepomis gibbosus*	pumpkinseed
Gobiidae	*Gobiosoma bosci*	naked goby

Table 6. Summary of Salinity and Temperature Records for Fish Collections at Harrier Meadow Impoundments

Date	Salinity (ppt)	Temperature (oC)
May-00	7-9	
May-01	8-10	
May-02	10-11	16-22
June-00	8	
June-01	6-7	27-38
June-02	8-10	33-35
July-00	10-11	
July-01	6	28-29
July-02	18	32-34
August-99	14-16	
August-00	5-7	
August-01	10	35
August-02	15-18	29-35
September-99	6-8	
September-00	5-10	
September-01	14-15	24-25
September-02	16-17	29-31

Figure 2. Abundance of *Fundulus* and *Menidia* at Harrier Meadow Impoundments

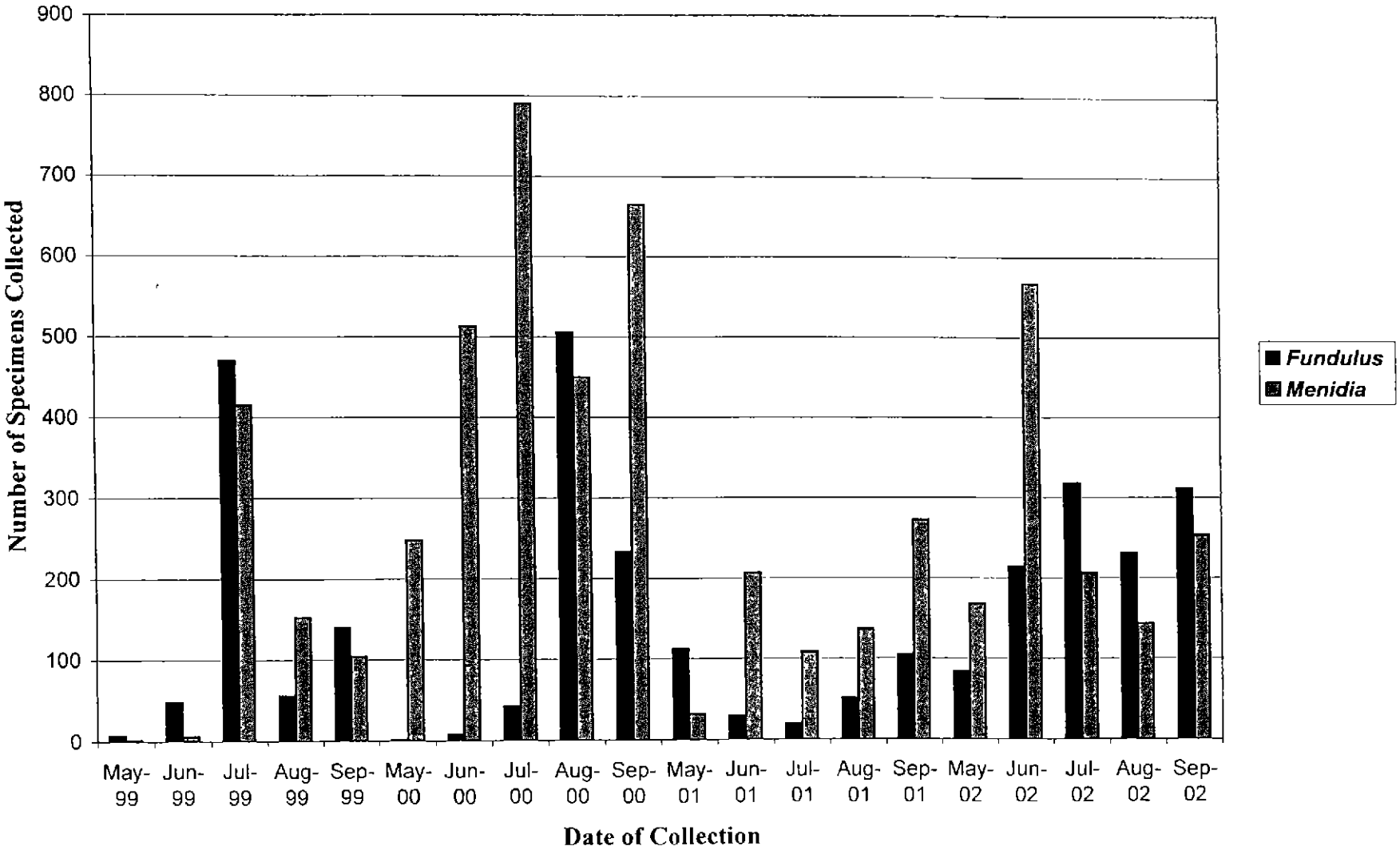


Figure 3. Mean Length of Primaily Mature *Fundulus* and *Menidia* Collected at Harrier Meadow Impoundments

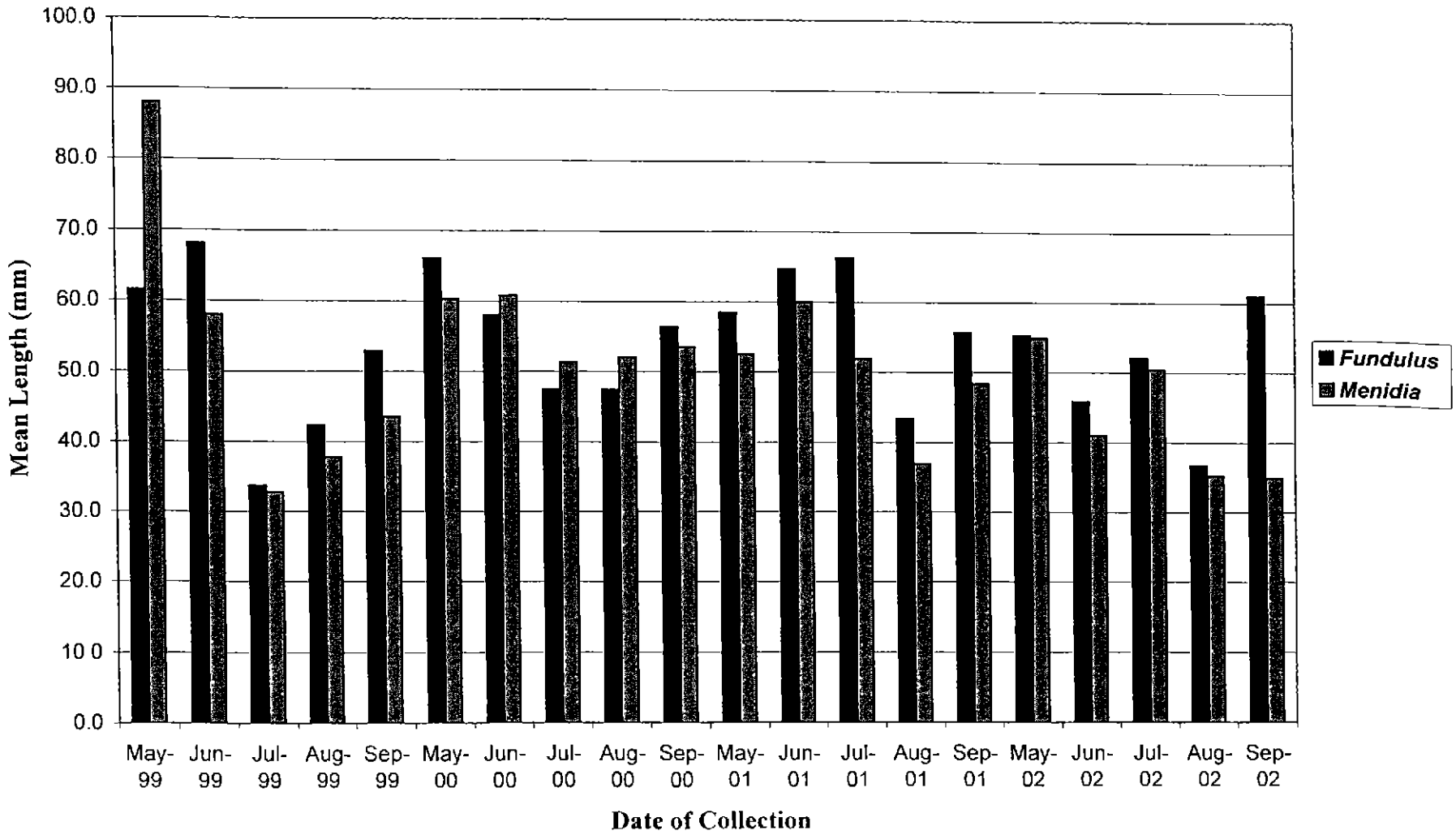




Figure 1

Sampling Stations for Monitoring Fish at Harrier Meadow Wetland Mitigation Site

NEW JERSEY MEADOWLANDS COMMISSION

fish sampling locations

site boundaries

200 0 200 400 600 Feet

map prepared November 7, 2003

APPENDIX M:

Monitoring of Benthic Invertebrates at the Harrier Meadow Wetlands Mitigation Site

Monitoring of Benthic Invertebrates at the Harrier Meadow Wetlands Mitigation Site

Ross M. Feltes, Ph.D.

Introduction

Benthic invertebrates are a trophic connection between the detritus and vertebrates. They cycle organic matter by breaking down detritus and mixing sediment. These organisms provide food for fish, birds, and other predators acting as a link between primary producers and higher order consumers. Benthic invertebrates make up a significant portion of the faunal diversity in a salt marsh (Levin et al. 1997). They are numerically important and their diversity allows for a variety of assemblages in tidal salt marshes. Density and taxonomic composition reflect the functioning of the system. Some taxa are indicative of conditions at a marsh. Benthic macrofauna are widely used as indicators of habitat condition in estuarine monitoring (Alden et al. 1997). A thriving benthic community is necessary to support the fish and bird populations that are goals of the Harrier Meadow Wetland Mitigation Site.

Methods

Benthic invertebrates were sampled using 3.8 cm diameter acrylic core samplers. The top 5 cm of sediment was removed from each core and then fixed in 20% formalin in the field. After fixation for approximately one week, the samples were washed through a 300-μm sieve. The samples were then preserved and stained with rose bengal in 70% ethanol. Samples were sorted and identified with the aid of dissecting microscopes. The level of taxonomic resolution varied with the taxa. Some taxa such as Nematoda and Ostracoda make significant percentages of the specimens in the samples, but highly specialized techniques are necessary for identification within these groups. Specimens identified only to a higher or more inclusive taxonomic rank were thought to be distinct from other recorded subordinate taxa.

Nine stations were established in 1999 at Harrier Meadow for the purpose of collecting benthic core samples. These stations represented varying aquatic habitats at the site including tidal creeks (stations 7, 8, and 9), mudflats (4 and 5), impoundments (10, 11, and 12), and high marsh pools (14). Preliminary benthic core samples were taken in taken in January, March, April, June, August, and November. Three replicate samples were collected at each station for a total of 27 samples. Stations 4, 8, and 10 were considered redundant and dropped from further monitoring. Six stations were sampled in 2000, 2001, and 2002 (Figure 1). Benthic cores were collected at Harrier Meadow once per month in June, August, and November in 2000, 2001, and 2002. These months were determined to be the periods of relatively high benthic abundance. Four (4) replicate samples were collected at each station for a total of twenty-four (24) samples in each of these years.

The surface area of a core sample is $\pi r^2 = 3.1416 \times (1.9cm)^2 = 11.3\ cm^2$ or $1/885.0\ m^2$. The mean number of organisms in replicates for a collection is multiplied by 885 to estimate the number of organisms per m^2. The total density was calculated as the sum of the individual densities of each taxa.

Results

Thirty-two taxa were distinguished in the sediment samples taken at Harrier Meadow (Table 1). Foraminifera were noted in the collections, but only invertebrate metazoans were considered here. There was not a significant change in the number of taxa taken in each of the years monitored.

Table 2 gives a summary of the monthly collections from 1999 through 2001 including the number of taxa, the estimated density of organisms, the three most abundant major taxa in order of abundance, and their combined percentage of the total density. Species richness ranged from 14 to 27 taxa during the collection periods, with the lowest occurring in August 1999 and November 2000 and the greatest diversity occurring in August 2001(Figure 2). The estimated total densities of all benthic organisms for a monthly collection ranged from 103,656 individuals m^{-2} in June 2000 to 281,024 individuals m^{-2} in June 2001 (Figure 3). There is no correlation between either the number of taxa or total density of organisms and particular months of the year over the monitoring effort.

The sum of the three most abundant taxa make up 74% to 91 % of the total abundance of all organisms in a collection period. Nematodes dominate six of the nine collection periods (Figure 4 representing up to 76% of the abundance. Ostracods had the highest abundance of major taxa in three of the collection periods. They were 58% of the organisms collected in November 2001. The ostracods taken at the site are in the Superorder Podocopa (per. comm. Louis Kornicker 2003). Other major taxa that rank among the top three in density for at least one month are Polychaeta, Oligochaeta, Insecta, and Copepoda. The insects collected are in the orders Coleoptera, Collembola, Diptera, and Hemiptera. Six families of dipterans were recognized. Chironomid larvae (Diptera) made up the vast majority of the insects collected in the benthic samples. Probably all belonged to a single species in the *Chironomus decorus*-group.

The number of taxa did not differ markedly between habitats, except for the high marsh station in some months (Figure 5). The density of benthic invertebrates in the samples was significantly greater at the station on the mudflat bordering the Site (Figure 6). Some months the high marsh station was dry and no collections were made. There was a lack of correspondence between densities of organisms collected at the impoundments and in the tidal creeks from month to month.

The relative abundance of the major taxa collected in the impoundments (Figure 7) was significantly different for the Site considered as a whole. Major changes in the abundance of taxa occurred from collection period to collection period, such as polychaetes and

insects from June to August of 1999. Such dramatic changes are documented in other studies. The ostracods had very high densities in August 2000 and in all three collections in the impoundments during 2001. Relatively fewer nematodes were present in the samples from the impoundments.

Discussion

The total number of taxa collected at Harrier Meadow, 32, is within the range documented in other surveys, such as 24 in a study in Virginia (Havens et al. 1995), 32 in a North Carolina study (Cammen 1979), and 41 from 14 sampled marshes in North Carolina (Sacco et al. 1994). Angradi et al. (2001) identified 71 taxa from a brackish marsh in southern New Jersey. Thirty-two of these were identified taxa of insects. Differences in environmental parameters, especially salinity, limit comparisons between studies. The collection methods and sieve mesh size for retaining specimens varies between studies and results in the capture of different taxa, especially affecting the smaller organisms. Obviously the degree of taxonomic resolution in identification of specimens has a great bearing on the number of taxa recognized and thus conclusions about diversity and ecological relationships. The degree of taxonomic resolution certainly differed between studies. Like other studies nematodes and oligochaetes are very abundant, but taxonomic resolution requires specialized examination and is very seldom performed. This is also true for ostracods.

Different methods of collection and processing result in even more striking disparities in densities reported from studies. Though this was essentially a survey of macrofauna, the 300μm sieve used in this study captures some organisms considered as meiofauna, but meiofauna taxa is underrepresented here. The range of densities of 103,656 individuals m^{-2} to 281,024 individuals m^{-2} collected in this study is high compared to other studies on macrofauna, usually restricted to organisms taken in 500μm sieves. Other studies include collections from a North Carolina marsh which had a density of benthic invertebrates of 26,000 individuals m^{-2} (Levin and Hewitt 1998) or a Georgia study where Kneib (1984) reported macrofauna densities from 1.9×10^4 to 1.8×10^5 individuals m^{-2}. The density of organisms observed at the Site would be expected to be relatively high compared to other macrofauna studies, given the collections in this study took some organisms often considered meiofauna. Meiofauna may have a density up to between 10^6 and 10^7 m^{-2} individuals m^{-2} (Kneib 1984; Kreeger and Newell 2000). Angradi et al. (2001) reported mean densities in a New Jersey *Spartina* marsh of 96,885 individuals m^{-2} and 81,891 individuals m^{-2} in *Phragmites* marsh using 300μm sieves.

There are differences in the understanding of how long it takes for a constructed or enhanced marsh to have the diversity and density of infauna of a natural marsh. Constructed salt marshes are readily occupied by invertebrates (Fell et al 1991). Havens et al. (1995) study concluded a four year old constructed marsh in Virginia was similar to a natural marsh. Havens et al. (2002) re-examined these same tidal marshes 12 years after construction and found the benthic communities had not changed since they previously studied the constructed and natural marshes, thus they were still similar.

Sacco et al. (1994) made a comparison between natural and artificially established marshes in North Carolina. Artificially established marshes ranged in age from 1to17 years. Natural and artificial marshes had similar component organisms but total densities and densities of the different trophic groupings were lower in the created marshes. Organic content of the natural marsh was nearly twice that of created march and this is thought to be associated with higher density of organisms in the natural marsh. A study in marshes along the Texas coast (Minello and Zimmerman 1992) showed new marshes to have less organic matter and lower densities of macro-invertebrates. Some macroinvertebrates returned to a Connecticut restoration site within 5 years while others were expected to take decades to become established at natural densities. A comparison of a four and an eight year old marsh established on dredged material in South Carolina showed a similar invertebrate fauna, though the older marsh had a much higher density of organisms (LaSalle et al. 1991). Invertebrate recovery does not directly correspond to the rate of vegetation recovery (Warren et al. 2002).

In this study nematodes, ostracods, polychaetes, oligochaetes, chironomid insect larvae, and copepods dominated the collections and are ranked in this order relative to their contribution to the total abundance in all collections made at the Site. The abundance of the top three major taxa reported in Angradi et al. (2001), oligochaetes, polychaetes, and nematodes, made up 81 % and 91% of the total density for the *Spartina* and *Phragmites* marshes they examined, respectively. Kneib (1984) reported nematodes as the dominant taxa in salt marshes in both a macrofaunal study in Georgia and a meiofauna study in South Carolina. Ostracods ranked second in one of the macrofauna stations in the Georgia study. Natural marshes with higher salinity have much of the abundance and biomass made up by polychaetes, especially Capitellidae. Polychaetes make up a lesser percentage in constructed marshes Cammen (1976). Collections from a North Carolina *Spartina alterniflora* salt marsh with salinity of 22-36 ppt had 32 taxa, of which 19 were polychaetes. Density ranged from 2,200 to 15,500 individuals m^{-2}. *Nereis succinea*, *Streblospio benedicti*, and Capitellidae, followed by Oligochaeta dominated that community. Together they accounted for 96% of the total number of individuals. Other studied marshes in North Carolina were dominated by a few species (Cammen 1979). In this study the maximum density of polychaetes was 58,115individuals m^{-2}. Again the finer mesh sieve used in this study captured more organisms than some other studies. *Nereis succinea, Manayunkia aestuarina, Streblospio benedicti*, *Capitella capitata*, and *Fabricia* are cited as being the most common polychaetes in salt marshes (Cammen 1976, 1979; Havens et al. 1995; Havens et al. 2002; Kneib 1984; Rader 1984). *Manayunkia aestuarina, Nereis, Capitella*, and *Hobsonia florida* were the significant representatives of Polychaetae at the Site. In August 2000 21% of the total abundance of benthic invertebrates for the Site was made up of *Manayunkia aestuarina* and these were collected only at the mudflat station, with an estimated density at that station of 273,244 individuals m^{-2}. This was the dominant polychaete in a study by Angradi et al. (2001) at an oligohaline/mesohaline study site on the Mullaca River, New Jersey. *Manayunkia aestuarina* is a common dominant or subdominant member of benthic assemblages. It is tolerant of a wide range of salinities and has very extensive geographic range. Bell's (1982) study in South Carolina showed populations were maintained at least at densities of approximately 1,500 individuals m^{-2} through out the year, with several peaks in

numbers. Peaks in May-June and August noted in Bell (1982) coincide with peaks in densities observed in the present study. She notes the densities reported are an order of magnitude lower than reported for England. The present study has values from most collection periods comparable to what she refers to in England.

Oligochaetes usually are less abundant than polychaetes in mesohaline or more saline habitats. Oligochaetes are a major part of freshwater benthic communities (Cuomo and Zinn 1997). Sacco et al. (1994) found Oligochaetes were the most abundant organism collected in sampling from 14 North Carolina *Spartina alterniflora* salt marshes, making up 35% of total density. Those marshes generally had higher salinities than observed at Harrier Meadow. During three of the collection periods at the Site oligochaetes contributed approximately 12% of the abundance. During other collection periods they were less abundant.

The insect community of intertidal pools in another New Jersey salt marsh consisted of twenty species, only eight of which appeared with regularity. *Trichocorixa* (Corixidae) was the most numerous insect followed by *Chironomus* sp. (Campbell and Denno 1978). The diversity of insects is less at Harrier Meadow. *Chironomus* was often the only insect taken in collections at the Site and sometimes in large numbers, while Corixidae were only occasionally taken here.

Angradi et al. (2001) found elevation, salinity, and vegetation type are major factors controlling the faunal composition. They found abundance and composition of the benthic fauna varied with distance from vegetation. Variation in the macro and microtopography, as in a *Spartina alterniflora* marsh adds to macro and meiofaunal abundance and diversity. This is added to by the burrowing activity of *Uca* species (Bell et al. 1978). These are generally lacking in the habitats sampled at Harrier. Most of the sampling stations at the Site lack topographic variation and vegetation, yet the density of organism was relatively high. The highest density of organisms in stations sampled was in the mudflat off the southern tip of the mitigated area. Microalgae production can be high at the surface of mudflats and numerous salt marsh fauna ingest benthic microalgae (Sullivan and Currin 2000). The relative abundance of taxa varied widely from one collection period to another. If diversity and abundance are used to measure functioning of a system, then the monitoring conducted at Harrier Meadow suggests the open water habitats within the Site are contributing to the system that supports fish and bird populations stated as goals of the restoration plan.

Literature Cited

Alden III, R. W., S. T. Weisberg, J. A. Ranasinghe and D. M. Dauer. 1997. Optimizing temporal sampling strategies for benthic environmental monitoring programs. Marine Pollution Bulletin 34(1):913-922.

Angradi, T. R., S. M. Hagan and K. W. Able. 2001. Vegetation type and the intertidal macroinvertebrate fauna of a brackish marsh: *Phragmites* vs. *Spartina*. Wetlands. 21(1):75-92.

Bell, S. S.1982. On the population biology and meiofaunal characteristics of *Manayunkia aestuarina* (Polychaeta: Sabellidae: Fabricinae) from a South Carolina salt marsh. Estuaries, Coastal and Shelf Science 14(2):215-221.

Bell, S. S., M. C. Watzin and B. C. Coull. 1978. Biogenic structure and its effect on the spatial heterogeneity of meiofauna in a salt marsh. J. Exp. Mar. Biol. Ecol. 35(2):99-107.

Cammen, L. M. 1976. Abundance and production of macroinvertebrates from natural and artificially established salt marshes in North Carolina. American Midland Naturalist. 96(2): 487-493.

Cammen, L. M. 1979. The macro-infauna of a North Carolina salt marsh. American Midland Naturalist 102(2):244-253.

Campbell, B. C. and R. F. Denno. 1978. The structure of the aquatic insect community associated with intertidal pools on a New Jersey salt marsh. Ecological Entomology. 3:181-187.

Fell, P. E., K/ A. Murphy, M. A. Peck and M. L. Recchia. 1991. Reestablishment of *Melampus bidentatus* (Say) and other macroinvertebrates on a restored impounded tidal marsh: Comparison of populations above and below the impoundment dike. Journal of Experimental Marine Biology and Ecology 152:33-48.

Havens, K. J., L. M. Carnell and J. G. Bradshaw. 1995. An assessment of ecological conditions in a constructed tidal marsh and two natural reference tidal marshes in coastal Virginia. Ecological Engineering 4:117-141.

Havens, K. J., L. M. Varnell and B. D. Watts. 2002. Maturation of a constructed tidal marsh relative to two natural reference tidal marshes over 12 years. Ecological Engineering 18:305-315.

Kneib, R. T.1984. Patterns of invertebrate distribution and abundance in the intertidal salt marsh: causes and question. Esturaries 7(4A):392-412.

Kreeger, D. A. and R. I. Newell. 2000. Trophic complexity between producers and invertebrate consumers in salt marshes. Pages 187-220 *in* M. P. Weinstein and D. A. Kreeger. Concepts and controversies in tidal marsh ecology. Kluwer Academic Pub. Dordrecht, The Netherlands.

LaSalle, M. W., M. C. Landin, and J. G. Sims.1991. Evaluation of the flora and fauna of a *Spartina alterniflora* marsh established on dredged material in Winyah Bay, South Carolina. Wetlands 11:191-208.

Levin, L.A., D. Talley, T. Talley, A. Larson, A. Jones, G. Thayer, C. Currin, and C. Lund. 1997. Restoration of *Spartina* marsh function: An infaunal perspective. Pages 190-194 *in* K. B. Macdonald and F. Weinmann, eds. Wetland and Riparian Restoration: Taking a Broader View. EPA 910-97-007. *Proceedings of the Society for Ecological Restoration International Conference,* Seattle.

Levin, L., T. Talley and J. Hewitt. 1998. Macrobenthos of *Spartina foliosa* (Pacific Cordgrass) saltmarshes in southern California: Community structure and comparison to a Pacific mudflat and a *Spartina alterniflora* (Atlantic Smooth Cordgrass) marsh. Estuaries 21:129-144.

Minello, T. J. and R. J. Zimmerman. 1992. Utilization of natural and transplanted Texas Salt marshes by fish and decapod crustaceans. Marine Ecology Progress Series 90:273-285.

Rader, D. N. 1984. Salt-marsh benthic invertebrates: small-scale patterns of distribution and abundance. Estuaries 7(4A):413-420.

Sacco, J. N., E. D. Seneca, and T. R. Wentworth. 1994. Infaunal community development of articially established salt marshes in North Carolina. Estuaries 17(2):489-500.

Sullivan, M. J. and C. A. Currin. 2000. Community structure and functional dynamics of benthic microalgae in salt marshes. Pages 81-106 *in* M. P. Weinstein and D. A. Kreeger. Concepts and controversies in tidal marsh ecology. Kluwer Academic Pub. Dordrecht, The Netherlands.

Warren, R. S, P. E. Fell, R. Rozsa, A. H. Brawley, A. C. Orsted, E. T. Olson, V. Swamy, W. A. Niering. 2002. Salt marsh restoration in Connecticut: 20 years of science and management. Restoration Ecology 10(3):497-513.

Table 1. Benthic Invertebrate Taxa Collected at Harrier Meadow 1999-2001

Phylum	Class	Order	Family	Genus species
Cnidaria	Anthozoa			
Platyhelminthes	Turbellaria			
Nemertea				
Nematoda				
Mollusca	Gastropoda			
Annelida	Polychaeta	Capitellida	Capitellidae	*Capitella* sp.
Annelida	Polychaeta	Orbiniida	Orbiniidae	
Annelida	Polychaeta	Phyllodocida	Nereidae	*Nereis* sp.
Annelida	Polychaeta	Sabellida	Sabellidae	*Manayunkia aestuarina*
Annelida	Polychaeta	Spionida	Spionidae	*Streblospio benedicti*
Annelida	Polychaeta	Spionida	Spionidae	
Annelida	Polychaeta	Terebellida	Ampharetidae	*Hobsonia florida*
Annelida	Polychaeta			
Annelida	Oligochaeta			
Arthropoda	Arachnida	Acari		
Arthropoda	Ostracoda			
Arthropoda	Copepoda			
Arthropoda	Malacostraca	Amphipoda	Gammaridae	
Arthropoda	Malacostraca	Decapoda	Palaemonidae	*Palaemonetes pugio*
Arthropoda	Malacostraca	Decapoda		
Arthropoda	Malacostraca	Isopoda	Corophiidae	*Corophium* sp.
Arthropoda	Malacostraca	Isopoda	Cyathuridae	*Cyathura polita*
Arthropoda	Insecta	Coleoptera		
Arthropoda	Insecta	Collembola	Entomobryidae	*Anurida maritima*
Arthropoda	Insecta	Diptera	Ceratopogonidae	
Arthropoda	Insecta	Diptera	Chironomidae	
Arthropoda	Insecta	Diptera	Culicidae	
Arthropoda	Insecta	Diptera	Dolichopodidae	
Arthropoda	Insecta	Diptera	Ephydridae	
Arthropoda	Insecta	Diptera		
Arthropoda	Insecta	Hemiptera	Corixidae	
Arthropoda	Insecta			

Table 2. Summary of Monthly Collections of Benthic Invertebrates at Harrier Meadow, 1999-2001

date of collection	number of taxa	total density (individuals m^{-2})	most abundant major taxa	abundant major taxa as % of total
June-99	25	189226	nematodes, polychaetes (mostly *Manayunkia* and *Nereis*), and insects (mostly *Chironomus*)	73.5
August-99	14	137618	nematodes, copepods, and polychaetes (mostly *Manayunkia aestuarina*)	85.6
November-99	20	258322	nematodes, oligochaetes, and polychaetes (mostly *Capitella*)	89.5
June-00	19	103656	nematodes, polychaetes (mostly *Manayunkia* and *Hobsonia*), insects (mostly *Chironomus*)	78.0
August-00	21	220476	ostracods, polychaetes (mostly *Manayunkia aestuarina*), and nematodes	79.5
November-00	14	173770	nematodes, oligochaetes, and insects	91.4
June-01	21	281024	ostracods, nematodes, and oligochaetes	76.9
August-01	27	225941	nematodes, ostracods, and polychaetes	83.6
November-01	18	251221	ostracods, nematodes, and polychaetes	90.1

Figure 2. Number of Taxa Collected at Harrier Meadow

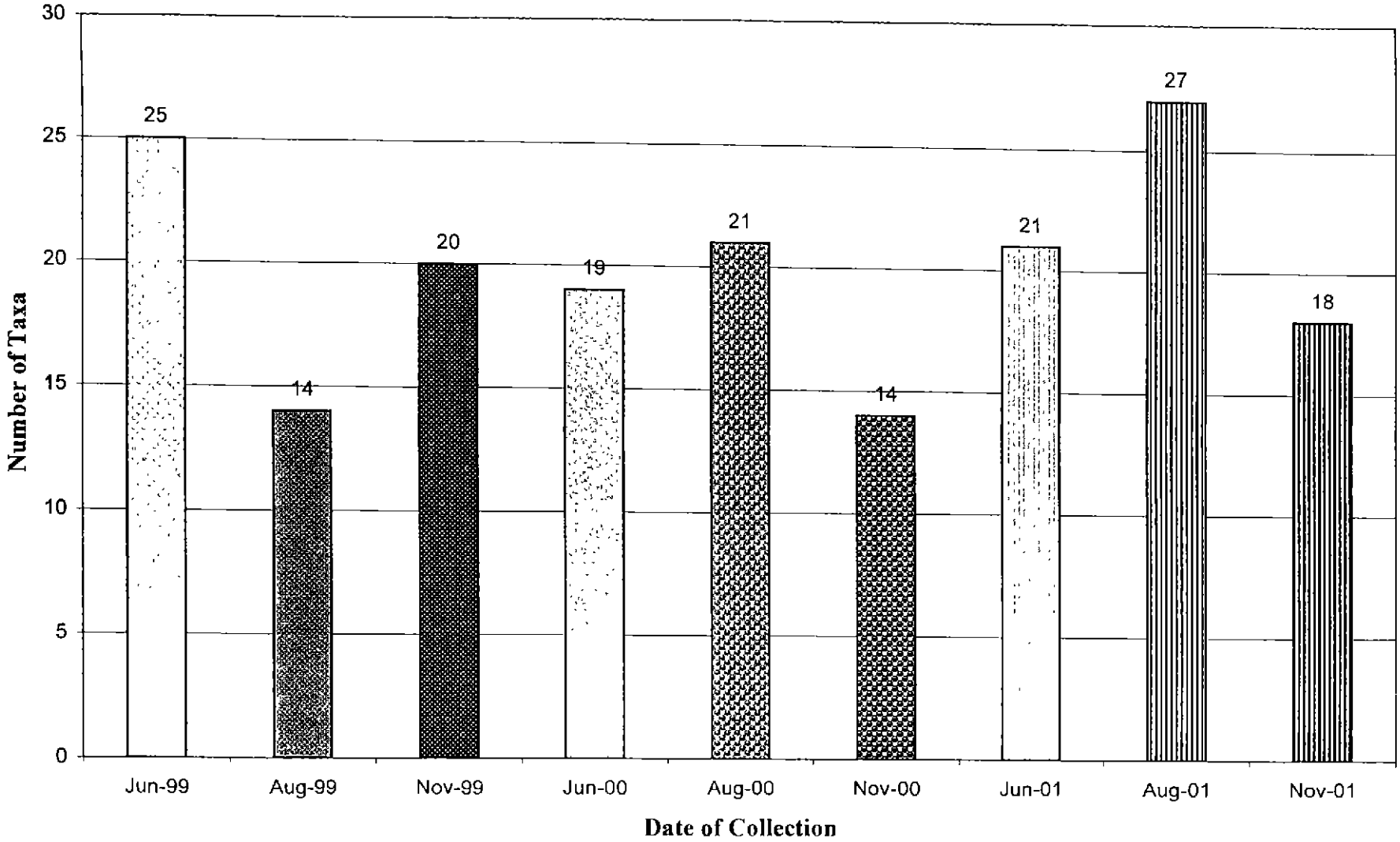


Figure 3. Total Density of Benthic Invertebrates Collected at Harrier Meadow

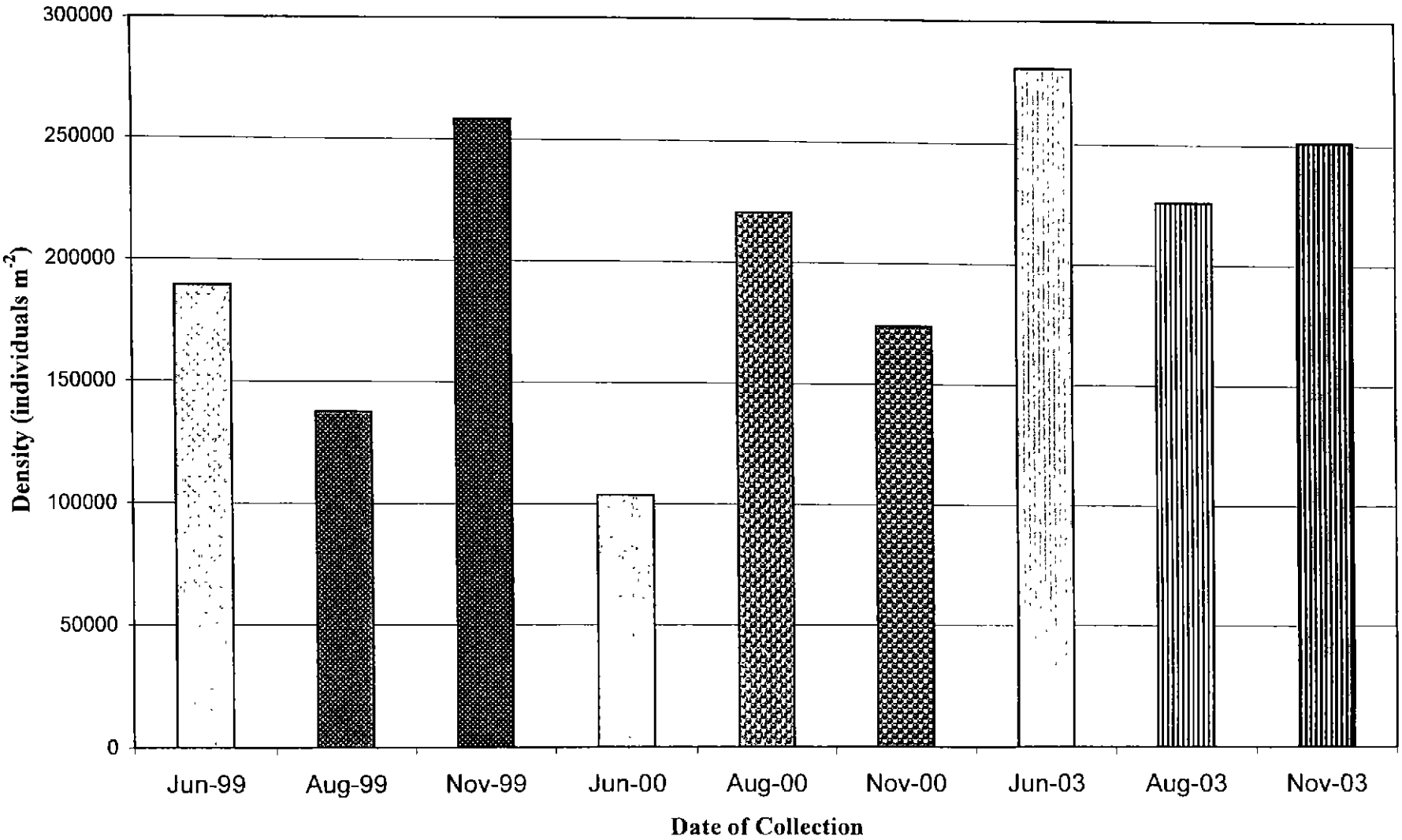


Figure 4. Relative Abundance of Benthic Invertebrates Collected at Harrier Meadow

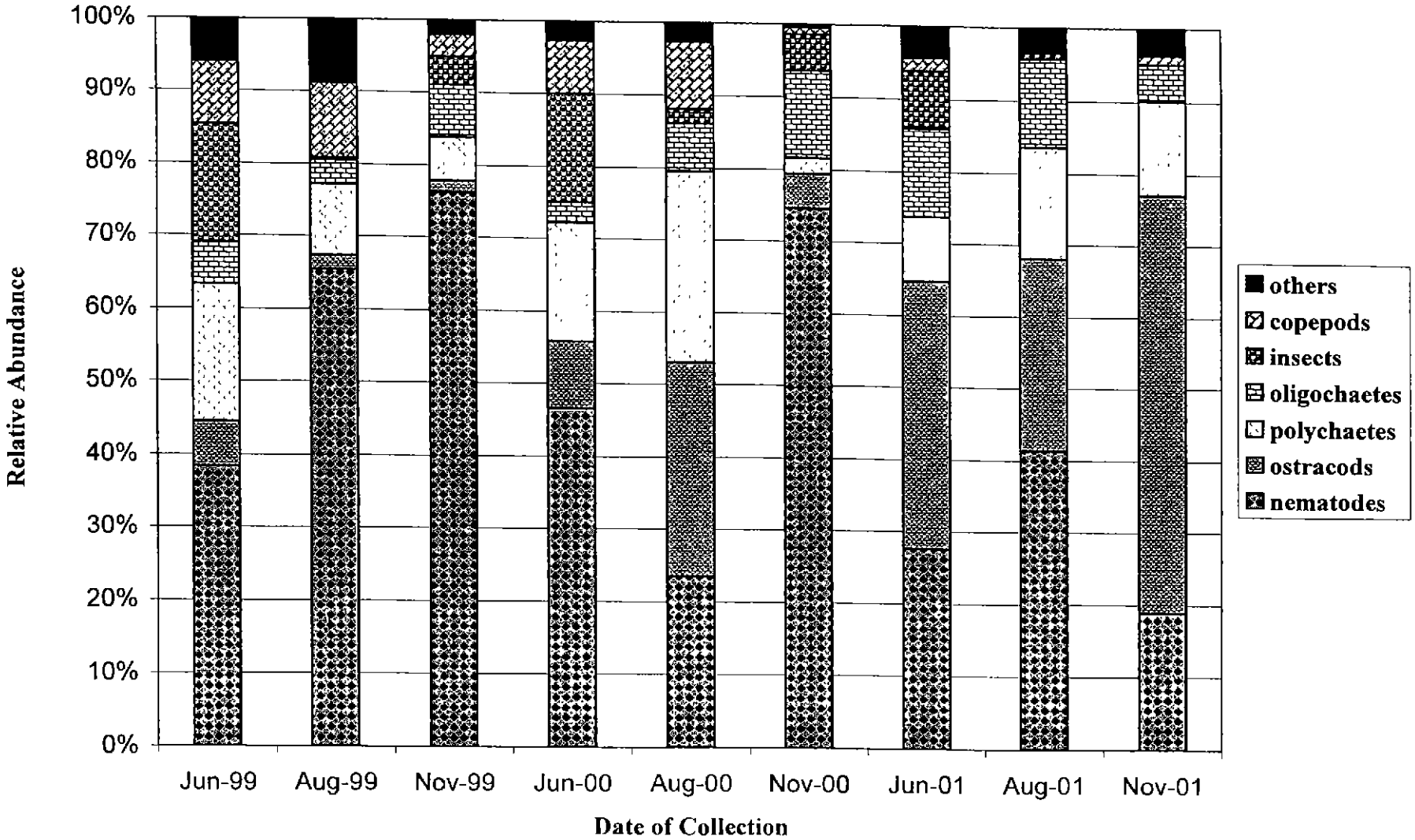


Figure 5. Number of Benthic Invertebrate Taxa Collected at Harrier Meadow

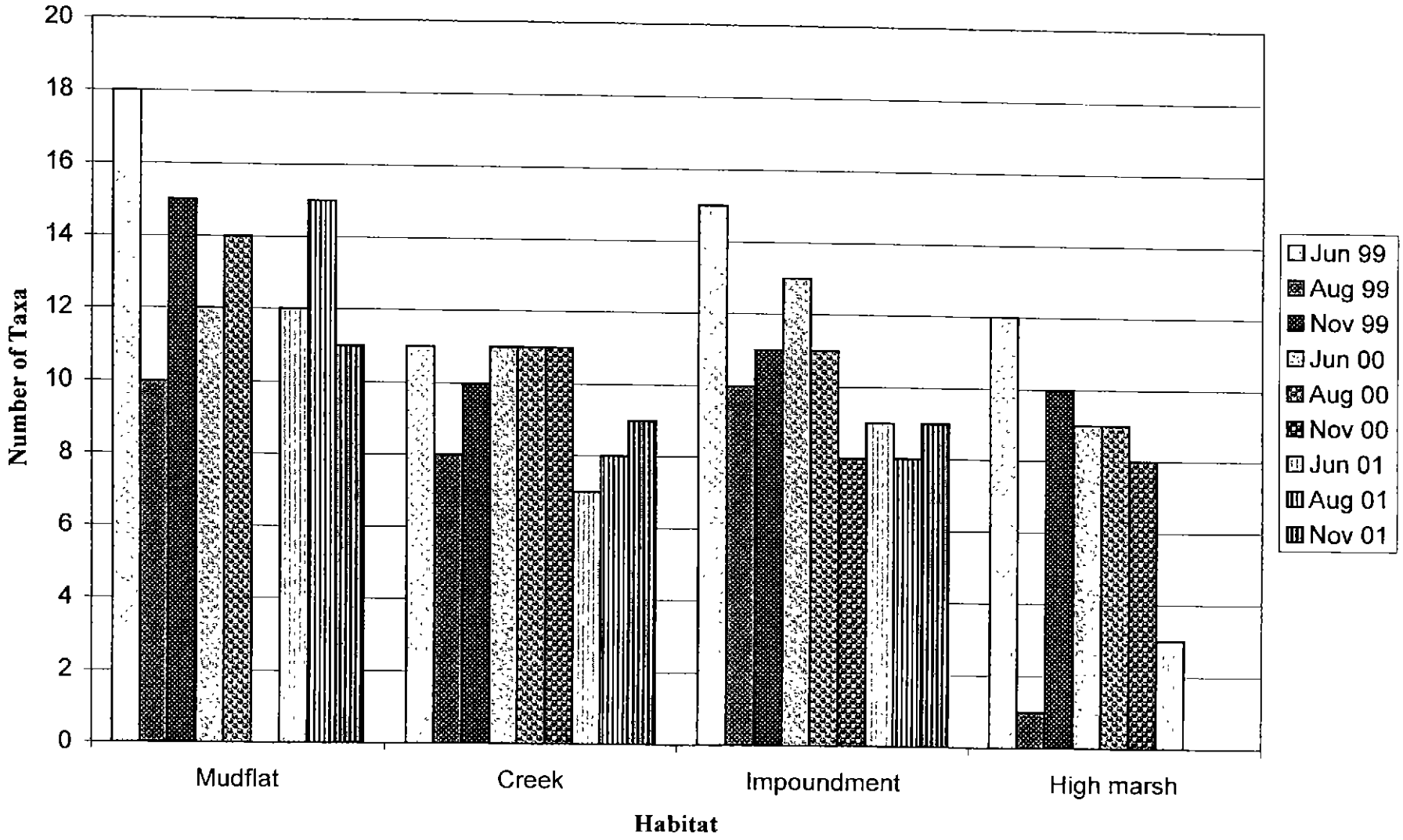


Figure 6. Total Mean Abundance of Benthic Invertebrates Collected at Harrier Meadow

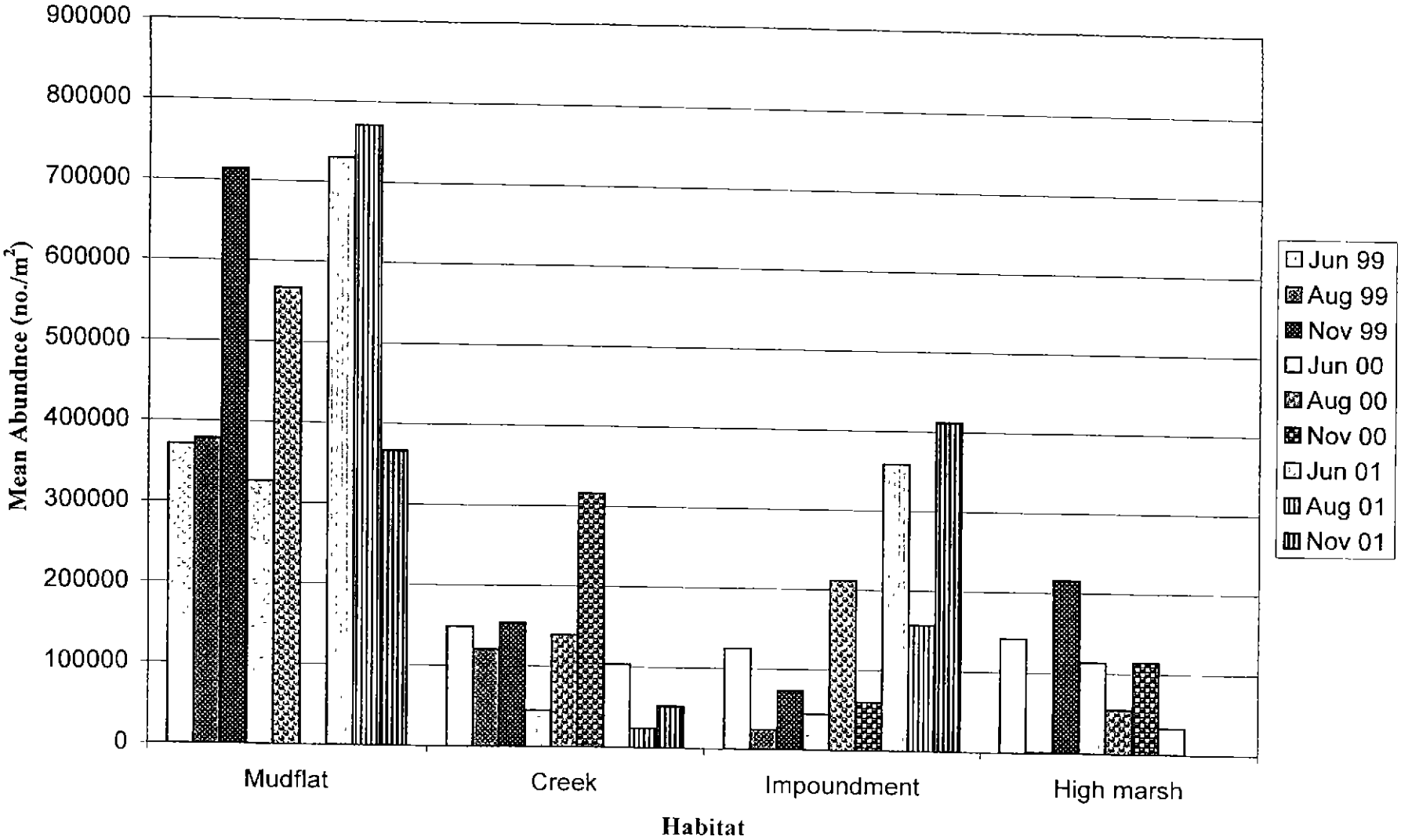


Figure 7. Relative Abundance of Benthic Invertebrates Collected at Harrier Meadow Impoundments

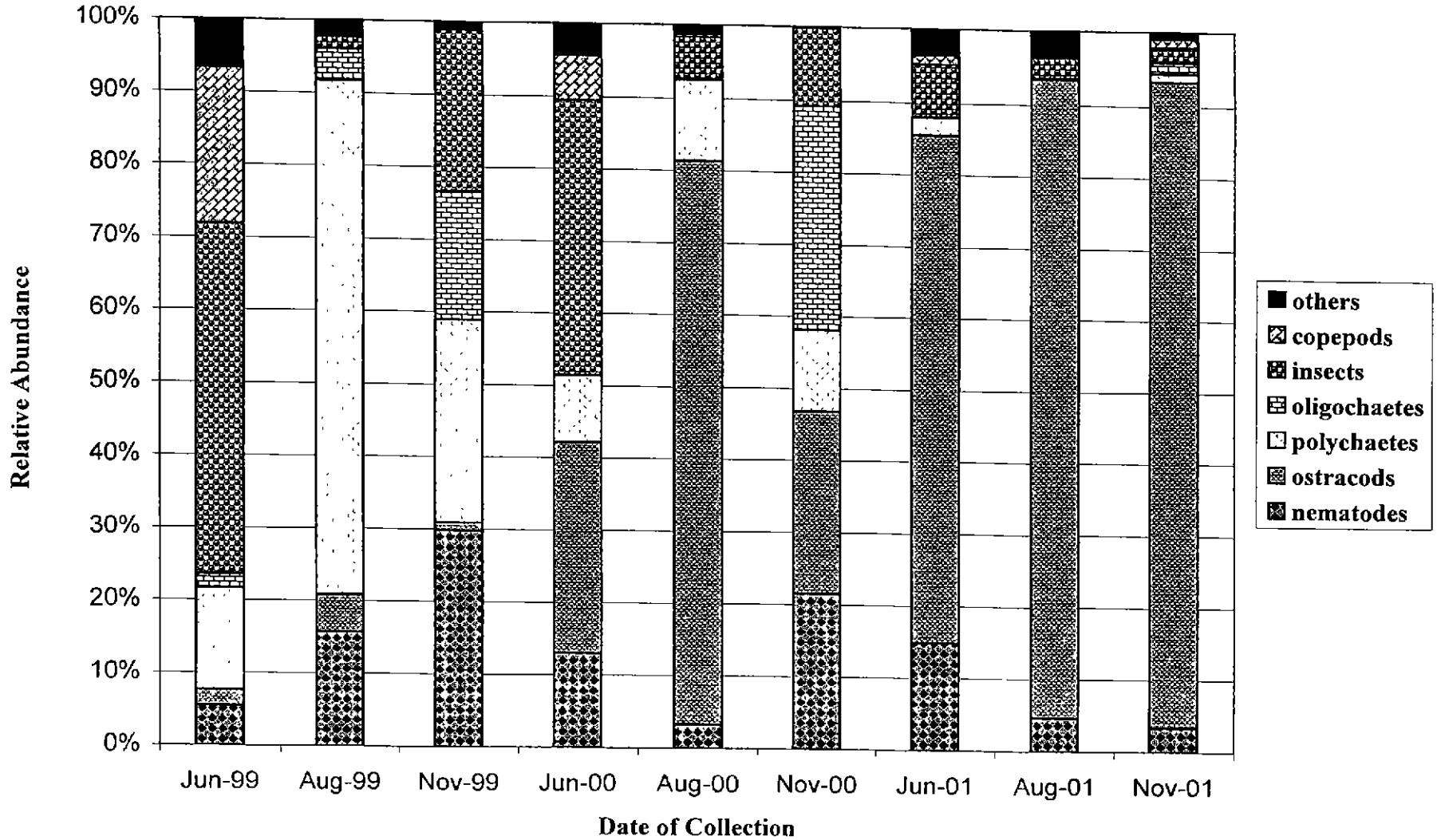




Figure 1

Sampling Stations for Monitoring Benthic Invertebrates at Harrier Meadow Wetland Mitigation Site

NEW JERSEY MEADOWLANDS COMMISSION

benthic sampling locations

site boundaries

200 0 200 400 600 Feet

map prepared November 7, 2003

APPENDIX N:

Survey of Fiddler Crabs at the Harrier Meadow Wetlands Mitigation Site

Survey of Fiddler Crabs
at the Harrier Meadow Wetlands Mitigation Site

Ross M. Feltes, Ph.D.

Introduction

In the course of monitoring other taxa, macroinvertebrate crustaceans observed in the open waters or associated mudflats were noted. Fiddler crabs are one of the most common and abundant inhabitants of salt marshes in eastern North America (Bertness and Miller 1984). They are detritus feeders and by virtue of their numbers may play a major role in energy flow in most marshes (Wolf et al 1975). Bertness (1985) documents a relationship of facultative mutualism between *Uca pugnax* and *Spartina alterniflora.* While considered scarce in the Meadowlands in the 1970s, fiddler crabs are now widespread along the banks of the Hackensack River and its tributaries south of, and including, Overpeck Creek (Kiviat and MacDonald 2002). The colonization of the substrate around the constructed waterways at Harrier Meadow would be expected.

Methods

A general survey of fiddler crab (*Uca* spp.) presence and abundance was carried out at Harrier Meadow in 2001. Surveillance of some areas surveyed in 2001 was carried out in 2002. Habitats including mudflats bordering created impoundments and salt-marsh creeks, high-marsh pannes, depressions, and pools were examined for crab burrows. When burrows were found, their location was noted on a map of the Site. A long screwdriver was used to coax the crabs out of the burrows for species identification. The initial survey was conducted at Harrier Meadow on July 18 and August 1, 2001. Extensive areas at the Site have yet to be surveyed for the presence of fiddler crabs.

Results

Specimens of *Uca pugnax* were found at Harrier Meadow during the 2001 survey (Figure 1). A single burrow was observed on the southeast bank near the end of the channel running between the north impoundment and the middle or western impoundment. A few burrows were noted along the southwest boundary of the Site on the dike adjacent to the mudflats. Eleven burrows were found northwest of the western water-control structure. Some burrows were located between the numerous rocks at water-control structures. Isolated burrows were seen along the shore of the southern impoundment. The greatest concentration of burrows and crab specimens was along the banks of the low areas paralleling the southeast site boundary, especially at the mouth of the creeks that breach the dike.

In 2002 *Uca pugnax* burrows were again observed near the mudflats around the water-control structures for the middle or western and the southern impoundments (Figure 2). Colonies observed along the banks of the impoundments were not present in 2002.

During the collections made for fish monitoring there was incidental capture of *Palaemonetes pugio* (daggerblade grass shrimp), which was common in seine hauls. Harrier Meadow has a large population of *Callinectes sapidus* (blue crab) in the impoundments and channels, especially near the water-control structures and the tidal creeks in the unrestored area. *Rhithropanopeus harrisii* (Harris mud crab) was occasionally found at the Site.

Discussion

Uca pugnax exists in habitats surrounding the Harrier Site including the mudflat side of the earthen dike adjacent to the water-control structures. 2001 observations indicate the crustacean is able to colonize the constructed impoundments, presumably through the water-control structures. Some areas with acceptable substrate obviously are present in the constructed area. *U. pugnax* can exist at different elevations and inhabit various vegetation types, but is often clumped in its distribution within a habitat (Wolf et al 1975). Typical habitats occupied by fiddler crabs have tidal flow that floods vegetation (Bertness and Miller 1984).

Water levels were very low throughout most of 2002. The location of the colonies observed in 2001around the impoundments were left 3 to 8 meters from the open water and no burrows were observed again at those locations in 2002. Teal (1958) suggests the distribution of *U. pugnax* is determined principally by preference for a substrate composed largely of mud and the presence of vegetation. The lack of vegetation or rocks near the new water line may inhibit new colonization around the impoundments at Harrier Meadow.

The larger *Uca minax* has been observed at other sites in the Meadowlands, but not documented in our observations at Harrier Meadow.

Literature Cited

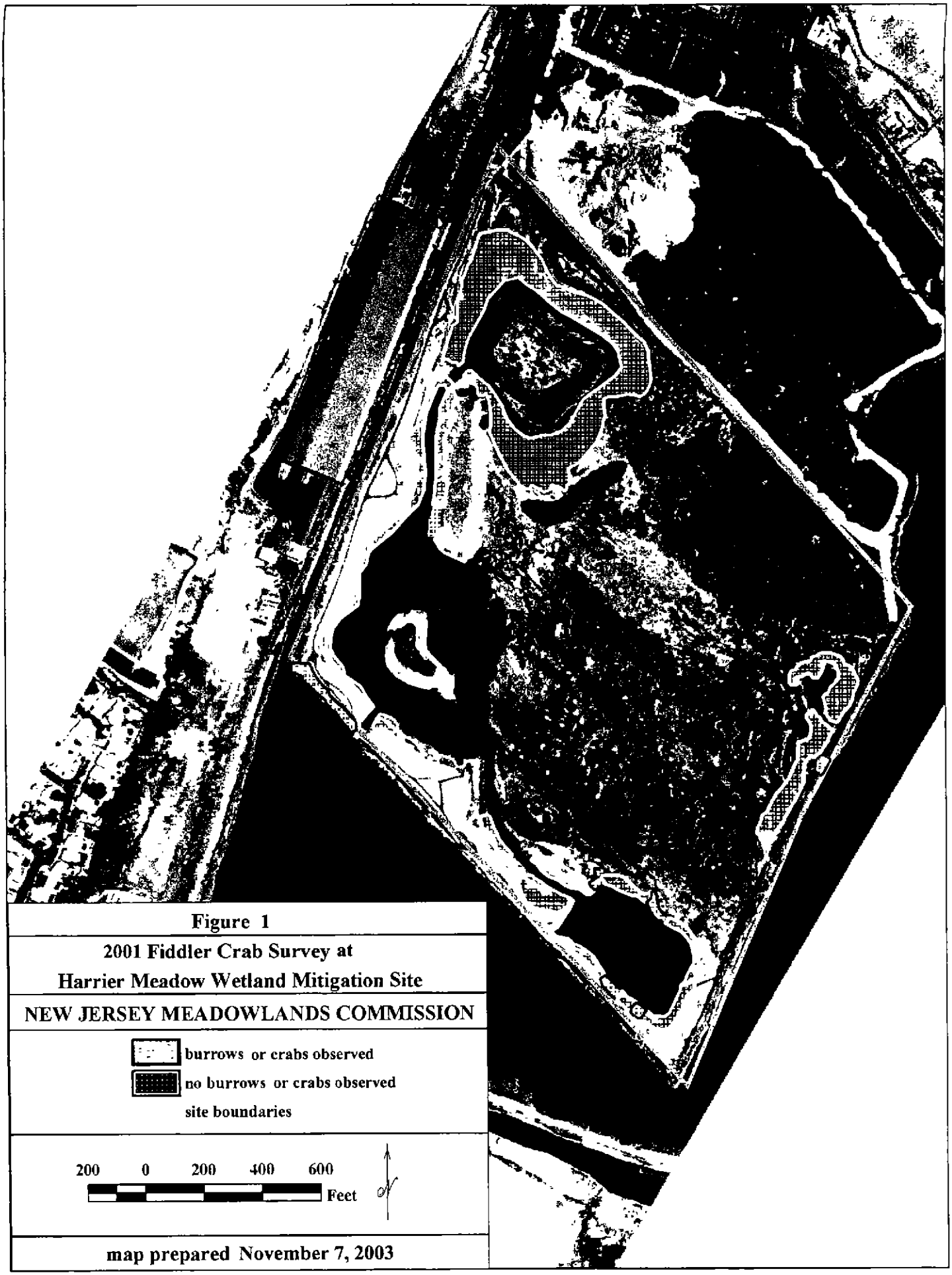
Bertness, M. D. 1985. Fiddler crab regulation of *Spartina alterniflora* production on a New England salt marsh. Ecology 66(3):1042-1055.

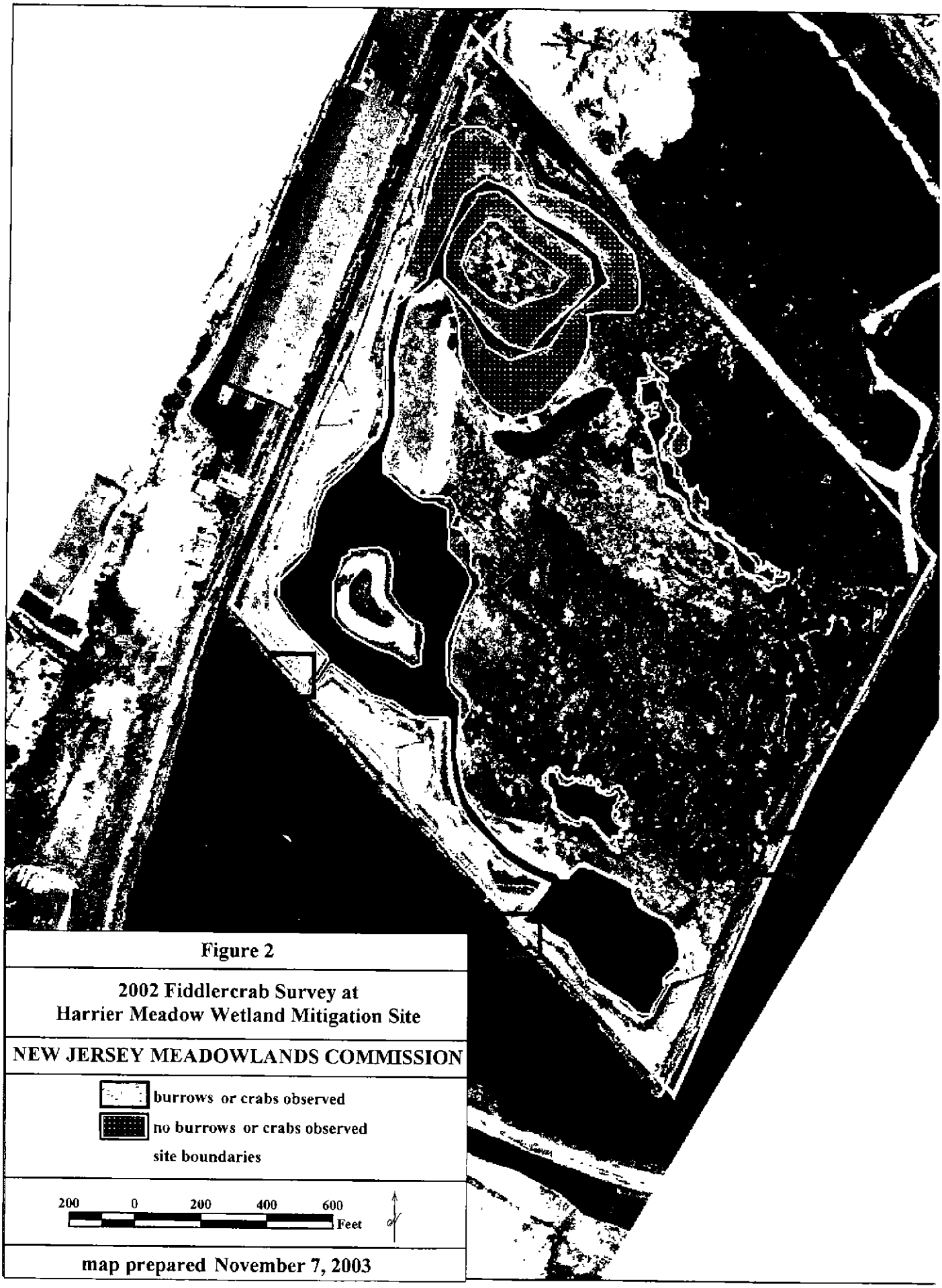
Bertness, M. D. and T. Miller. 1984. The distribution and dynamics of *Uca pugnax* (Smith) burrows in a New England salt marsh. J. Exp. Mar. Biol. Ecol. 211-237.

Kiviat, E. and K. MacDonald. 2002. Hackensack Meadowlands, New Jersey, biodiversity: A review and synthesis. Hudsonia, Annandale, New York. http://www.meadowlandspartnership.org/images/hm%20alert%20-%20kiviat%20report.pdf and http://www.meadowlandspartnership.org/images/hm%20alert%20-%20combined%20tables.pdf .

Teal, J. M. 1958. Distribution of fiddler crabs in Georgia salt marshes. Ecology 39(2):185-193.

Wolf, P. L. S. f. Shanholtzer, and R. J. Reimold. 1975. Population estimates for *Uca pugnax* (Smith, 1870) on the Duplin Estuary Marsh, Georgia, U.S.A (Decapoda Brachyura, Ocydodidae). Crustaceana 29(1):79-91.


Figure 1
2001 Fiddler Crab Survey at
Harrier Meadow Wetland Mitigation Site
NEW JERSEY MEADOWLANDS COMMISSION
burrows or crabs observed
no burrows or crabs observed
site boundaries
200 0 200 400 600
Feet
N
map prepared November 7, 2003


Figure 2
2002 Fiddlercrab Survey at
Harrier Meadow Wetland Mitigation Site
NEW JERSEY MEADOWLANDS COMMISSION
burrows or crabs observed
no burrows or crabs observed
site boundaries
200 0 200 400 600
Feet
map prepared November 7, 2003

APPENDIX O:

Monitoring of Terrestrial Insects at the Harrier Meadow Wetlands Mitigation Site

Monitoring of Terrestrial Insects at the Harrier Meadow Wetlands Mitigation Site

Ross M. Feltes, Ph.D.

Introduction

Insects significantly influence the plant, fish, and bird populations that are important to the goals of the restoration of Harrier Meadow Wetlands Mitigation Site. The purpose of the collection effort was to sample the full range of species at the Site and thus collections were made at different areas using a variety of methods. Other arthropods were taken in this survey.

Methods

A variety of methods of capture were employed at six stations (Figure 1) for collections made from 1998 through 2000. Stations 1 and 3 were in upland transition zones; station 2 and 4 were high marsh; and stations 5 and 6 were in low marsh.

Black-light traps used a modified Robinson trap available from BioQuip Products. Each light trap consisted of one 12-volt U-shaped ultraviolet light tube suspended in the center of a transparent Plexiglas baffle. The baffle-light assembly sat on the rim of a five-gallon bucket. Insects were attracted to the light, hit the baffle, and fell into an aluminum funnel which was fitted inside the mouth of the bucket. Insects accumulated in the bottom of the bucket and were immobilized by a Dichlorvos fumigant strip. Each trap ran approximately seven hours on a 6-volt rechargeable tractor battery. A photosensitive switch was added to the circuit between the battery and the light tube ballast, which turned the light on after sundown and allowed the trap to be set up in the field during the day. Each trap sample consisted of the contents of one light trap after one night.

Yellow pan traps consisted of bright yellow plastic pails containing a small quantity of detergent to break the surface tension of the water, which allows captured arthropods to drown. Each yellow pail sample consisted of a line of pails spaced approximately five meters apart. Each group of pails in a row was considered a single composite transect sample. Buckets were filled at least two-thirds full, staked with wire flags, and left in at the Site for 24 hours. Upon retrieval, all buckets in a transect were drained through a sieve together, and the arthropod portion of the contents of the sieve was preserved in 70% ethanol. Days that were warm and sunny were selected to target pollinators and folivores.

Malaise traps are small oblong tent-like enclosures that capture flying insects and then funnel them into a killing chamber at the top of the structure. This method is particularly effective in capturing Hymenoptera and Diptera. Traps were erected during daylight and collected approximately 24 hours later.

Non-standardized walks were performed with a sweep net at various areas in the Site in order to selectively capture dragonflies, damselflies, butterflies and other noteworthy insects.

Dates and methods of collection are shown in Table 1.

Results

Eleven orders of insects including 114 families were represented in the collections made at Harrier Meadow (Table 2). The most diverse of the orders in terms of number of represented families are Diptera (flies) (43), Hymenoptera (ants, wasps, bees) (23), Coleoptera (beetles) (22), and Hemiptera (bugs) (14). The greatest number of specimens taken throughout the survey was in the order Diptera, with 3,218. Specimens of Chironomidae made up 1,362 of these and all were probably a single species in the *Chironomus decorus*-group. Dolichopodidae had the second largest representation with 659 specimens. Hydrophilidae contributed 182 of the 615 specimens of Coleoptera followed by 111 individuals of Carabidae. Hemiptera, with 608 specimens, was dominated by 192 individuals of Aphididae, and 161 Cicadellidae.

The arachinids Acari (mites), Araneae (spiders), and Opiliones (harvestmen) were also taken in addition to the Insecta collected at the Site. Two taxa of Acari were identified and 10 families of Araneae were present in the collections. Seventy-four of the total 166 spiders taken were members of Lycosidae. Arachnids made up 4% of the total terrestrial arthropod collections. Four Isopoda were also trapped. Specimens from three families of Collembola (springtails) were taken.

The relative abundance of organisms by order in collections made by Malaise and yellow pan traps reflect the trends of the total collections showing the dominance of Diptera, followed by Coleoptera and Hemiptera. Diptera was clearly the most abundant at all stations (Figure 2). Representatives of that order made up a the greatest percentage at the Stations 5 and 6, comprising more than 90% of the total number of specimens collected at Station 5. Coleoptera had its greatest relative abundance at Station 1. This order was conspicuously absent from collections made at Stations 5 and 6. Hemiptera was collected most often at Station 4, dominated by *Distichlis spicata*, and least as often at Stations 5 and 6. Some taxa were taken at only one or a few stations. Collembola was taken primarily at Station 1 followed by Station 3. The largest collection of Araneae was made at Station 2.

Figure 3 shows the abundance of members of the different orders of all terrestrial arthropods taken during each monthly collection period as the logarithm of the actual count. The relative abundance of representatives of the more common hexapod orders is shown in Figure 4. Coleoptera was especially numerous in July 1999 and to a lesser extent in May 2000. July 1999 was the only month when the number of representatives of another order significantly surpassed the number of dipterans collected. Collembola

was taken in numbers greater than just a few specimens only in the May 2000. Diptera dominated, or was very numerous in most collection periods. Hemiptera numbers peaked in July 1999 and June 2000. August 1998 was the only month Homoptera specimens were taken in significant numbers. Hymenoptera has moderate to low numbers relative to other orders in each month. The fewest representatives of this order was taken in May 2000. Lepidoptera was prevalent in each month sampled in 1998 but not in 1999 and 2000. Trichoptera was present only in the July 1999, May 2000, and June 2000 samples, and then only as a few individuals. The arachnid order Araneae was prominent in collections from June 2000. May 2000 was the only period with collections containing many specimens belonging to Opiliones.

Discussion

Station 1 was in an upland transition zone that was varied in plant cover but generally dominated by *Ambrosia artemisiifolia*. Station 1 had the highest relative abundance of Coleoptera. Station 3 was in an upland transition zone that was planted with trees and had adjacent areas dominated by *Artemisia vulgaris*. Stations 2 and 4 were in a high marsh zone dominated by *Distichlis spicata*. Station 4 had the highest relative abundance of Hemiptera. Stations 5 and 6 were in a low marsh area dominated by *Phragmites australis*. Diptera made up a larger percentage of the collections at these stations than at others.

In a study of distribution of insects in salt marshes of North Carolina (Davis and Gray 1966) specimens of Homoptera were the most numerous in most collections, followed by Diptera, Orthoptera and Hemiptera. The importance of Homoptera deminished with a decrease in elevation. The species of this order are distributed zonally by elevation and vegetation. Orthoptera was relatively successful in open stands. Homoptera and Orthoptera made up less than 1% of the collections in the Harrier Meadow survey. The number of insects varied widely between stations in the North Carolina study. The difference in population size of individual species greatly affects total sample sizes. A single homopteran comprised 30% or more of the specimens from each of six stations in the published study. At Harrier Meadow the single species in the *Chironomus decorus*-group (Diptera) made up 28% of all specimens collected. There was a significant difference in the density of insects taken in areas of different kinds of vegetation. In the Davis and Gray (1966) study it was concluded that shelter and food affect the size of insect assemblages more than tidal fluctuations. The majority of insects in all marsh types are herbivores and the principal carnivores are spiders.

Kiviat and MacDonald (2002) summarized the findings of a collection by Grossmueller at 16 stations in the tidal and nontidal Carlstadt-Moonachie marshes in October 2000. Macroinvertebrates were sampled in the aboveground vegetation by sweep-netting, and in leaf litter by Berlese funnel separation. Insect families that were noted as diverse included Aphididae (aphids, Homoptera), Miridae (plant bugs, Hemiptera), Cicadellidae (leafhoppers, Homoptera), Culicidae (mosquitoes, Diptera), Chironomidae (midges, Diptera), and Platygasteridae (a family of parasitic wasps, Hymenoptera). All of these

families except Platygasteridae were recognized in collections of the present study at Harrier. Nevertheless Hymenoptera was diverse at the Site. Other arthropods collected were representatives from five spider families, 1 taxon of Opiliones, one family of Acari, and one Isopoda. Acari and Collembola were cited as being the most abundant in the Grossmueller study, while they were among the least abundant in the Harrier collections. Presumably this discrepancy is largely due to the differences in collection methods.

Though not taken in the deliberate collections for terrestrial arthropods, specimens of *Dermacentor variabilis* (American dog tick) have been removed from the clothing of field workers near Impoundment 1 and Impoundment 3. These were observed during inspection in the grassy upland areas, but the workers had passed though various habitats.

Literature Cited

Davis, L. V. and I. E. Gray. 1966. Zonal and seasonal distribution of insects in North Carolina salt marshes. Ecological Monographs 36(3):275-295.

Kiviat, E. and K. MacDonald. 2002. Hackensack Meadowlands, New Jersey, biodiversity: A review and synthesis. Hudsonia, Annandale, New York. http://www.meadowlandspartnership.org/images/hm%20alert%20-%20kiviat%20report.pdf and http://www.meadowlandspartnership.org/images/hm%20alert%20-%20combined%20tables.pdf .

Table 1. Dates and Methods of Collection of Terrestrial Arthropods at Harrier Meadow.

Date	Collection Method	# stations
05/28/98	black-light	1
05/28/98	yellow pan	1
05/29/98	sweep	1
06/03/98	black-light	2
06/03/98	yellow pan	6
08/19/98	yellow pan	4
08/20/98	black-light	1
06/24/99	yellow pan	1
07/06/99	black-light	2
07/14/99	Malaise	1
05/09/00	Malaise	2
05/09/00	yellow pan	2
06/02/00	sweep	1
06/08/00	sweep	1
06/09/00	Malaise	3
06/09/00	yellow pan	2
06/23/00	Malaise	1

Table 2. Abundance of Terrestrial Arthropods Collected at Harrier Meadow 1998-2000.

Class	Order	Family (or higher rank *)	Count	% of class total
Malacostraca	**Isopoda**		**4**	100.00
Arachnida	Acari	Ixodidae	1	
	Acari	Parasitiformes *	3	
	Acari	unknown	6	
	Acari total		**10**	4.85
	Araneae	Corinnidae	2	
	Araneae	Linyphiidae	2	
	Araneae	Lycosidae	74	
	Araneae	Mimetidae	1	
	Araneae	Philodromidae	7	
	Araneae	Salticidae	19	
	Araneae	Tetragnathidae	4	
	Araneae	Theridiidae	5	
	Araneae	Theridiosomatidae	1	
	Araneae	Thomisidae	3	
	Araneae	unknown	48	
	Araneae total		**166**	80 58
	Opiliones	unknown	**30**	14.56
	Arachnida total		**206**	
Hexapoda	Coleoptera	Anthicidae	49	
	Coleoptera	Cantharidae	3	
	Coleoptera	Carabidae	111	
	Coleoptera	Chrysomelidae	41	
	Coleoptera	Cicendelidae	1	
	Coleoptera	Coccinellidae	36	
	Coeloptera	Cucujidae	1	
	Coleoptera	Curculionidae	7	
	Coleoptera	Dermestidae	1	
	Coleoptera	Dytiscidae	5	
	Coleoptera	Elateridae	52	
	Coleoptera	Erotylidae	1	
	Coleoptera	Heloidae	1	
	Coleoptera	Heteroceridae	5	
	Coleoptera	Hydrophilidae	182	
	Coleoptera	Mordellidae	8	
	Coleoptera	Pselaphidae	3	
	Coleoptera	Rhipiphoridae	1	
	Coleoptera	Scarabaeidae	7	
	Coleoptera	Scydamaeridae	2	
	Coleoptera	Staphylinidae	62	
	Coleoptera	Trogositidae	7	
	Coleoptera	unknown	28	
	Coleoptera total		**614**	12.77
	Collembola	Entomobryidae	32	
	Collembola	Isotomidae	9	
	Collembola	Sminthuridae	2	
	Collembola total		**43**	0.89

Table 2. Abundance of Terrestrial Arthropods Collected at Harrier Meadow 1998-2000.

	Diptera	Agromyzidae	8	
	Diptera	Anthomyiidae	6	
	Diptera	Asilidae	1	
	Diptera	Asteiidae	1	
	Diptera	Calliphoridae	14	
	Diptera	Cecidomyiidae	16	
	Diptera	Ceratopogonidae	15	
	Diptera	Chamaemyiidae	4	
	Diptera	Chironomidae	1362	
	Diptera	Chloropidae	162	
	Diptera	Conchopteridae	1	
	Diptera	Conopidae	2	
	Diptera	Culicidae	7	
	Diptera	Dixidae	3	
	Diptera	Dolichopodidae	659	
	Diptera	Drosophilidae	152	
	Diptera	Dryomyzidae	2	
	Diptera	Ephydridae	145	
	Diptera	Heleomyzidae	14	
	Diptera	Lauxaniidae	45	
	Diptera	Lonchaeidae	82	
	Diptera	Lonchopteridae	4	
	Diptera	Micropezidae	10	
	Diptera	Muscidae	72	
	Diptera	Mycetophilidae	25	
	Diptera	Oestridae	2	
	Diptera	Otitidae	3	
	Diptera	Phoridae	21	
	Diptera	Pipunculidae	7	
	Diptera	Psychodidae	6	
	Diptera	Rhagionidae	2	
	Diptera	Rhinophoridae	2	
	Diptera	Sarcophagidae	7	
	Diptera	Sciaridae	40	
	Diptera	Sciomyzidae	4	
	Diptera	Sepsidae	4	
	Diptera	Sphaeroceridae	13	
	Diptera	Stratiomyidae	6	
	Diptera	Syrphidae	38	
	Diptera	Tabanidae	9	
	Diptera	Tachinidae	4	
	Diptera	Tephritidae	23	
	Diptera	Tipulidae	131	
	Diptera	unknown	83	
	Diptera total		**3217**	66.90

Table 2. Abundance of Terrestrial Arthropods Collected at Harrier Meadow 1998-2000.

	Hemiptera	Achilidae	12	
	Hemiptera	Anthocoridae	2	
	Hemiptera	Aphididae	192	
	Hemiptera	Cercopidae	19	
	Hemiptera	Cicadellidae	161	
	Hemiptera	Cixiidae	1	
	Hemiptera	Corixidae	64	
	Hemiptera	Fulgoroidea *	6	
	Hemiptera	Lygaeidae	5	
	Hemiptera	Membracidae	2	
	Hemiptera	Miridae	89	
	Hemiptera	Nabidae	2	
	Hemiptera	Reduviidae	33	
	Hemiptera	Tingidae	18	
	Hemiptera	unknown	2	
	Hemiptera total		**608**	12.64
	Homoptera	Aphididae	6	
	Homoptera	Cicadellidae	5	
	Homoptera total		**11**	0.23
	Hymenoptera	Andrenidae	1	
	Hymenoptera	Anthophoridae	10	
	Hymenoptera	Apidae	2	
	Hymenoptera	Braconidae	23	
	Hymenoptera	Chacidoidea *	8	
	Hymenoptera	Chalicididae	1	
	Hymenoptera	Chrysididae	1	
	Hymenoptera	Colletidae	5	
	Hymenoptera	Cynipidae	2	
	Hymenoptera	Diapriidae	7	
	Hymenoptera	Eulophidae	2	
	Hymenoptera	Formicidae	21	
	Hymenoptera	Gasteruptiidae	1	
	Hymenoptera	Halictidae	9	
	Hymenoptera	Ichneumonidae	33	
	Hymenoptera	Megachilidae	4	
	Hymenoptera	Mutillidae	1	
	Hymenoptera	Mymaridae	3	
	Hymenoptera	Perilampidae	1	
	Hymenoptera	Pompillidae	3	
	Hymenoptera	Sphecidae	12	
	Hymenoptera	Tenethrediinidae	1	
	Hymenoptera	Tiphiidae	1	
	Hymenoptera	unknown	9	
	Hymenoptera total		**161**	3.35

	Lepidoptera	Arctiidae	5	
	Lepidoptera	Elachistidae	1	
	Lepidoptera	Noctuidae	17	
	Lepidoptera	Pieridae	1	
	Lepidoptera	Pyralidae	24	
	Lepidoptera	unknown	72	
	Lepidoptera total		**120**	2.50
	Neuroptera	Chrysopidae	3	
	Neuroptera total		**3**	0.06
	Odonata	Coenagrionidae	4	
	Odonata	unknown	3	
	Odonata total		**7**	0.15
	Orthoptera	Acrididae	4	
	Orthoptera	Tettigoniidae	7	
	Orthoptera total		**11**	0.23
	Psocoptera	unknown	6	
	Psocoptera total		**6**	0.12
	Trichoptera	Hydropsychidae	1	
	Trichoptera	unknown	7	
	Trichoptera total		**8**	0.17
	total Insecta		**4809**	

Figure 2. Relative Abundance of Hexapod Orders at Harrier Meadow 1999-2001

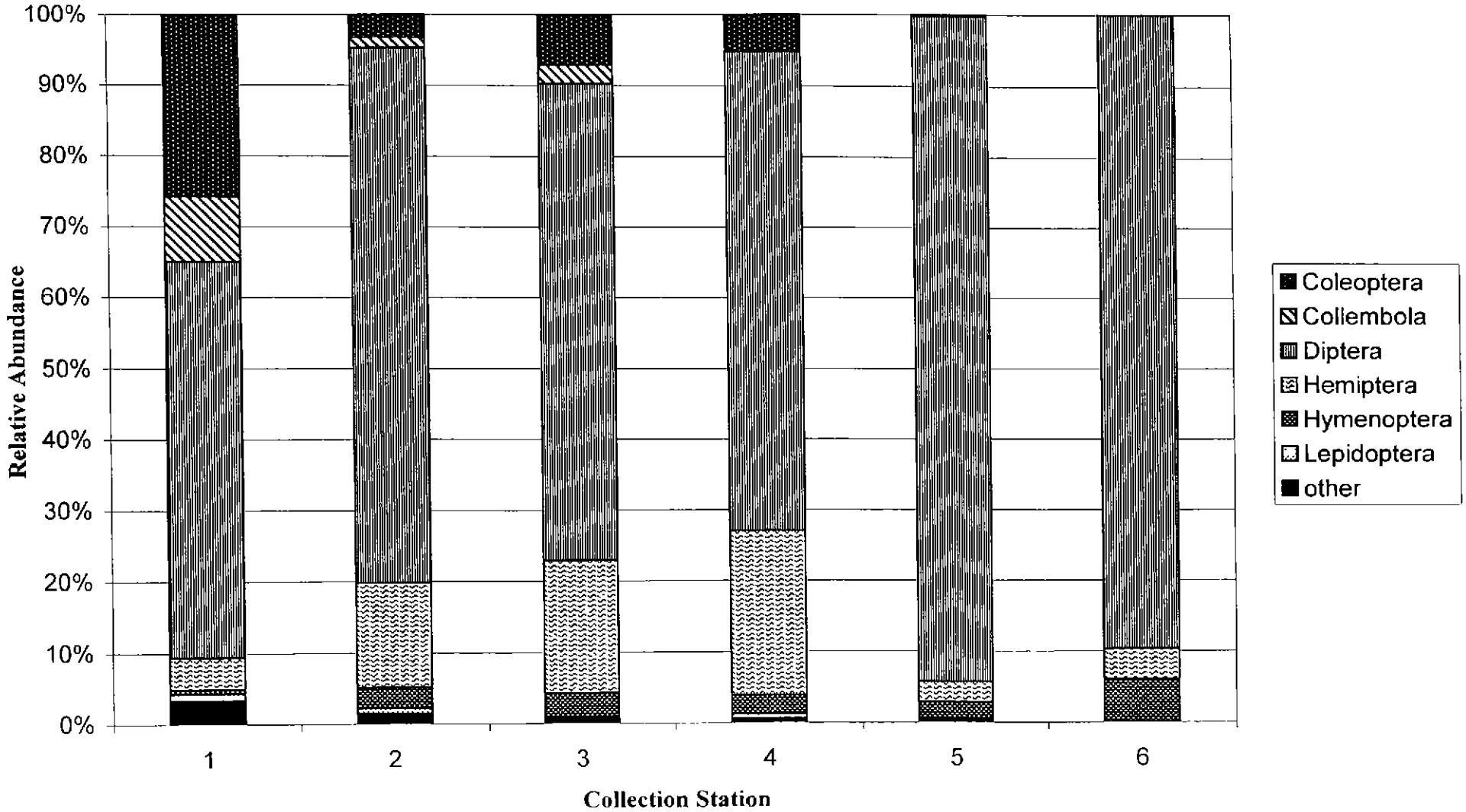


Figure 3. Abundance of Numerically Significant Orders of Terrestrial Arthropods Collected at Harrier Meadow

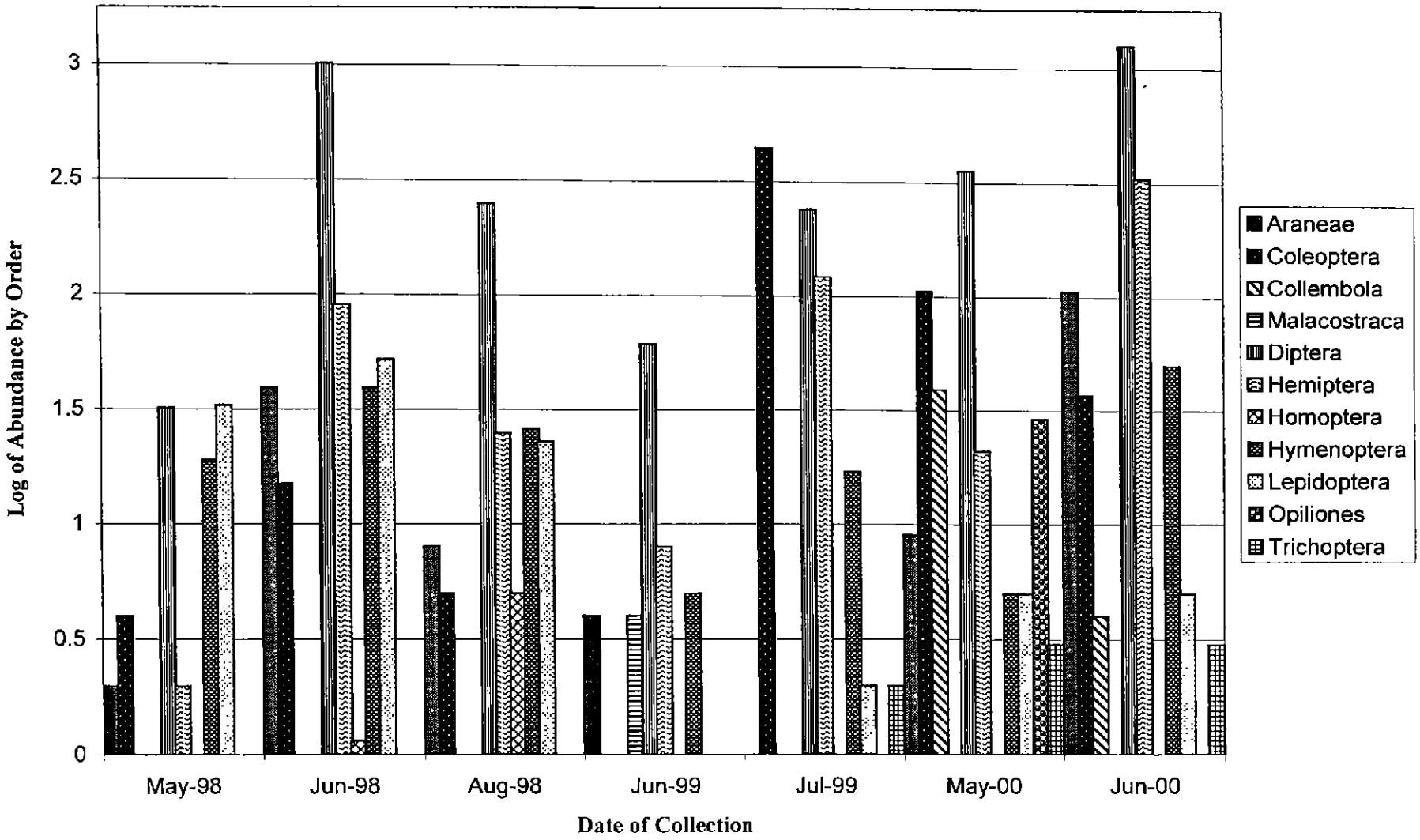


Figure 4. Relative Abundance of Hexapod Orders by Month at Harrier Meadow 1998-2000

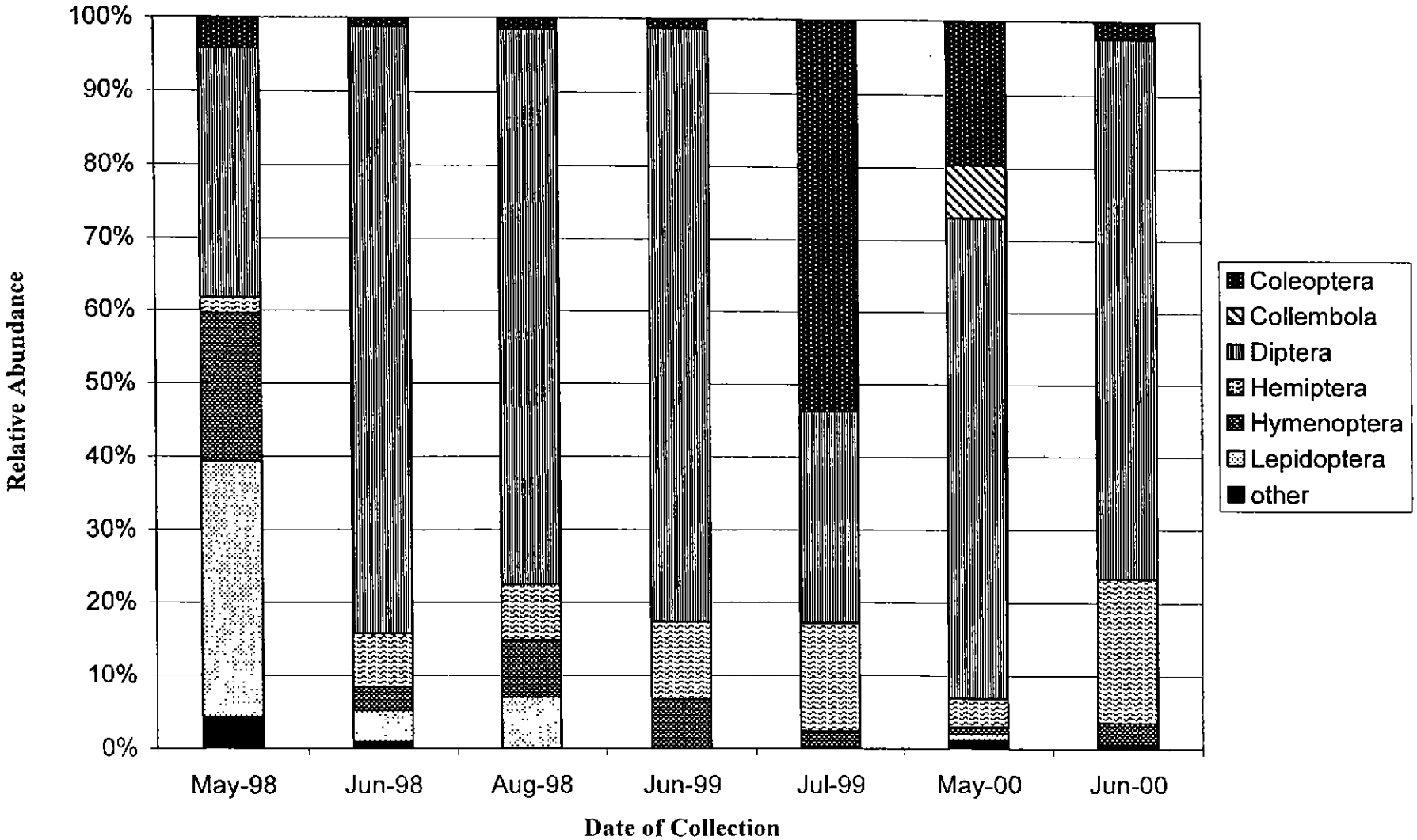




Figure 1

Sampling Stations for Monitoring Terrestrial Arthropods at Harrier Meadow Wetland Mitigation Site

NEW JERSEY MEADOWLANDS COMMISSION

terrestrial arthropods sampling locations

site boundaries

200 0 200 400 600 Feet

map prepared November 7, 2003

APPENDIX P:

Study on the Density of Chironomid Insect Larvae in Different Habitats at the Harrier Meadow Wetlands Mitigation Site

Study on the Density of Chironomid Insect Larvae in Different Habitats at the Harrier Meadow Wetlands Mitigation Site

Andrew Krivenko, Ross M. Feltes, PhD, and Mark Wong

Introduction

Larvae of the Chironomidae (Diptera) are often the most abundant insects in aquatic ecosystems. They dominated the representation of insects in the monitoring of benthic invertebrates, often being the only insect in the samples and present in large numbers. Several studies have illustrated their importance as food items to fauna occupying higher levels of the food web. The importance of chironomids in the diets of waterfowl has been documented for various species (Ashley et al 2000, Belanger and Couture 1988). Chironomids are major prey items for numerous fishes. The abundance of some shorebird species has been correlated with chironomid densities (Ashley et al. 2000). In created brackish lagoons in England twenty species of shorebirds were directly observed consuming chironomid larvae (Rehfisch 1994).

Given the importance of the Chironomidae in aquatic food webs, a specific study of this part of the benthos was carried out to determine monthly density and biomass of chironomids in created impoundments versus other existing aquatic habitats at Harrier Meadow. Existing aquatic habitats present at the Site prior to construction of the impoundments include tidal mudflats, tidal creeks and high marsh pannes. Preliminary data collected in August and October of 2000 suggested the abundance of chironomids would be greater in created impoundments at the Site than in the previously existing habitats.

Methods

Permanent one square meter sampling stations were established at Harrier Meadow (Figure 1) in March 2001. Three stations each were established in created impoundments (IM1, IM2, IM3), tidal mudflats (MF1, MF2, MF3), tidal creeks (TC1, TC2, TC3) and high marsh pannes (HM1, HM2, HM3).

The tidal mudflats sampled during the study were located adjacent to the Harrier Meadow mitigation site. These mudflats were exposed during low tide. Each station was located within one meter of *Spartina alterniflora* that fringes the outer edges of Harrier Meadow.

The tidal creeks sampled drained toward the eastern boundary of the Harrier Meadow Sites. TC1 and TC2 sampling stations were in the same creek system, one towards the mouth of the creek and the other on a large tidal pool approximately 300 meters upstream. A third tidal-creek station was established in a separate creek system at the northern edge of the Site. Collections yielded very few or no chironomid larvae at this station and sampling at TC3 was discontinued.

High marsh panne habitats are periodically flooded small-pool habitats surrounded by and containing vegetation such as *Distichlis spicata* and *Juncus gerardi*. The stations were not flooded by tides during the study period. The only source of replenishment for these habitats was rainfall.

Five samples were collected randomly from each station once per month from March 2001 through October 2001. The top 5 cm of sediment was taken using a 4.7 cm diameter acrylic core sampler. Samples were preserved in 70% ethanol and stained with rose bengal. Samples were sieved with a 250-micron mesh sieve and then sorted by hand. Quantities of individuals in each sample were recorded and head capsule width was determined for the purpose of separating individuals into instar classes. The first instars were highly visible without the aid of magnification. Only aquatic insects were retained from the samples. Other benthic organisms were discarded since they are being investigated in a separate study.

Average dry weight biomass was calculated for instar 3 and 4 individuals. An average mass of 8.8×10^{-4} g per individual was determined for the entire site. Biomass of individuals collected during a sampling was established by multiplying the average mass by the number of individuals collected.

Mann-Whitney tests were used to determine if there were differences in the larval chironomid populations between the created impoundments and the three other habitats.

Results

Only one species, a member of the *Chironomus decorus*-group, was collected during the study period. Figure 2 shows chironomid densities in each aquatic habitat at Harrier Meadow for each of the collections.

The total number, and relative number, of chironomid larvae collected in the different habitats varied through the months sampled. With the exception of the high marsh panne stations, there were a large number of chironomids taken in May, June, and July, but not the other months sampled. There was a moderate peak of abundance at the created impoundments in October.

In July and August, chironomid abundance was significantly less in samples from the created impoundments than those from the tidal mudflats. In September and October there were no chironomids present in samples collected on the mudflats.

Created impoundment, tidal mudflat, and tidal creek collections all included large numbers of chironomids in May. Chironomid abundance was significantly less in samples from the created impoundments than those from the tidal creeks and tidal mudflats in June and July. Larval abundance in impoundment samples exceeded those from the tidal creeks and mudflats in September and October.

The number of chironomid instars 3 and 4 collected in the created impoundments at Harrier Meadow is significantly different from mudflat collections for the months of July through October and from tidal creek collections in June. High marsh stations were dry for several sampling periods. Chironomids were found at these stations only in April, June and July, and then at much lower densities than at the impoundment stations.

No significant differences were found between the mean abundance of all instars over the entire collection period at the impoundment and the tidal creek stations. Significant differences existed between the impoundment and the high marsh stations, but as noted the latter were often dry. No significant differences were found between the mean abundance or calculated biomass of just instars 3 and 4, except high marsh. High marsh pannes were periodically dry prohibiting the survival of larval chironomids.

The calculated biomass of instars 3 and 4 larvae for the impoundments had a range for the monthly collections of 0.78 to 17.97 g $^{m-2}$; mudflats 0 to 24.43 g $^{m-2}$; tidal creeks 0.10 to 29.54 g $^{m-2}$; and high marsh pannes 0 to 0.29 g $^{m-2}$.

Discussion

Natural bodies of water usually have a diversified midge fauna. High densities of *Chironomus* often indicates shallow eutrophic bodies of water. The densities of larvae obtained in this study are consistent with the magnitude documented in Utberg's (1980) study on *Chironomus decorus* in the Hackensack Meadowlands. Utberg also observed a sudden rise in instars 3 and 4 in May with peak densities in July.

Chironomids can occupy broad niches in oligohaline and mesohaline areas of estuaries. These feed primarily on organic detritus. They are in turn fed upon by other invertebrates and most species of fish at least during part of their life history (Menzie 1980).

The constructed impoundments are offering shallow habitat for chironomids. In the first year of monitoring the benthic invertebrates at Harrier Meadow, 1999, chironomid larvae made up 16% of the overall abundance in June. The presence of this species was notable in the June benthos collections in 2000 and 2001 as well. During months of the greatest numbers of larvae, May through July, the density is high in the impoundments, but often exceeded in the sediments of the tidal creeks and mudflats. The high marsh pannes are frequently dry and the presence of chironomid larvae there is sporadic and low in number. Significant differences between created impoundments and high marsh pannes were most likely a result of the erratic water levels in the high marsh. In some months of lower abundance of chironomid larvae, September and October, the sediments of the impoundments had a higher density than the other habitats.

Literature Cited

Ashley, M.C., J.A. Robinson, L.W. Oring, and G.A. Vinyard. 2000. Dipteran standing stock biomass and effects of aquatic bird predation at a constructed wetland. Wetlands 20(1):84-90.

Belanger, L. and R. Couture. 1988. Use of man-made ponds by dabbling duck broods. J. Wildlife Management 52(4):718-723.

Gilinsky, Ellen. 1984. The role of fish predation and spatial heterogeneity in determining benthic community structure. Ecology 65(2):455-468.

Menzie, C. A. 1980. The chironomid (Insecta:Diptera) and other fauna of a *Myriophyllum spicatum* L. plant bed in the lower Hudson River. Estuaries. 3(1):38-54.

Rehfisch, M.M. 1994. Man-made lagoons and how their attractiveness to waders might be increased by manipulating the biomass of an insect benthos. Journal of Applied Ecology 31: 383-401.

Utberg, G. L. 1980. The biology of *Chironomus decorus* (Chironomidae) in Northern New Jersey. MS thesis. New Brunswick. Rutgers, the State University of New Jersey. pp 68.

Figure 2. Density of Chironomid Larvae in Aquatic Habitats at Harrier Meadow, North Arlington, Bergen County, NJ, 2001

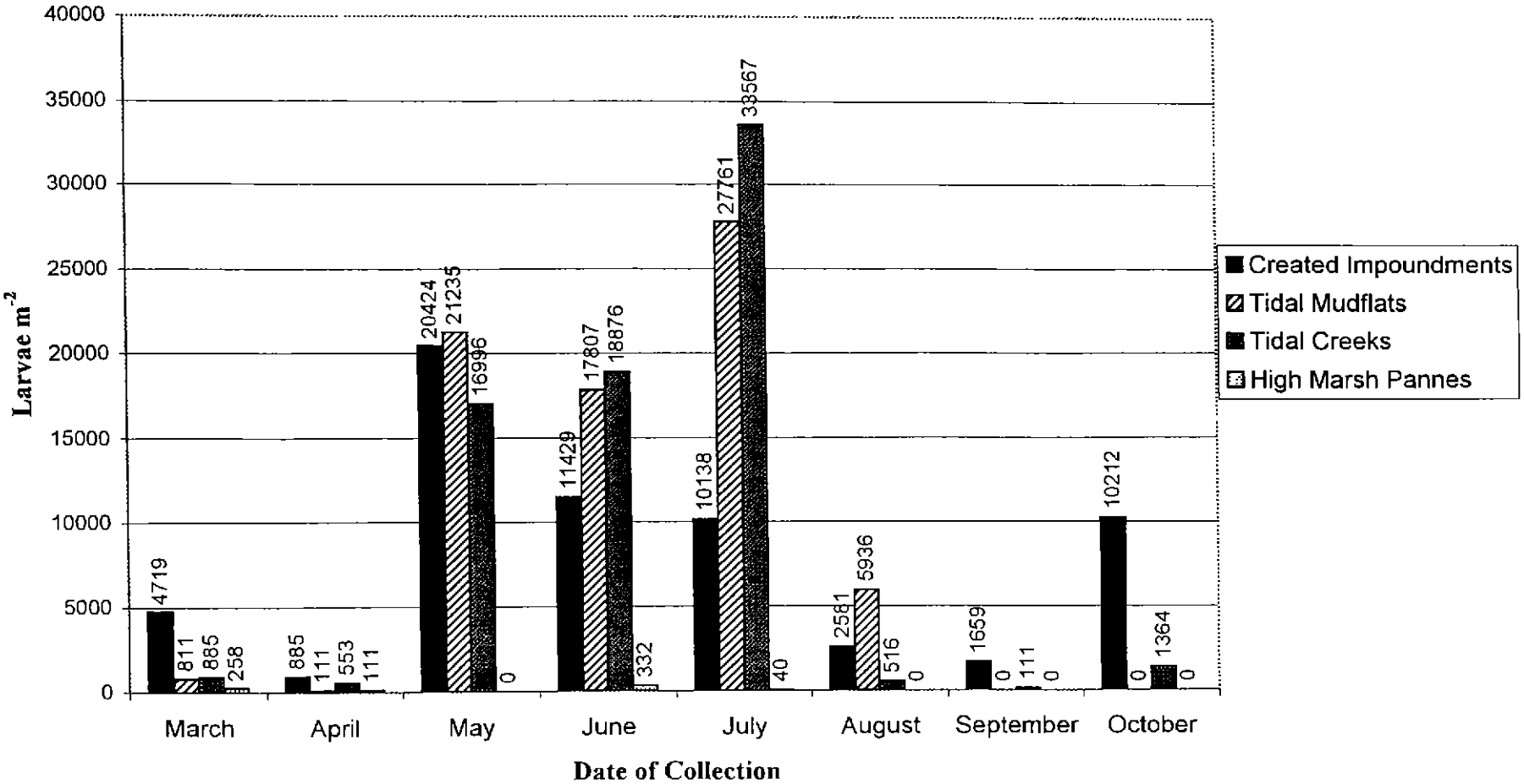




Figure 1

Sampling Stations for Monitoring Chironomids at Harrier Meadow Wetland Mitigation Site

NEW JERSEY MEADOWLANDS COMMISSION

insect sampling locations

site boundaries

200 0 200 400 600 Feet

map prepared November 7, 2003

Note
TC = tidal creeks
IM = impoundments
HM = high marsh
MF = mudflats