Monitoring Biological Diversity in the Hackensack Meadowlands

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Report to the Meadowlands Environmental Research Institute
of the New Jersey Meadowlands Commission

Lyndhurst, New Jersey

3 June 2007
Revised 18 August 2007

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Abstract: The Meadowlands Environmental Research Institute asked Hudsonia to initiate a biodiversity monitoring program in the Hackensack Meadowlands, New Jersey. MERI and Hudsonia selected several animal taxa for monitoring. In 2006 Hudsonia conducted pilot sampling of frogs (call surveys at two freshwater sites during three periods in spring) and butterflies, dragonflies, and damselflies (strip transect counts at five sites in early summer). We also reviewed Meadowlands fish data and made recommendations about monitoring fishes.

Frog surveys detected a single species, the southern leopard frog, in small but widespread populations at both sampled sites (Teterboro Airport and Upper Penhorn Marsh). On the insect surveys we found 25 species of butterflies, 14 dragonflies, and 10 damselflies, at the five sites collectively (1E Landfill – Harrier Meadow, Kearny Marsh West, Laurel Hill, Paterson Lateral Gas Pipeline – Richard P. Kane Natural Area, and Bergen County Utilities Authority - Mehrhof Pond). Numbers of individuals and numbers of species represent substantial biodiversity to conserve and monitor in an urban area.

We recommend: 1. Repeating the frog surveys with a transition to automated recorders (frog loggers); 2. Repeating the insect surveys with a larger number of transects (sites); and 3. Repeating fish surveys performed in 1987-1988 and 2001-2003 with months, gears, and stations selected for cost-efficiency and clearer relationships to environmental quality (e.g., water quality or marsh vegetation). All three monitoring programs should aim to accumulate long time series of data.

Several species are of conservation concern. Southern leopard frog has apparently disappeared from Long Island in recent years, and is rare in northern New Jersy, thus the Meadowlands population may be important. A dragonfly (Needham’s skimmer), a damselfly (big bluet), and a butterfly (long dash), are tracked by the New Jersey State Landscape Program indicating potential conservation concern. Presence of both the rare and common species of animals that use complementary wetland and upland habitats suggests the importance of protecting and managing for wildlife the seminatural upland habitats as well as the wetlands.

Key words: Biodiversity; Fishes; Frogs; Hackensack Meadowlands; Lepidoptera; Monitoring; Odonata; Urban ecology; Wetlands.

This report should be cited as:

Kiviat, E., editor. 2007. Monitoring biological diversity in the Hackensack Meadowlands. Report to the Meadowlands Environmental Research Institute, New Jersey Meadowlands Commission, Lyndhurst, New Jersey. 55 pages.

Introduction

by Erik Kiviat

Biological diversity (or biodiversity) is the variety of life in nature at all levels from genes to ecosystems and landscapes. Biodiversity is usually used with reference to native species because it is these species that are commonly the effective target of conservation studies and implementation. Monitoring diversity of species is important for gaining information about changes in environmental quality and to focus efforts in conservation, management, and restoration of habitats and species. Monitoring data are also valuable for educational purposes.

It is often discovered in monitoring populations and communities of species that there is a large amount of variation in numbers across space and through time. Thus monitoring programs typically must be designed to obtain large numbers of samples and to continue through long time periods in order to improve ability to interpret the data, and to detect population responses that may lag greatly behind causal factors or respond to multiple factors (Spellerberg 1991, Garden et al. 2006). Relatively few biodiversity monitoring studies are conducted in urban areas of the U.S. These environments present special challenges for monitoring including access to sites for long-term study, vandalism of markers and biota, the presence of many non-native species, and a greater fragmentation and patchiness of habitats than is typically found in non-urban areas. At the same time, some common and rare native species thrive in urban areas, large numbers of people have the opportunity to appreciate biodiversity in the urban areas where they live, and we need to learn more about urban biodiversity to inform environmental planning and management in the extensive urban and urbanizing areas of the U.S. (see, e.g., Brack 2006, Garden et al. 2006). Considering that half of the world's population lives in urban areas, Murphy (1988) deemed the protection of urban biodiversity emblematic of our ability to care for the global environment.

The Meadowlands Environmental Research Institute of the New Jersey Meadowlands Commission requested a proposal from Hudsonia Ltd. to initiate a biodiversity monitoring study in the Meadowlands. Several taxa (groups) of plants and animals were originally considered for monitoring at Hudsonia's suggestion (Table 1). Because a major bird study was conducted by New Jersey Audubon in 2005-2006, birds were not considered further. Following a series of discussions, it was agreed that Hudsonia would begin monitoring surveys for frogs in selected freshwater wetlands and for butterflies and odonates (dragonflies and damselflies) in various habitats in spring and summer 2006. Frog surveys were included in the biodiversity monitoring study at the request of MERI. It was also agreed that Hudsonia would review the fish sampling data from previous studies and make recommendations concerning fish monitoring. Because 2006 was the first year the frog and butterfly-odonate surveys were performed, and no prior quantitative data on these groups of animals were available for the Meadowlands, Hudsonia's 2006 work focused on the development and testing of survey methods.

This report is organized in three sections (frogs, insects, and fish). The insect and frog sections have been prepared in the form of manuscripts for potential submission to scientific journals.

Table 1. Originally proposed habitats, groups of organisms, and methods for biodiversity monitoring in the Meadowlands.

Habitat	Organisms	Methods	Season, frequency
Tidal creek	Migrant waterbirds	Time-constrained observation	Annual; fall-winter-spring
	Fishes	Seining	Annual; summer
Smooth cordgrass tidal marsh	Breeding birds	Point counts	Annual; spring
	Insects and spiders	Sweepnetting; dissection of plants; observation	Alternate years; summer-fall
Common reed tidal marsh	Breeding birds	Point counts	Annual; spring
	Insects and spiders	Sweepnetting; dissection of plants; observation	Alternate years; summer-fall
Common reed nontidal marsh	Breeding birds	Point counts	Annual; spring
	Insects and spiders	Sweepnetting; dissection of plants; observation	Alternate years; summer-fall
Dry meadows on fill	Breeding birds	Point counts	Annual; spring
	Bees	Pan traps	Annual; summer
	Lichens and mosses	Qualitative collection	Alternate years; fall or winter
Swamp forests and wet woods	Breeding birds or spring migrants	Point counts	Annual; spring
	Ground beetles	Pitfall traps	Annual; summer
	Mosses	Qualitative collection	Alternate years; fall-winter
Rocky crests	Breeding birds	Point counts	Annual; spring
	Lichens and mosses	Qualitative collection	Alternate years; fall-winter
Special species	Floating marsh pennywort	Stand size and density	Three sites; annual; summer
	Clam shrimp	Dipnetting	One site; annual; summer
	Wintering raptors	Route counts	Annual; winter

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Frog Call Surveys in an Urban Wetland Complex, the Hackensack Meadowlands, New Jersey

by Erik Kiviat

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Abstract

In many areas of the world, frogs are affected by multiple environmental stresses, therefore the ability of frogs to tolerate urban conditions is of interest. In spring 2006, I surveyed calling frogs during three periods at each of two sites in the Hackensack Meadowlands just outside New York City in northeastern New Jersey, USA. I detected small choruses of a single species, southern leopard frog (*Rana sphenocephala utricularia*), at multiple wetland and pond locations within each site. The occurrence of populations of this species in the Meadowlands is noteworthy because it is rare or disappearing in nearby regions. The tolerance of southern leopard frog for slightly brackish water and the persistence of small areas of adjoining uplands may enable it to survive in a coastal urban environment.

Key words: Amphibia, monitoring, southern leopard frog, urban biodiversity, water quality, wetlands.

Introduction

Frogs are considered good indicators of environmental quality because adults and larvae integrate aquatic and terrestrial environments, are sensitive to water quality and contaminants, and generally do best where alteration of hydrology and soils has been minimal. Recently there has been intense interest in the viability of frog species worldwide because many populations have been severely affected by habitat loss, diseases, parasites, introduced animals, pesticides, other toxic contaminants, and increased ultraviolet radiation (e.g., Green 1997, Lannoo 2005). Although some frog species manifest a degree of tolerance to urbanization, there is little published information on frogs in American urban environments.

The Hackensack Meadowlands of northeastern New Jersey are a large complex of urban wetlands affected by contamination and habitat degradation yet undergoing landscape preservation and ecological restoration (Kiviat and MacDonald 2004). Frog diversity in the Meadowlands is low compared to nearby rural areas. Remediation of contamination and certain types of habitat management could be favorable for frogs in the Meadowlands, and may eventually increase the abundance of individuals and diversity of species. Because of the general declines and local management opportunities, frogs should be a good group of organisms for biodiversity monitoring. Moreover, frogs are being monitored at many locations in North America and those data potentially afford comparisons to the Meadowlands. Frog larvae (tadpoles) are more difficult to sample and identify than calling adult male frogs; therefore, we decided to sample frogs by means of call surveys. In this report, "frogs" includes all members of the order Anura, i.e., true frogs, true toads, spadefoot toads, chorus frogs, cricket frogs, and treefrogs

Methods

I conducted frog surveys at two freshwater sites, Teterboro Airport in the municipalities of Moonachie and Teterboro, Bergen County, and "Upper Penhorn Marsh" (Guarini Tract) in North Bergen, Hudson County (Figure 1). Teterboro Airport (including Teterboro Airport Woods) is bordered by Route 36 (Moonachie Avenue) on the south, Route 43 (Redneck Avenue) on the east except for an area of wet woods and wetland east of Redneck Avenue and north of Moonachie Avenue, Industrial Avenue on the west, and Route 46 on the north. The site comprises developed areas (airport, industrial, recreation), stormwater ponds, ditches, herb and shrub-dominated wet and dry areas, and extensive, well-developed swamps and wet woodlands with mixed-species stands of mature hardwoods. There is extensive evidence of historic drainage, including deep ditches. Upper Penhorn Marsh is on Penhorn Creek and is bordered by the New Jersey Turnpike Eastern Spur and Exit 16E ramps on the west and north, by the New Jersey Transit – "Penn Central" railroad on the southeast, and by Secaucus Road on the southwest. This upper portion of Penhorn Creek is above a tidegate, and accumulated stormwater is pumped from above the tidegate to below it (Don Smith, personal communication). The nontidal marsh is dominated by common reed (*Phragmites australis*) with several broad straight artificial channels in addition to the winding channel of the creek. Numerous stumps of Atlantic white cedar (*Chamaecyparis thyoides*) are present. There are small fishes in Upper Penhorn Marsh and Teterboro Southeast Pond; I do not know if fish are present in the other Teterboro habitats.

I conducted three evening-long surveys at each of the two sites (Teterboro and Penhorn), for a total of six surveys. Each site was surveyed three times during spring (Table 1), to intersect the calling periods of the species of frogs that occur in northeastern New Jersey. Periods of cold or windy weather made it difficult to schedule the surveys. Because no prior information existed as to the species of frogs present and their locations at Teterboro and Penhorn, each survey consisted of an approximately three-hour period (beginning just before dusk) of visiting potential habitats and listening for calling frogs. At Teterboro, I visited several ponds and swamps (Figure 1) on foot during each survey. I was not permitted to enter the secure areas of the airport, hence all survey work was done outside the perimeter security fences. Because of this restriction and the pervasive noise of airplanes and road vehicles, it was difficult to hear natural sounds; I may have been unable to detect species calling in secure areas deep within the airport.

At Penhorn, I conducted the surveys by canoe. Each survey date I put the canoe into the southwest end of the central channel (south corner of the marsh; Figure 1) at the Amtrak maintenance road a short distance north of the Amtrak maintenance trailer near the railroad bridge over Secaucus Road. I paddled northeast to the northeast end of the central channel, and

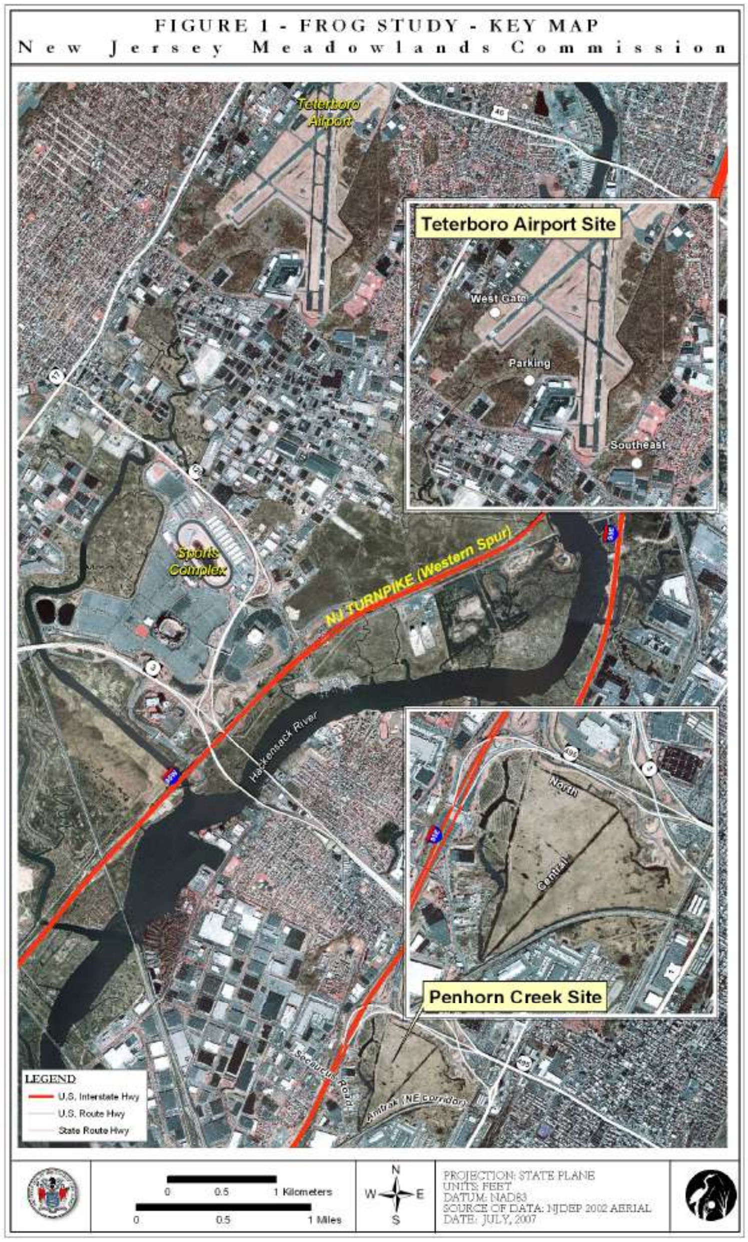

Figure 1. Frog survey sites in the Hackensack Meadowlands (Teterboro Airport and Upper Penhorn Marsh). Insets show locations where southern leopard frogs called at Teterboro Airport and Upper Penhorn Marsh, spring 2006.

west to the west end of the northern channel. On the April survey date I dragged the canoe over a low spoil mound and paddled south along the western channel and back to the put-in point. In the April survey I heard no frogs along the western channel, which was subject to higher hydrodynamic energy and turbidity from the mainstem of Penhorn Creek. Therefore, on the May and June surveys, I retraced my path along the northern and central channels instead of returning by the western channel. Noise from frequent commuter trains and vehicles on the Turnpike interfered with auditory detection and I may have been unable to hear frogs calling more than, e.g., 50-100 m away. The northern channel east of the central channel was not passable by canoe.

Among frog species of the northeastern states, only males produce advertisement calls or "songs." Advertisement calls generally serve to define a calling territory, attract later-arriving males to breeding areas, and attract females (Emerson 2001, Zug et al. 2001). (Both male and female frogs may produce sounds with other functions, such as distress calls emitted when caught by a predator, but the other calls of northeastern species are easily distinguished from male advertisement calls.) Human hearing cannot distinguish the individual frogs in a chorus unless the number is small, thus it is necessary to use an ordinal variable to express the size of a chorus. I used a widely adopted ranking system described by Lepage et al. (1997) and Brander et al. (2007):

0 = no individual heard
1 = calls of individuals can be counted separately, with space between calls
2 = calls of individuals are distinguishable with some calls overlapping
3 = full chorus with calls being continuous, overlapping, and too numerous to be counted

I recorded water quality data at Teterboro Airport on 12 June and at Upper Penhorn Marsh on 13 June with a HydroLab Surveyor 4 portable water quality probe.

Results

The results of the surveys are shown in Table 1. Despite the airport and highway noise, on the first survey date I heard choruses of southern leopard frog (*Rana sphenocephala utricularia* = *R. utricularia*) at three widely separated locations at the airport complex (Figure 1). These locations were the southeastern pond (a stormwater pond north of the 115 Moonachie Avenue building), small swampy pools on the west side of the airport passenger parking area (west of the Jet Aviation building), and flooded ditches(?) between the western airport gate (Industrial Avenue) and the runways. On the second survey date I heard no frogs, and on the third date I heard a single southern leopard frog. I heard no frogs at any of the pools or ditches in the swamps and wet woods of the "East Woods" (west of Redneck Avenue), "South Woods" (north of Route 36, apart from the area adjoining the west side of the commuter parking lot), or the wetlands adjoining the southwestern portions of the airport. Had I visited the Teterboro Southeast Pond a little later in the evening on the April survey, I might have heard a larger chorus of southern leopard frogs there – when I started the survey before dusk, this chorus was just beginning.

Table 1. Frog call survey results at two sites in the Hackensack Meadowlands, spring 2006.

Teterboro Airport			**Upper Penhorn Marsh**		
Date	*Location*	*Call rank*	*Date*	*Location*	*Call rank*
12 April	Southeast Pond	2	2 April	Central channel	1
	Pools W of parking	1		North channel	1
	Back (west) gate	2			
3 May	Southeast Pond	0	24 April	Central channel	2
	Pools W of parking	0		North channel	1
	Back (west) gate	0			
12 June	Southeast Pond	1	13 June	Central channel	0
	Pools W of parking	0		North channel	0
	Back (west) gate	0			

At Penhorn, I heard choruses of southern leopard frogs on the first and second survey dates, and no frogs on the third date. Frogs called at several locations along and near the northern half of the central channel, and in the northern channel west of the central channel. An area just west of the middle portion of the central channel supported the largest chorus of frogs, heard on the May survey date; this chorus was not accessible by canoe and was in an area of common reed stands interspersed with small channels and pools.

At both sites, I heard the characteristic "chucks" and interspersed "growls" of the southern leopard frog (White and White 2002; also see Schwartz and Golden 2002), although I did not necessarily hear both call types at each instance of frog vocalization. I did not see frogs during the call surveys. I saw two juvenile southern leopard frogs and photographed one of them in the small pools west of the passenger parking lot at Teterboro Airport on 1 July 2005. On 31 March 2006, Brett Bragin observed an adult southern leopard frog and we observed large tadpoles, presumably of the same species, in the "Southeast Pond" at Teterboro Airport.

Discussion

I have assigned the frogs detected in my surveys to southern leopard frog on the basis of published range information. Current literature identifies southern leopard frog as ranging throughout northern New Jersey and extreme southern New York, whereas northern leopard frog (*Rana pipiens*) is believed to range only as far south as the southern Hudson Valley of New York (Schwartz and Golden 2002, Gibbs et al. 2007). However, leopard frogs have recently been found in the Great Swamp of northern New Jersey, ca. 32 km (20 miles) west-southwest of my study areas, that appear morphologically intermediate between southern and northern leopard frogs (Jason Tesauro, J. Tesauro Ecological Consulting, personal communication, 2007).

Although only one species of frog was found on the surveys, the presence of small choruses of southern leopard frog in the freshwater wetlands of the Meadowlands is noteworthy. The southern leopard frog is common in southern New Jersey; it is considered rare in northern New Jersey (Schwartz and Golden 2002; J. Tesauro, personal communication 2007). Schlauch (1978) considered southern leopard frog "extremely endangered" in the Nassau County region of Long Island, New York. Mathewson (1955) considered the southern leopard frog (therein called *Rana pipiens* because northern and southern species had not yet been split) "common" on Staten Island. Southern leopard frog has now disappeared from Long Island and Staten Island (Jeremy Feinberg, Rutgers University, personal communication), and is listed as Special Concern in New York. Southern leopard frog is listed as Endangered in Pennsylvania where urbanization is considered the principal threat and the species occurs only in the southern Delaware Valley (Hulse et al. 2001).

Table 2a. Water quality data from the Teterboro Airport area, 12 June 2006.

Variable	**Southeast Pond – SE corner**	**Southeast Pond – NW corner**	**Ditch W of Southeast Pond**	**Ditch W of Redneck Av at Joseph St**
Time, EDT	1947	2000	2005	2040
Water depth, cm	20	12	7	15
Temperature, C	23.0	23.2	18.2	18.8
Dissolved oxygen, ppm	1.45	1.1	1.0	1.02
Dissolved oxygen, % saturation	20.0	16.0	12.7	13.2
Specific conductance, millisiemen/cm	0.347	0.108	0.262	1.278
Salinity, ppt	0.17	0.04	0.13	0.66
pH	6.23	6.28	6.20	6.36

Table 2b. Water quality data from Upper Penhorn Marsh, 13 June 2006 (readings taken ca. 10 cm below surface). Water depths were ca. 25-50 cm where water quality measurements were taken.

Variable	**Central channel (S) near sheds on RR**	**Central channel ca. 2/3 way SW to NE**	**Junction central and north channels**	**W end of north channel**
Time, EDT	2005	2045	2105	2125
Water depth, cm	Not recorded	Not recorded	Not recorded	Not recorded
Temperature, C	23.4	23.0	25.2	25.3
Dissolved oxygen, ppm	0.00	1.00	1.40	1.26
Dissolved oxygen, % saturation	0	14.0	15.9	18.8
Specific conductance, millisiemen/cm	0.943	1.206	1.396	1.436
Salinity, ppt	0.49	0.64	0.74	0.76
pH	6.87	6.85	6.72	6.88

Species may persist or thrive in urban areas for a variety of reasons, including reduced pressure from competitors, predators, or diseases; abundant food; extensive complexes of habitat; or other favorable physical and chemical conditions. The Meadowlands and the Great Swamp are both in the beds of postglacial lakes, which might make these areas more suitable for leopard frogs (J. Tesauro, personal communication), perhaps due to greater calcium availability than in the intervening landscape.

I was surprised not to hear other species of frogs during these surveys, inasmuch as habitats appeared suitable for, e.g., green frog (*Rana clamitans*), bullfrog (*Rana catesbeiana*), and American toad (*Bufo americanus*), and these other species have been observed recently in the Meadowlands. For example, on 3 May 2006, I heard an American toad calling at Laurel Hill. On 19 July 2004, I saw a frog that was probably a green frog at Laurel Hill. Possibly I failed to detect calls of other frog species because small populations called for brief periods between the dates of my surveys. American toad, for example, choruses briefly and in some years multiple times, in the Mid-Hudson region of New York (Kiviat, personal observation). If Meadowlands populations of American toad, green frog, and other frog species are very small (e.g., 1 or 2 calling males per location), calling might be very limited in seasonal and diel (daily) scope. It is also possible that transportation noise masked other species that were calling in areas inaccessible to me (central areas of Teterboro Airport and the marsh interior at Upper Penhorn).

Eleven species of frogs, all native, occur in northeastern New Jersey according to the range maps in Conant and Collins (1991) and Schwartz and Golden (2002) (if we consider the two chorus frogs mentioned in Schwartz and Golden as members of a single species; Table 3). All 11 species have been reported in the Meadowlands, although some species have apparently not been documented by means of specimens or photographs, and some of the reports are old (Table 3). Whereas it is likely that the eastern spadefoot, not reported in the Meadowlands since 1936, is extirpated from the area, other species that have not been reported recently such as Fowler's toad may still occur in the Meadowlands. I have not observed the bullfrog in the Meadowlands but it has been reported recently in two areas near Overpeck Creek (Teaneck and Leonia) in the northeastern Meadowlands (Mary Arnold, personal communication; Steven Covacci, personal communication).

Many amphibians require still water with abundant living or dead plant material and lacking connections to larger water bodies. These small, quiet pools are vulnerable to the accumulation of pollutants. Water quality was poor where I recorded data (Table 2). Dissolved oxygen was mostly 1-1.5 ppm, with a single reading of 0 ppm in a "stagnant" area covered with plant debris and garbage in the southern corner of Upper Penhorn Marsh. Although frog larvae are facultative air breathers, low DO may be stressful to some species. Salinity was always < 1 ppt; however, the highest readings (0.64. 0.66, 0.74, 0.76 ppt) might exclude the more sensitive species. pH, between 6 and 7, should not be a challenge to northeastern amphibians, and likewise the water temperatures were not too high.

Table 3. Frog species reported from the Meadowlands. Common and scientific names follow Schwartz and Golden (2002). Sources: ACOE = US Army Corps of Engineers 2000; AMNH = American Museum of Natural History (specimens); McCormick = McCormick & Associates 1978; NJTA = New Jersey Turnpike Authority 1986; Quinn = Quinn 1997.

Common name	**Scientific name**	**Last reported**	**Data source**
Northern cricket frog	*Acris crepitans crepitans* Baird	Before 2000	ACOE
American toad	*Bufo americanus* Holbrook	2006	ACOE; E Kiviat
Fowler's toad	*Bufo fowleri* Hinckley	1960s	ACOE; AMNH; RP Kane
Northern gray treefrog	*Hyla versicolor* Le Conte	Before 2000	ACOE; NJTA
Spring peeper	*Pseudacris crucifer* Wied-Neuwied	Before 2000	ACOE; NJTA
Chorus frog	*Pseudacris* sp.	Before 2000	ACOE
Bullfrog	*Rana catesbeiana* Shaw	2007	M. Arnold, S. Covacci
Green frog	*Rana clamitans melanota* Latreille	2004	McCormick; Quinn; E Kiviat
Pickerel frog	*Rana palustris* Le Conte	Before 1997	Quinn
Southern leopard frog	*Rana sphenocephala utricularia* Harlan	2006	This study
Eastern spadefoot	*Scaphiopus holbrookii* (Harlan)	1936	American Museum of Natural History

I believe that the impoverishment of the Meadowlands frog fauna is a result of salinity intrusion, loss of natural upland soils, toxic contamination, poor water quality, and fragmentation of the landscape (Kiviat and MacDonald 2002, 2004). The Teterboro area, for example, was intensively farmed during the early 1900s before airport development (Patrick Bonner, New York – New Jersey Port Authority, personal communication). A frog species like the spring peeper, very common in rural areas of northeastern New Jersey, could have been extirpated from Teterboro by agriculture and land development. Once an amphibian species has been extirpated from an urban area, it may be unable to recolonize due to the fragmented character of habitats and the lack of dispersal corridors such as undeveloped riparian areas and unpolluted streams. Spring peeper, and many other amphibians including common, ecologically tolerant, species such as green frog, require large areas (many hectares) of adjacent wetland and upland habitats. Although the Upper Penhorn Marsh is largely protected from salinity intrusion by a tidegate and stormwater pumping (Don Smith, personal communication, 2006), and the quality of the habitat appears generally good, there is virtually no undeveloped upland adjoining the marsh. This lack of the necessary habitat combination may make Penhorn unsuitable for establishment of a resident population of green frogs or spring peepers. Although southern leopard frog is known to travel far from water (Schwartz and Golden 2002, White and White 2002), these frogs may be able to survive in the Upper Penhorn Marsh with little access to upland habitat, and may be protected by the large expanses of common reed (*Phragmites australis*) from flooding and pollution in Penhorn Creek. Southern leopard frog is known to tolerate mildly brackish water (Schwartz and Golden 2002, White and White 2002, Dodd and Barichivich 2007, Kenney et al. no date).

I recommend continuation of frog surveys in the Meadowlands because the frog community is useful as an indicator of biodiversity quality and environmental quality, and the public is interested in frogs. My intensive frog surveys were necessary to locate frog choruses in the first study year. I recommend, however, that in 2008 a network of automated remote recording devices ("frog loggers"; Heyer et al. 1994, Barichivich 2003) be established and calibrated. Once frog loggers are deployed in appropriate locations, it should be possible to monitor frog choruses with less human effort. Even in noisy locations like Teterboro, transportation noise might be electronically filtered out of frog logger recordings, making it easier to detect frog calls, identify species, and rank abundance of individuals. Frog loggers will need to be calibrated in the field by human observers. Calibration of loggers and interpretation of the data must be performed by persons who know the vocalizations of the regional frogs well, as illustrated by the following anecdote. On the 13 June survey at Penhorn, I briefly thought I heard a northern cricket frog, which is a rare possibility in the Meadowlands. On careful listening, however, I determined that it was the song (*tick-et* or *kid-ick*) of a Virginia rail (a bird) rather than a frog call.

To obtain a more representative survey of Meadowlands frogs, in addition to the Teterboro Airport and Upper Penhorn Marsh, other sites should be monitored. Visits in early May would allow confirmation of frog choruses (if present) at fresh or nearly-fresh sites such as Kearny Marsh West (Kearny Freshwater Marsh), a sand pit pond at upper Bellmans Creek, small pools at Laurel Hill, and (albeit outside the Meadowlands District) two locations where bullfrogs have been found recently at tributaries of Overpeck Creek. It would be helpful to obtain permission from New York – New Jersey Port Authority to reconnoiter and to install and maintain frog-loggers at Teterboro Airport at key locations inside the security fences.

It would be useful to supplement the call surveys with a netting or trapping survey for larvae (tadpoles). This might discover frog species not heard calling, as well as the potential occurrence of salamanders such as the red-spotted newt or spotted salamander. Larval surveys could be performed by dipnetting in June (Nyman 2001), accompanied by setting unbaited, weighted, plastic minnow traps; substantial effort would be required due to low population densities. Recommendations for netting amphibian larvae were provided by Heyer et al. (1994).

Acknowledgments

Brett Bragin showed me candidate survey sites. Joseph Sarnoski loaned and calibrated the HydroLab 4; Stuart Findlay and Bob Schmidt helped with interpretation of water quality. Francisco Artigas and Christine Hobble worked with me on the logistics of the surveys. Patrick Bonner provided information about Teterboro Airport and made arrangements for access. Tina Schvejda provided information on frog-loggers. Alex Martí collected the GPS data and prepared the transect maps and I thank Dom Elefante for this service. Brett Bragin, Jeremy Feinberg, and Jason Tesauro commented on a draft of this paper. This study was funded by the Meadowlands Environmental Research Institute of the New Jersey Meadowlands Commission. This is Bard College Field Station – Hudsonia Contribution 104.

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Butterfly, Dragonfly, and Damselfly Transect Surveys in an Urban Wetland Complex of the Hackensack Meadowlands, New Jersey

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Abstract

We tested a strip transect sampling technique for adult odonates and butterflies in the Hackensack Meadowlands, New Jersey, an urban wetland complex. We sampled five 1-km walking transects on dirt roads, divided in 100 m segments at 10 min each segment. We identified and counted all adult odonates and butterflies seen within 5 m either side of the roadbed, once each transect, on mornings at the end of June 2006. Counts totaled 106 individuals of 21 species of butterflies, and 303 individuals of 22 species of odonates (12 dragonflies, 10 damselflies). Damselflies were virtually limited to two transects. Four additional species of butterflies and two of odonates were recorded within 100 m of the transects on the survey days. We identified and ranked abundance of woody plants and selected nectar plants on transects by segment. Dragonfly abundance and species richness, and butterfly abundance and richness, were similar among transects. Damselfly abundance and richness, and the rank sums and species richness of trees, shrubs, vines (woody and herbaceous combined), and nectar plants were significantly different among transects. Dragonfly abundance and richness were negatively correlated with almost all woody plant rank sum and richness variables (all $p < 0.03$), damselfly abundance and richness were positively correlated with all woody plant rank sum and richness variables (all $p < 0.02$), but butterfly abundance and richness were not correlated with any vegetation component including nectar plants (all $p > 0.2$). Apparently dragonflies and butterflies are mobile enough to adjust their activities to spatial variation in vegetation. Our transect method seems effective for sampling urban butterflies and odonates in the Meadowlands and should be tested in other urban and non-urban environments.

Key words: Lepidoptera, monitoring, Odonata, urban biodiversity, vegetation habitat, water quality, wetlands.

Introduction

Little is known about butterflies and odonates (dragonflies and damselflies) in urban areas of the United States, and knowledge of these organisms in the Hackensack Meadowlands of New Jersey is limited to a few qualitative reports. Butterflies and odonates are increasingly recognized as indicators of environmental quality and as subjects of nature study (Glassberg 1993, Revkin 1999), and are considered useful for environmental monitoring (Kremen 1992, Catling and Brownell 2001, D'Amico et al. 2004, Catling 2005, Sawchik et al. 2005, Freest 2006). Pyle (1998) noted that butterflies are often useful as indicators or surrogates because they are conspicuous and relatively well-known, moderately species-rich, host plant and habitat-specific, and susceptible to environmental alterations. Butterfly abundance and diversity are related to the availability of larval food plants and nectar sources for adults, shelter, suitable microclimates, and an environment that is not significantly contaminated with insecticides (e.g., Takamura et al. 1991, Dover et al. 1997, Gochfeld and Burger 1997, VanReusel et al. 2007). Occurrence of butterfly species also may be related to soil characteristics (moisture, organic matter content, pH, and mineral nutrient levels; Sawchik et al. 2005). Some butterflies thrive in human-disturbed habitats including urban habitats, and many disturbed habitats support higher densities of butterflies than wilder habitats (Opler and Krizek 1984:24, Cech and Tudor 2005). Recently there has been much concern about declines of native pollinators, including butterflies, in the U.S. (e.g., Cane and Tepedino 2001, Shepherd et al. 2003).

Butterfly faunas have been monitored by means of the Fourth of July Butterfly Counts in North America (http://www.naba.org/counts.html; Swengel 1990, Gochfeld and Burger 1997), in which participants find and identify as many species and individuals as possible during an early summer day within a 15 mile (24.2 km) diameter circle. In the U.K., butterflies have been monitored by means of the British Butterfly Monitoring Scheme in which species and individuals are counted on a long strip transect (Pollard and Yates 1993). Standardized monitoring methods for odonates have not received as much attention in the U.S., although a few field workers have performed quantitative surveys at particular sites (e.g., Catling 2005, Bried and Ervin 2006). Adult odonates are also recorded during the Salisbury, Connecticut, Fourth of July Butterfly Count (David Wagner, University of Connecticut, personal communication). Our surveys, conducted on space and time-constrained walking transects, were designed to identify to species and quantitatively sample adult butterflies and odonates for the purpose of a biodiversity index that would be repeated annually for many years, i.e., a method for long-term monitoring of the butterfly and odonate communities as indicators of biodiversity.

Methods

The Hackensack Meadowlands (New Jersey Meadowlands) adjoin the tidal Hackensack River from the Oradell Dam downstream to Newark Bay in Bergen and Hudson counties, northeastern New Jersey, just north of the Wisconsinan glacial boundary and as few as 4 km west of Manhattan. The core portion of this area is the Meadowlands District which covers 7889 ha and includes portions of 14 municipalities (http://www.meadowlands.state.nj.us). In an area somewhat larger than the District, 2243 ha (5541 acres) of wetland remained in 1995 and this was 28% of the wetlands present in 1889 (Tiner et al. 2002). Although at various times large areas were dominated by Atlantic white cedar (*Chamaecyparis thyoides*) swamps or cordgrass (*Spartina*) marshes, the landscape is now a mixture of smooth cordgrass (*S. alterniflora*) marshes, tidal and nontidal common reed (*Phragmites australis*) marshes, upland meadows on inactive garbage landfills and other wetland fill, small areas of wet and dry hardwood forest, a variety of small patches and borders with upland or wetland vegetation, and industrial, commercial, residential and transportation development (Kiviat and MacDonald 2002, 2004; Tiner et al. 2002). Despite a legacy of habitat conversion, dumping, contamination, development, and pollution, native species diversity is moderate to high in some groups of organisms including vascular plants, birds, and fishes (Kiviat and MacDonald 2004). The bird fauna of the Meadowlands in particular is well known for its diversity and for the occurrence of many rare species.

Most adult butterflies and odonates are relatively easy to spot and identify in the field, and good field guides and identification manuals are available. We wanted to collect annual quantitative data on butterflies and odonates that could be analyzed in a time series for changes in the community. Few American researchers have sampled adults of these taxa with replicable techniques.

We used a strip transect method based on the British Butterfly Monitoring Scheme (Pollard and Yates 1993, Plant et al. 2005b) and adapted to serve the simultaneous sampling of butterflies and odonates. The British scheme uses dirt roads or footpaths of variable length (3 km is considered optimal) divided into habitat segments, with all butterflies counted within ca. 5 m either side of the road. There have been several variants on the width of the strip in which butterflies are counted, and the manner of counting (Gochfeld and Burger 1997). We found few examples of quantitative surveys of adult odonates. Bried and Ervin (2006) counted selected species of dragonflies on 10 m wide transects on uplands perpendicular to a lake shore in Mississippi. Catling (2005) made time-constrained (20 min) counts of adult odonates at individual sewage ponds in Ontario. Plant et al. (2005a and references cited therein) described odonate monitoring methods in Europe, and stated that under ideal conditions counts of adult odonates should be reasonably precise.

We identified a single, end of June, survey period when most of the odonates and butterflies of northeastern New Jersey are "flying," i.e., detectable in the adult stage. This period has been well established as late June – early July for purposes of the Fourth of July Butterfly Count which has been conducted since 1975. We analyzed the flight periods of the odonates of northeastern New Jersey based on data of the New Jersey Odonata Survey (http://www.njodes.com/njos/njosdata.asp?choice=date). Ninety per cent of the 29 damselflies and 92% of the 66 dragonflies are flying during the 27 June through 1 July period of our 2006 surveys. Three species of damselflies and 3 species of dragonflies fly only later than the end of our survey period, and 1 dragonfly flies only before the beginning of the period. At least two survey periods would be required to intersect the flight periods of all odonate species, one in early or mid-June, and the second in mid to late August.

We counted adult butterflies and odonates in space and time-constrained samples on 1 km long strip transects (Figure 1). Transects followed dirt roads (Pollard and Yates 1993) that were restricted or partly restricted from public use. We chose the 1 km length to fit within available sites and provide a large enough sample, and we wanted all transects to have the same dimensions so they could be considered statistical replicates. We selected sites in consultation with MERI, visiting a dozen candidate sites and selecting five on the basis of habitat composition, accessibility, and shelter from high winds (Table 1). We avoided salt marshes dominated by cordgrasses (*Spartina* spp.) because such habitats support few butterfly and odonate species. All selected transects had diverse floras of native and introduced woody and non-woody plants, and all were close to fresh or slightly brackish waters suitable as odonate larval habitats. We divided each transect in 10 marked segments each 100 m long. We marked segments with flagging tape but avoided stakes or more conspicuous markers due to concern about vandalism. MERI prepared GPS-GIS maps of the transects (Figure 1, Appendix 1).

We sampled each transect by walking slowly together, spending 10 min per segment (100 min for the whole transect). One of us focused on spotting insects and the other on recording data as well as spotting. We counted all adult butterflies and odonates, flying or perched, in a strip of vegetation 5 m wide outward from the vegetated edge of the road as well as insects flying over or perched on the unvegetated roadbed. We only counted insects in the transect segment we were surveying at the time, whether spotted in front of or behind us. We conducted the surveys on five consecutive days (27 June – 1 July 2006). The afternoon before each survey we visited the transect to familiarize ourselves with the segment flags and the fauna. Each survey began at 1000 hours EDT. During the surveys, the weather was warm with low wind speeds and variable sun and cloud cover (Table 1). There were heavy rainfalls early and late on some days. We netted individuals for closer examination if necessary for identification. We did not intentionally disturb the vegetation to flush insects although we occasionally left the road for a closer look at an unidentified species. One hundred minutes per transect allowed ample time for careful observation of a reasonable number of species and individuals. We collected voucher specimens of a few difficult species; Ken Soltesz (Westchester County, New York, Parks Department) confirmed our identifications. Any additional butterfly or odonate species observed within 100 m of the transect on the day of the survey was recorded as an off-transect observation.

After surveying each transect, we collected floristic data on the return trip. We identified all vascular plants within the strip transect, and ranked woody plants, all vines, and selected nectar plants on a scale of 0-4 (absent, rare, uncommon, common, or abundant, respectively) in each sector. We ranked the following nectar plants (in flower during the surveys): *Apocynum cannabinum, Asclepias syriaca, Centaurea maculosa, Chrysanthemum leucanthemum, Cirsium arvense, Coreopsis* sp., *Coronilla varia, Hypericum punctatum,* and *Lythrum salicaria.* Other herbaceous plants were simply recorded as present on the transect.

We measured surface water quality at selected locations on 3 of the 5 transects with a HydroLab Surveyor 4 portable water quality probe.

Data analysis

We summed species rankings (0, 1, 2, 3, or 4) separately for selected groups of plants: trees, shrubs, vines, and nectar plants, by transect segment ("vines" included both woody and herbaceous vines). We also calculated total individuals of damselflies, dragonflies, odonates (damselflies + dragonflies), butterflies, and butterflies + odonates for each segment, as well as the numbers of species (richness) for each of these groups for each segment (species richness excludes "unidentified" categories which may overlap identified species). We also counted the numbers of species (species richness) of vines, shrubs, and trees. We performed Spearman rank correlations on all possible pairs of the above-mentioned variables. We also performed Kruskal-Wallis ANOVAs by ranks to test the hypothesis of no difference in data distributions among transects on each of the same variables ($\alpha = 0.05$). Statistics were performed using segment as the sampling unit. All statistical and graphical analyses were performed with Statistica version 7 (StatSoft, Inc., Tulsa, Oklahoma).

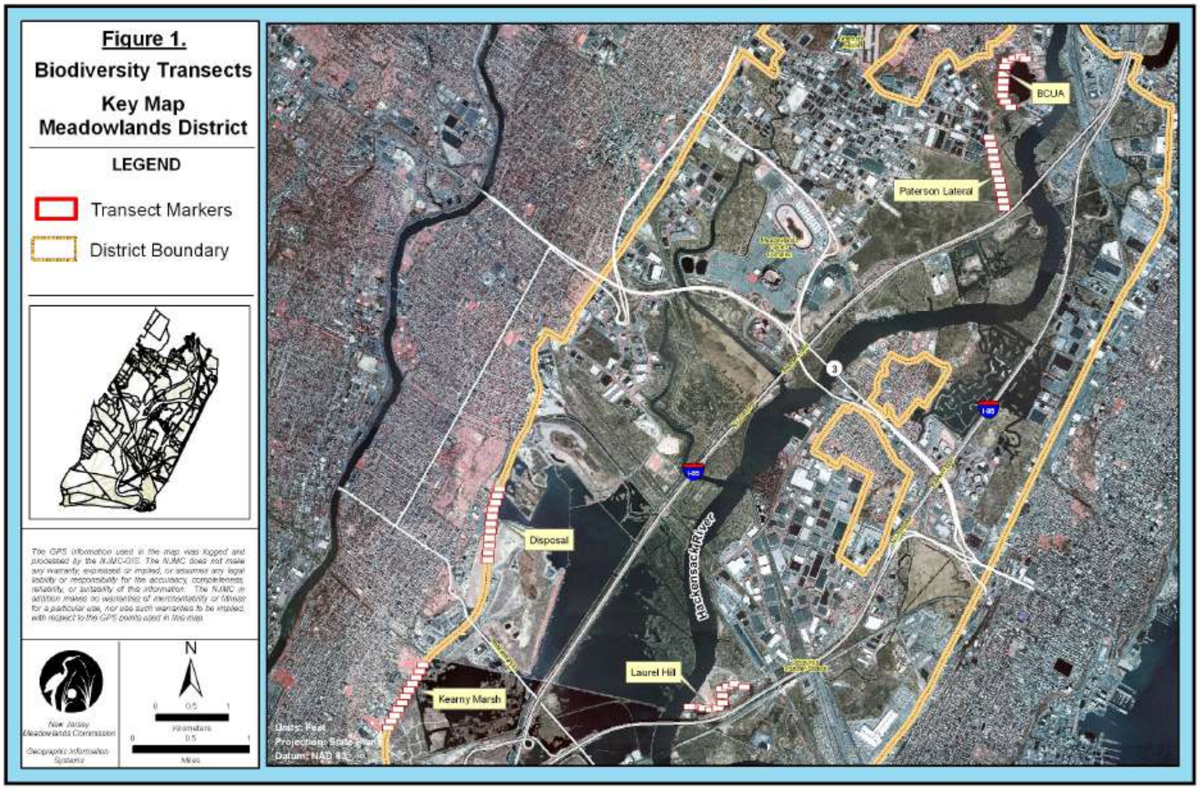

Figure 1. Map showing butterfly-odonate transect locations in the Hackensack Meadowlands, New Jersey. (See Appendix 1 for large-scale maps of the five transects.)

Table 1. Characteristics of transects for surveying adult butterflies and odonates, Hackensack Meadowlands, 2006. * indicates the transect route was open to the public *de facto*.

Transect	Municipality	Date surveyed	Weather**	Description
Kearny (Kearny Marsh West)*	Kearny	27 June	2-3, 75%, p	Nontidal reed marsh, inactive landfill, park, industrial; cinder road on old rail bed with abundant woody vegetation; much ORV use
BCUA (Bergen County Utilities Authority - Mehrhof Pond)	Little Ferry	28 June	1-2(3), 85%, p	Wet meadow, woods, lawn and weedy edges, clay pit lake; dirt road, limited ORV use
Laurel (Laurel Hill)*	Secaucus	29 June	0-1, 100%, n	Abandoned quarry floor (cut and fill), weedy areas, open woods, athletic fields, stump dump, near brackish tidal mainstem of Hackensack River; dirt maintenance roads and roadless areas; some ORV use
"Pat Lat" (Paterson Lateral Gas Pipeline segment crossing Richard P. Kane Natural Area)*	Carlstadt, South Hackensack	30 June	1-3(4), 5-45%, s	Nontidal reed marsh, thickets, industrial, woodland; sparse to abundant woody vegetation; near brackish tidal mainstem of Hackensack River; dirt road with many near-permanent rain pools, on gas pipeline; much ORV use
Disposal (west of Harrier Meadow – 1E Landfill)	North Arlington	1 July	1-2(3), 0%, s	Brackish tidal bay, wet meadow, woods, weedy-reedy edges; abundant woody vegetation; dirt road with light traffic, no ORV use observed

** Weather: Beaufort wind scale (0-3), cloud cover (%), sun (n = none, p = partly sunny, s = sunny).

Common and scientific names follow Gochfeld and Burger (1997) for butterflies, and Nikula et al. (2003) for odonates. Scientific names of vascular plants follow Gleason and Cronquist (1991).

Results

On the transects we recorded 21 species of butterflies (14 true butterflies and 7 skippers [Hesperiidae]; Table 2) and 22 species of odonates (12 dragonflies, 10 damselflies; Table 3). Four additional butterfly species and two additional odonate species that did not occur on any transect were recorded off-transect on the survey days (Table 4). Damselflies, which are generally weaker fliers than dragonflies, were common on two surveys (Kearny and BCUA) and nearly absent from the other three surveys. Overall, we counted 409 insects on the five surveys combined, for a mean of 81.8 insects per transect, or 8.18 insects per segment. There was a total of 106 butterflies (mean of 21.2 per transect), and a total of 303 odonates (mean of 60.6 per transect).

Figures 2-4 show the variation in total individuals and total species (species richness) of butterflies, damselflies, and dragonflies per segment by transect. Kruskal-Wallis ANOVAs suggest that the transects do not differ from one another by total dragonflies, dragonfly richness, odonate richness, total butterflies, and butterfly richness, but the transects do differ by total

Table 2. Butterfly species recorded on five 1-km strip transects along dirt roads in the Hackensack Meadowlands, New Jersey, in early summer 2006. See Table 1 for details of transect locations. Illustrations, geographic ranges, and life histories of these butterflies are in Gochfeld and Burger (1997) and Cech and Tudor (2005).

Common name	**Scientific name**	**Kearny**	**BCUA**	**Laurel**	**Pat Lat**	**Disposal**	**Total**
Monarch	**Danaidae**						
Monarch	*Danaus plexippus*	0	0	0	1	2	3
Skippers	**Hesperiidae**						
Delaware skipper	*Anatrytone logan*	0	1	0	0	0	1
Least skipper	*Ancyloxypha numitor*	2	0	0	1	0	3
Silver-spotted skipper	*Epargyreus clarus*	0	1	1	0	0	2
Wild indigo duskywing	*Erynnis baptisiae*	0	0	0	1	3	4
Broad-winged skipper	*Poanes viator*	0	0	0	0	3	3
Long dash	*Polites mystic*	0	0	0	1	0	1
Northern broken-dash	*Wallengrenia egeremet*	0	0	0	0	3	3
Blues	**Lycaenidae**						
Summer azure*	*Celastrina neglecta*	0	4	6	1	0	11
Eastern tailed blue	*Everes comyntas*	0	0	0	0	1	1
Brushfoots	**Nymphalidae**						
Common wood nymph	*Cercyonis pegala*	0	1	0	0	0	1
Little wood satyr	*Megisto cymela*	0	2	2	0	0	4
Mourning cloak	*Nymphalis antiopa*	0	1	0	0	1	2
Pearl crescent	*Phyciodes tharos*	0	0	1	0	0	1
Red admiral	*Vanessa atalanta*	0	0	0	1	1	2
Swallowtails	**Papilionidae**						
Eastern tiger	*Papilio glaucus*	3	1	0	1	0	5
Black swallowtail	*Papilio polyxenes*	0	0	1	0	2	3
Spicebush swallowtail	*Papilio troilus*	0	1	0	0	0	1
Whites and Sulphurs	**Pieridae**						
Orange sulphur	*Colias eurytheme*	0	0	7	2	4	13
Clouded sulphur	*Colias philodoce*	0	0	0	1	2	3
Cabbage white	*Pieris rapae*	9	10	6	3	11	39
Total individuals		14	22	24	13	33	106
Total species		3	9	7	10	11	21

*The genus *Celastrina* contains several cryptic species in the eastern states and azure taxonomy is a matter of much debate (see Pratt et al. 1994). Based on information in Gochfeld and Burger (1997), we assigned the azures on our transects to the summer azure (*C. neglecta*).

damselflies, damselfly richness, and total odonates. Thus the transects appear to be useful spatial replicates with regard to dragonflies and butterflies but not damselflies which are too heterogeneous in distribution. Spatial replication improves the utility of these surveys for monitoring purposes (of course, the five transects may not be as homogeneous in every year, and additional transects might make the set of transects heterogeneous).

No composite variable (abundance, species richness) was significantly correlated with segment (number 1-10; all P > 0.4). Thus there did not appear to be a time-of-day factor in count results from one end of a transect to another.

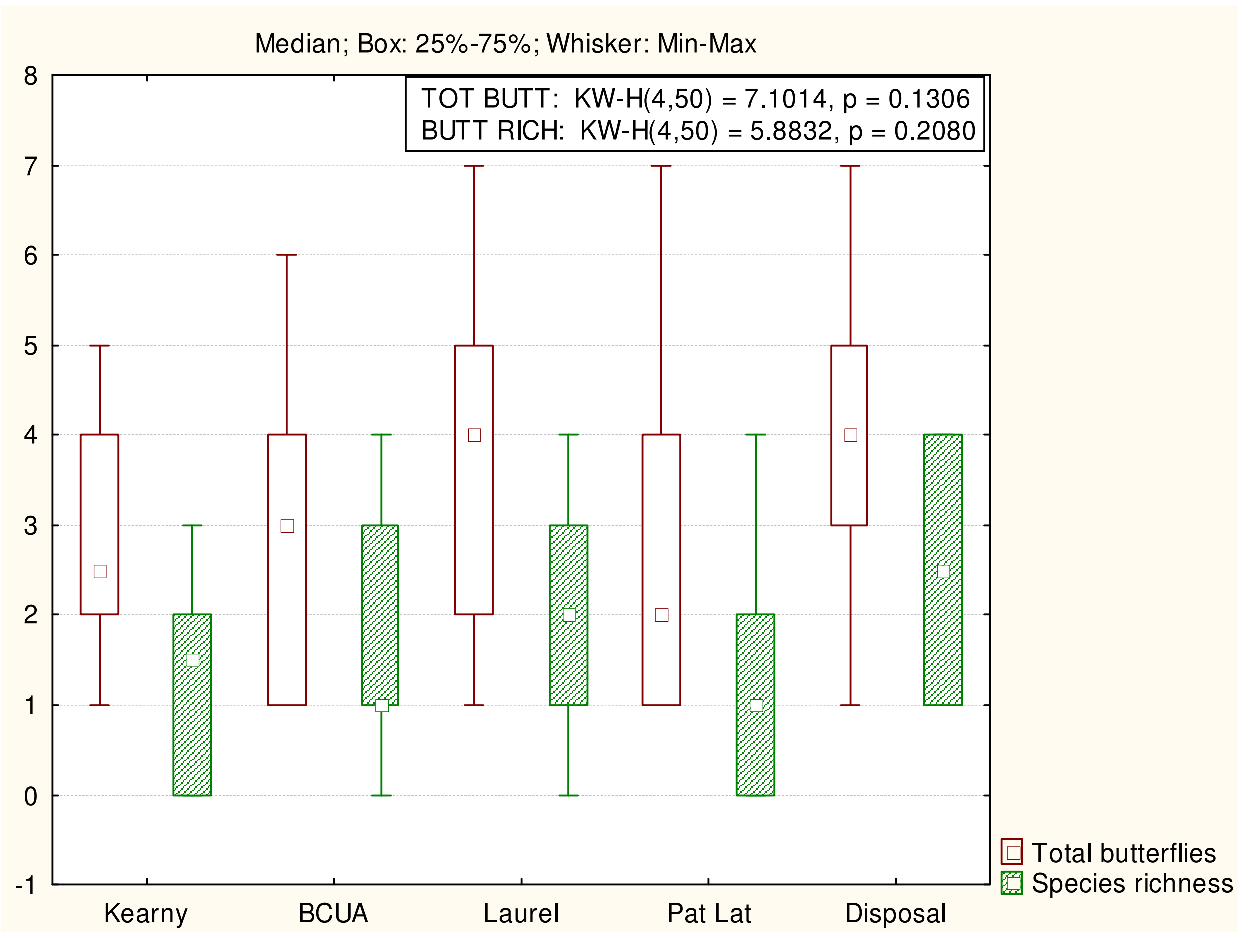

Figure 2. Total butterflies and butterfly species richness per 100 m segment on five transects in the Hackensack Meadowlands, early summer 2006. See Table 1 for details of transect locations. (The high probabilities generated by Kruskal-Wallis analysis of variance by ranks suggest the transects are similar on the butterfly variables.)

Table 3. Adult odonates recorded on five 1-km strip transects along dirt roads in the Hackensack Meadowlands, New Jersey, in early summer 2006. See Table 1 for details of transect locations. Total species (species richness) excludes "unidentified" categories which could overlap identified species. Photographs, range maps, and species descriptions of these odonates may be viewed on the Web at Odonata Central http://odonatacentral.bfl.utexas.edu/; also see Nikula et al. (2003).

Common name	Scientific name	Kearny	BCUA	Laurel	Pat Lat	Disposal	Total
Damselflies	**Zygoptera**						
Blue-fronted dancer	*Argia apicalis*	0	16	0	0	0	16
Powdered dancer	*Argia moesta*	0	1	0	0	0	1
Azure bluet	*Enallagma aspersum*	0	1	0	0	0	1
Familiar bluet	*Enallagma civile*	0	17	3	0	1	21
Big bluet	*Enallagma durum*	2	0	0	0	0	2
Orange bluet	*Enallagma signatum*	15	14	0	0	0	29
Unidentified bluet	*Enallagma* sp.	0	2	0	0	0	2
Fragile forktail	*Ischnura posita*	14	0	0	0	0	14
Rambur's forktail	*Ischnura ramburii*	9	0	0	0	0	9
Eastern forktail	*Ischnura verticalis*	14	2	0	0	0	16
Unidentified forktail	*Ischnura* sp.	14	0	0	0	0	14
Slender spreadwing	*Lestes rectangularis*	0	1	0	0	0	1
Unidentified spreadwing	Lestidae	2	0	0	0	0	2
Unidentified damselfly	Zygoptera	1	7	0	0	0	8
Dragonflies	**Anisoptera**						
Banded pennant	*Celithemis fasciata*	0	0	0	1	0	1
Halloween pennant	*Celithemis eponina*	0	0	0	0	1	1
Eastern pondhawk	*Erythemis simplicicollis*	2	0	6	0	0	8
Widow skimmer	*Libellula luctuosa*	0	1	0	0	0	1
Common whitetail	*Libellula lydia*	1	1	8	1	7	18
Needham's skimmer	*Libellula needhami*	2	0	0	22	5	29
Twelve-spotted skimmer	*Libellula pulchella*	0	1	0	0	0	1
Painted skimmer	*Libellula semifasciata*	0	0	0	1	0	1
Blue dasher	*Pachydiplax longipennis*	11	2	59	2	0	74
Spot-winged glider	*Pantala hymenaea*	0	0	0	10	4	14
Eastern amberwing	*Perithemis tenera*	2	3	1	1	1	8
Black saddlebags	*Tramea lacerata*	0	1	0	0	2	3
Unidentified dragonfly	Anisoptera	1	4	0	1	2	8
Total individuals		90	74	77	39	23	303
Total species (excluding "unidentified")		10	13	5	7	7	22

Interestingly, the plant variables (Figures 5-7), both rank sums and richness, are heterogeneous across transects. Kearny and BCUA have higher rank sums and higher richness for woody species. There are no significant correlations of butterfly abundance or species richness with the plant variables ($0.22 < p < 0.80$ for all correlations).

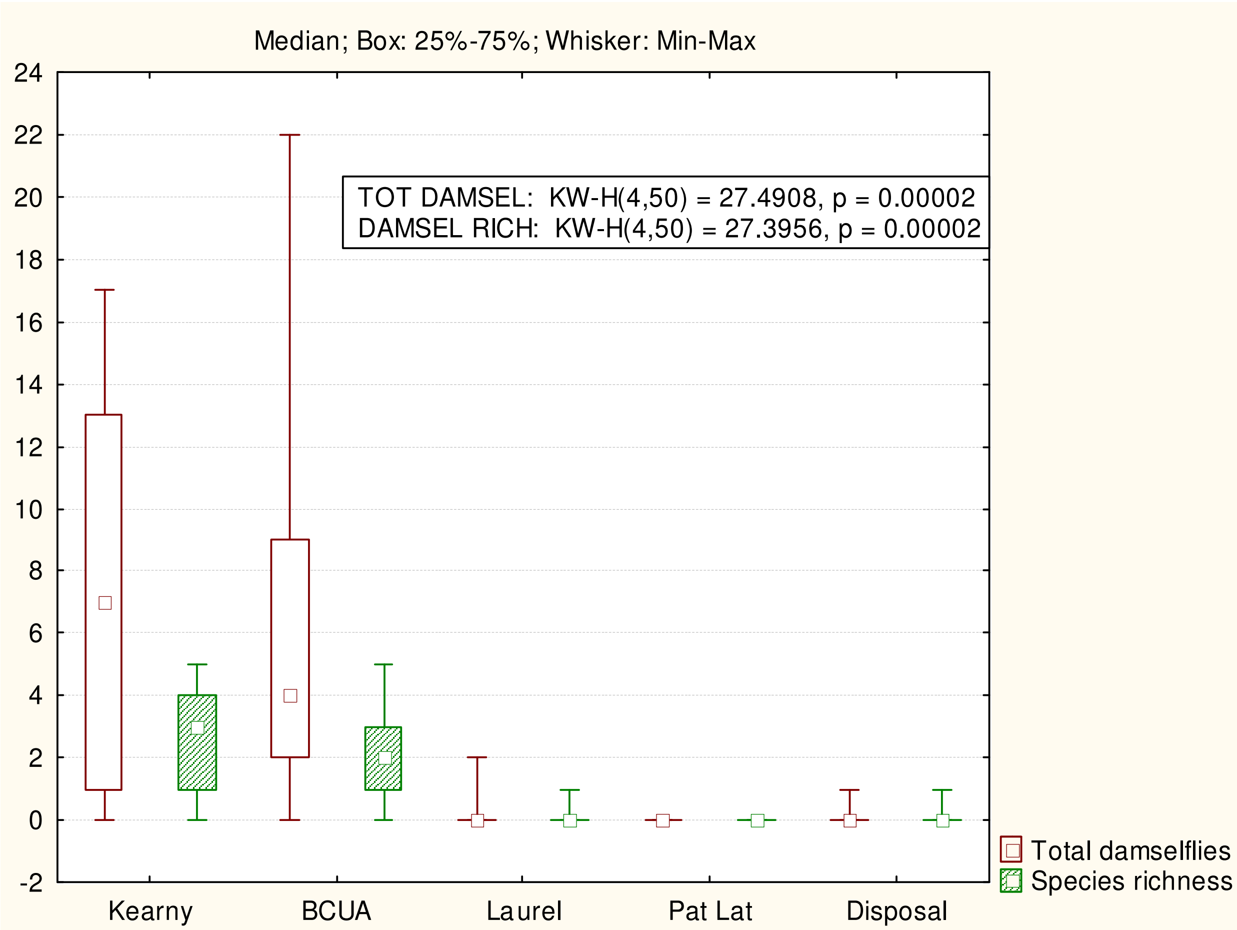

Figure 3. Total damselflies and damselfly species richness per 100 m segment on five transects in the Hackensack Meadowlands in early summer 2006. See Table 1 for details of transect locations. The Kruskal-Wallis analysis of variance by ranks statistic H, and the probability, are shown in the inset (the low probabilities suggest the transects are dissimilar on the damselfly variables).

Several species of butterflies and odonates were recorded off-transect at each of the five transects (Table 4). Six of these species (two odonates and four butterflies) were not found on any of the transects.

We noted a number of instances of butterflies visiting flowers for nectar (some are in Table 5). Many of the nectar plants are introduced species.

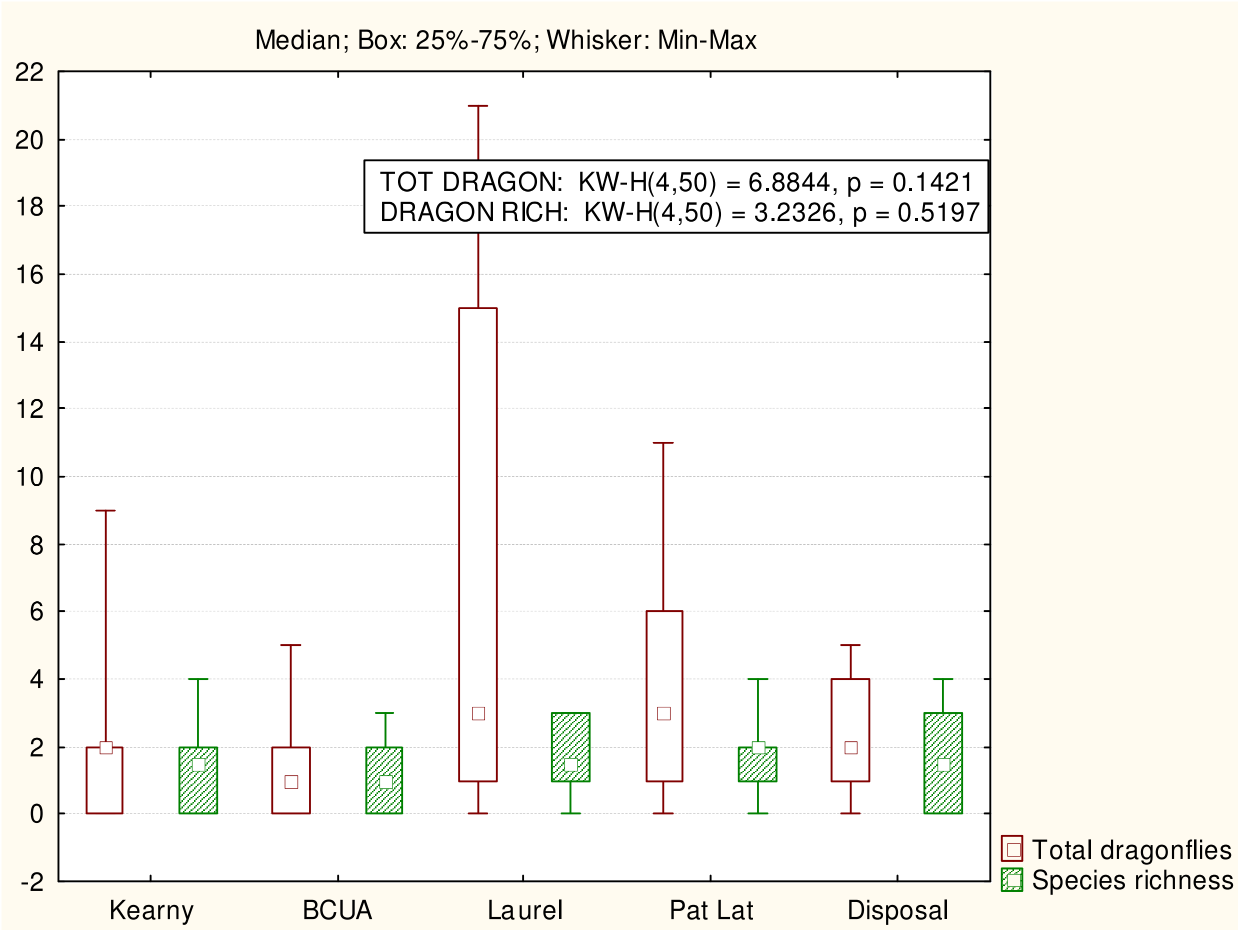

Figure 4. Total dragonflies and dragonfly species richness per 100 m segment on five transects in the Hackensack Meadowlands, early summer 2006. See Table 1 for details of transect locations. The high probabilities for Kruskal-Wallis H suggest the transects are similar on the dragonfly variables.

Butterfly numbers and species richness were not correlated with the rank sums of nectar plants (both $P > 0.27$), although the rank sums of nectar plants differed among transects (Figure 8).

Dragonfly numbers and species richness were negatively correlated with woody plant rank sums and species richness ($0.000247 < p < 0.01$), except for vine rank sum ($p = 0.08$) and vine richness ($p = 0.1$). Damselfly numbers and species richness were positively correlated with woody plant rank sums and species richness ($0.000001 < p < 0.0150$). The two transects on which damselflies were abundant, Kearny and BCUA, had woody vegetation bordering large areas of the transects (however, most of the damselflies were seen in open areas rather than shaded areas). A scatterplot of damselfly numbers against dragonfly numbers suggested an inverse correlation, but the Spearman rho was not significant ($p = 0.17$). Dragonfly abundance ($p = 0.032$) and richness ($p = 0.030$) were positively correlated with the rank sum of nectar plants. Damselfly abundance ($p = 0.00013$) and richness ($p = 0.00005$) were negatively correlated with the rank sum of nectar plants.

Table 4. Off-transect records of butterflies and odonates. These represent observations of species seen within 100 m of the transect on the same day as the count. Species indicated * were not found on any of the five transects. See Table 1 for details of transect locations.

Common name	**Scientific name**	**Kearny**	**BCUA**	**Laurel**	**Pat Lat**	**Disposal**
*Common green darner	*Anax junius*				1	
Familiar bluet	*Enallagma civile*	1				
Unidentified bluet	*Enallagma* sp.				1	
Eastern forktail	*Ischnura verticalis*			1		
Unidentified forktail	*Ischnura* sp.				1	
Needham's skimmer	*Libellula needhami*			3		
*Great blue skimmer	*Libellula vibrans*		1	1		
Blue dasher	*Pachydiplax longipennis*					1
Spot-winged glider	*Pantala hymenaea*	1	1	2		
Black saddlebags	*Tramea lacerata*			1		
Least skipper	*Ancyloxypha numitor*		1			1
Summer azure	*Celastrina neglecta*					2
Clouded sulphur	*Colias philodoce*	1				
Silver-spotted skipper	*Epargyreus clarus*	1				
Wild indigo duskywing	*Erynnis baptisiae*			4		
Eastern tailed blue	*Everes comyntas*		1			
*Common buckeye	*Junonia coenia*		1			
Little wood satyr	*Megisto cymele*	1				
Eastern tiger swallowtail	*Papilio glaucus*					1
Black swallowtail	*Papilio polyxenes*			1		
Pearl crescent	*Phyciodes tharos*					3
Broad-winged skipper	*Poanes viator*				1	9
*Questionmark	*Polygonia interrogationis*					1
*Little glassy wing	*Pompeius verna*			1		
*European skipper	*Thymelicus lineola*	1				
Red admiral	*Vanessa atalanta*			1		
Northern broken-dash	*Wallengrenia egeremet*			1		

Common reed (*Phragmites australis*) covers large areas of the Meadowlands, and was present to a variable degree at each transect. Dragonfly species richness was weakly correlated with common reed abundance rank ($p = 0.0290$). Other composite insect variables were not significantly correlated with reed abundance (all $p > 0.1$).

Discussion

Previous to our surveys, little had been published on butterflies and odonates in the Meadowlands. A few species of butterflies were mentioned by Kane and Githens (1997), Quinn (2000), and Kiviat and MacDonald (2002, 2004). The North American Butterfly Association (Anonymous 2000) posted a list of 28 butterfly species observed in the Meadowlands in DeKorte Park ca. 1.5 km east of the northern portion of our Disposal transect, and Quinn (2000) praised DeKorte Park as a butterfly-watching area. The NABA list contains 13 species we did not record on our transects (although 3 of the 13 were among our off-transect records), and we found 6 species on our transects and one additional species found only off-transect that are not on the NABA list.

Table 5. Opportunistic observations of butterflies visiting flowers for nectar, on and off-transect, at the Laurel, Paterson Lateral, and Disposal transects, Hackensack Meadowlands, 2006 (see Table 1 for details of transect locations). Scientific names of butterflies are in Table 2. N = native species of plant, I = introduced (nonnative) species.

Butterfly	**Flower**	**Native/introd.**	**Times seen***
Broad-winged skipper	Canada thistle, *Cirsium arvense*	I	9
Little glassy-wing	Knapweed, *Centaurea maculosa*	I	1
Long dash	Canada thistle, *Cirsium arvense*	I	1
Northern broken-dash	Crown-vetch, *Coronilla varia*	I	1
Northern broken-dash	Knapweed, *Centaurea maculosa*	I	1
Wild indigo duskywing	Bird's-foot trefoil, *Lotus corniculatus*	I	1
Wild indigo duskywing	Knapweed, *Centaurea maculosa*	I	1
Wild indigo duskywing	White sweet-clover, *Melilotus alba*	I	1
Summer azure	White sweet-clover	I	3
Little wood satyr	Smooth sumac, *Rhus glabra*	N	2
Orange sulphur	Crown-vetch, *Coronilla varia*	I	1
Orange sulphur	Fleabane, *Erigeron annuus*	N	2
Orange sulphur	Knapweed, *Centaurea maculosa*	I	2
Cabbage white	Indian-hemp, *Apocynum cannabinum*	N	2
Cabbage white	Knapweed, *Centaurea maculosa*	I	1
Cabbage white	St John's-wort, *Hypericum punctatum*	N	1

* Total number of individuals.

The numbers of species of odonates (22) and butterflies (21) on our transects (plus 6 additional species found only off-transect during our surveys) represent reasonable diversity for a small number of sites and visits in an urban area in the northeastern U.S. Tudor (2002a, b, 2003) reported a total of 90 species of dragonflies in the New York City region; Tudor's species list was based on many years of qualitative observation by numerous observers and includes rural areas with unpolluted streams and other habitats that do not exist in the Meadowlands. Ingraham et al. (no date) reported 69 species of butterflies from Jamaica Bay, a large area of brackish and fresh marshes, dredge spoil, and developed areas in New York City. Garber (1988) listed 20 species of dragonflies for Turtle Pond, a 1 ha (2.5 acre), old and silted, constructed pond in Central Park, Manhattan. We found 12 of those 20 species on the Meadowlands surveys, as well as 2 species (banded pennant and Needham's skimmer) not listed by Garber for Turtle Pond. Turtle Pond, currently insulated from salinity intrusion, may support some dragonfly species that require strictly fresh water.

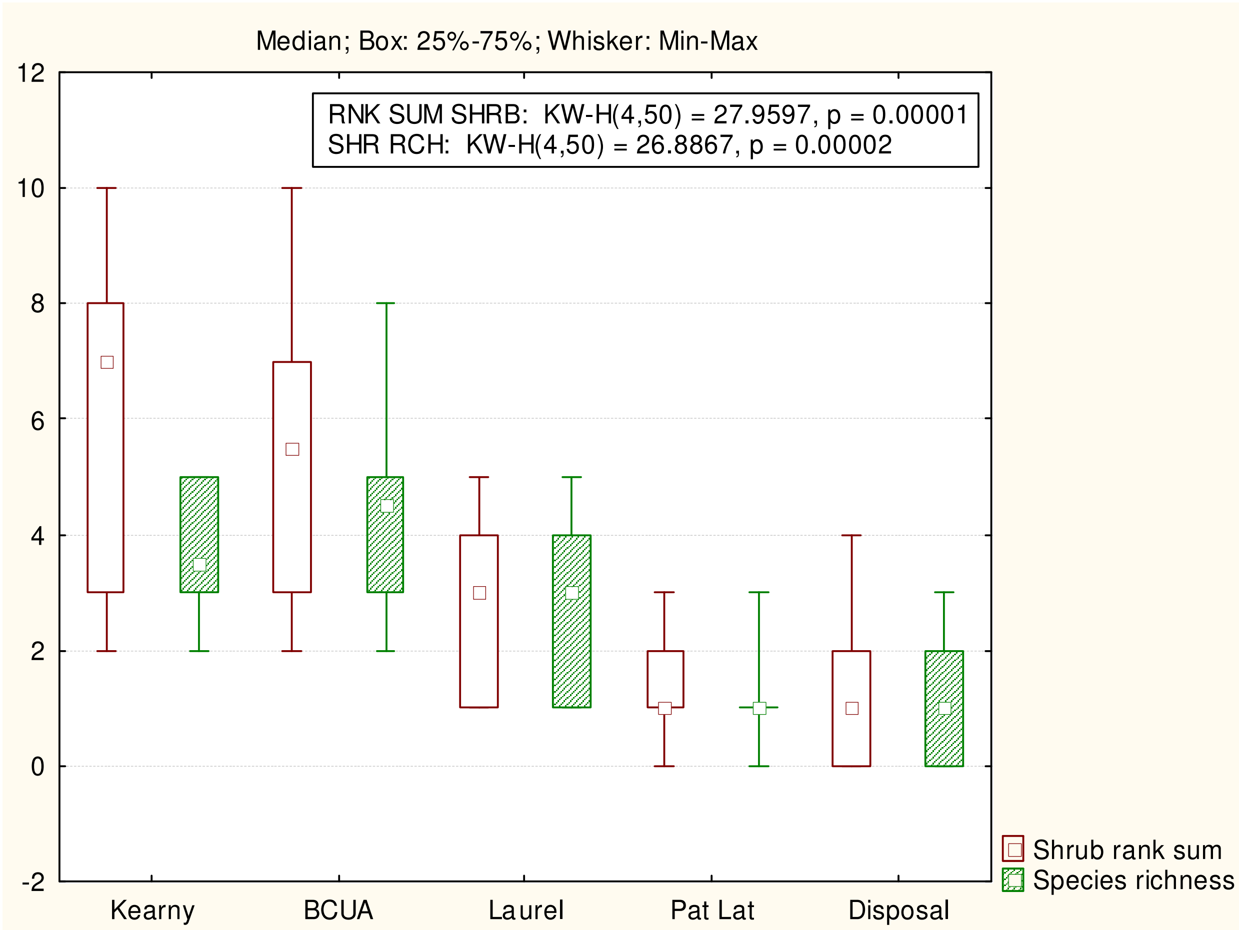

Figure 5. Rank sums and species richness of shrubs per 100 m segment on five transects in the Hackensack Meadowlands in early summer 2006. Statistics are from the Kruskal-Wallis ANOVA by ranks (null hypothesis of no difference among transects). See Table 1 for details of transect locations.

Different sources have provided various numbers of species for the total New Jersey odonate fauna: 184 species (54 damselflies and 130 dragonflies; http://odonatacentral.bfl.utexas.edu/, viewed February 2007); 182 species according to the New Jersey Odonate Survey (NJOS; www.njodes.com, viewed 15 April 2007), 179 species according to the U.S. Geological Survey (www.npwrc.usgs.gov/resource/distr/insects/dfly/nj/toc), or 169 species (May and Carle 1996). NJOS listed 94 species for Bergen County and only 12 species for Hudson County. Our observations add 4 species to the NJOS list for Bergen, and 9 to the list for Hudson County.

The odonate fauna of New York State numbered 175 species according to Donnelly (1992); more species have undoubtedly been discovered, most recently in connection with the New York State Dragonfly and Damselfly Survey that began in 2005. We almost certainly missed some odonates that fly later in the summer; for example, the meadowflies (*Sympetrum* spp.), two of which were reported by Garber (1998) from Turtle Pond in Manhattan. Other factors limiting the number of species on our surveys include the scarcity of strictly freshwater habitats, water quality, and of course the urban environment. Nonetheless, some odonates are known for their ability to colonize artificial or altered aquatic habitats including ponds in urban parks (e.g., Catling and Brownell 2001, Lam 2004, Bried and Ervin 2005).

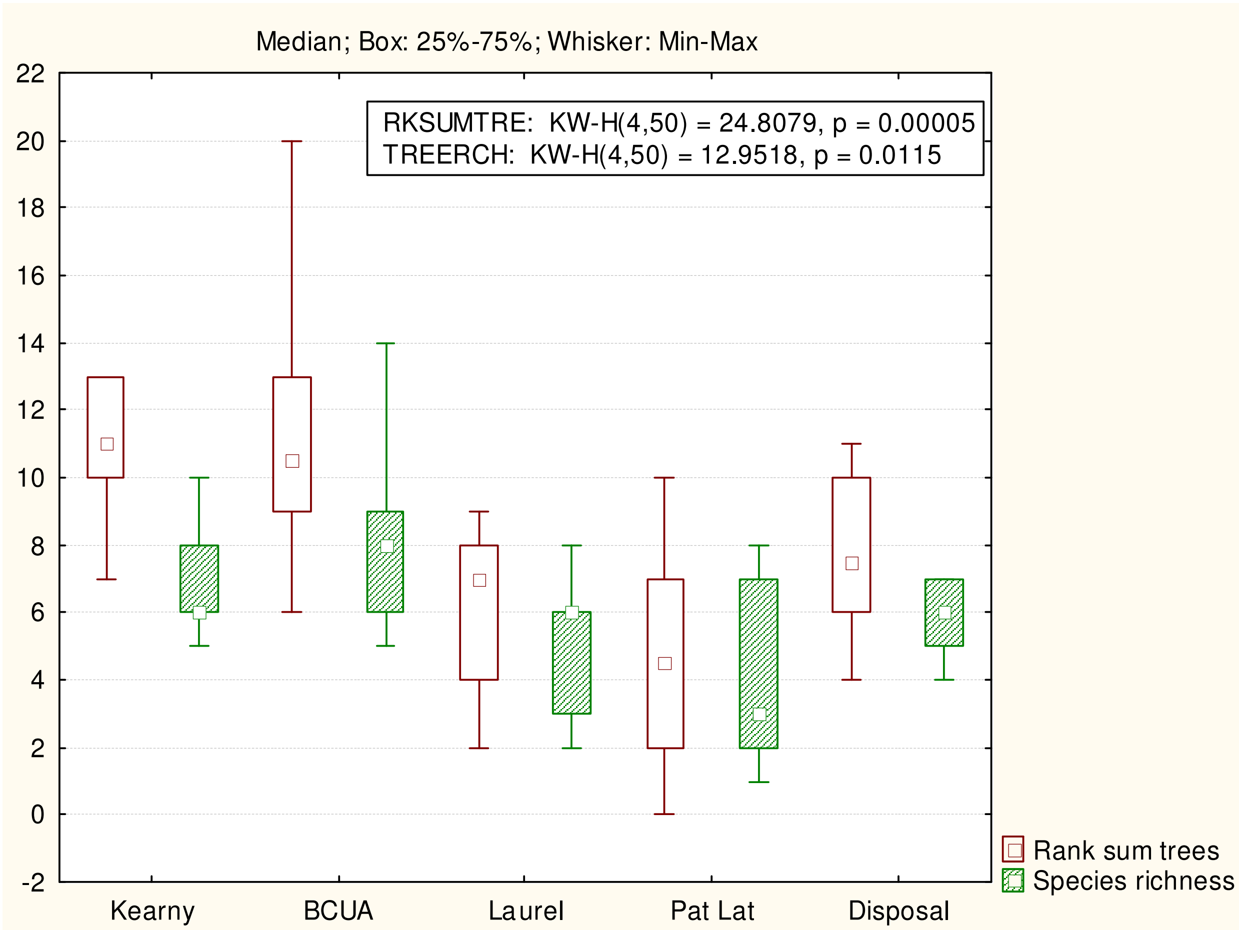

Figure 6. Rank sums and species richness of trees per 100 m segment on five transects in the Hackensack Meadowlands in early summer 2006. Statistics are from the Kruskal-Wallis ANOVA by ranks (null hypothesis of no difference among transects). See Table 1 for details of transect locations.

The butterfly fauna of New Jersey numbers 149 species (Gochfeld and Burger 1997). No Fourth of July Butterfly Count has been conducted in the Meadowlands. Shapiro (1970) listed 73 butterfly species for the region of Tinicum Marsh (now John Heinz National Wildlife Refuge), an urban wetland complex in Philadelphia, Pennsylvania, ca. 125 km southwest of the Meadowlands. Shapiro stated, “Most of the resident species of the Tinicum region are insects of wide geographical range and typically are associated with open habitats and areas disturbed by man.” Shapiro and Shapiro (1973) listed 106 butterfly species for Staten Island (92 of which had been observed “recently”), an urban area of New York City with fairly extensive wetlands and varied upland habitats, ca. 15 km south of the Meadowlands.

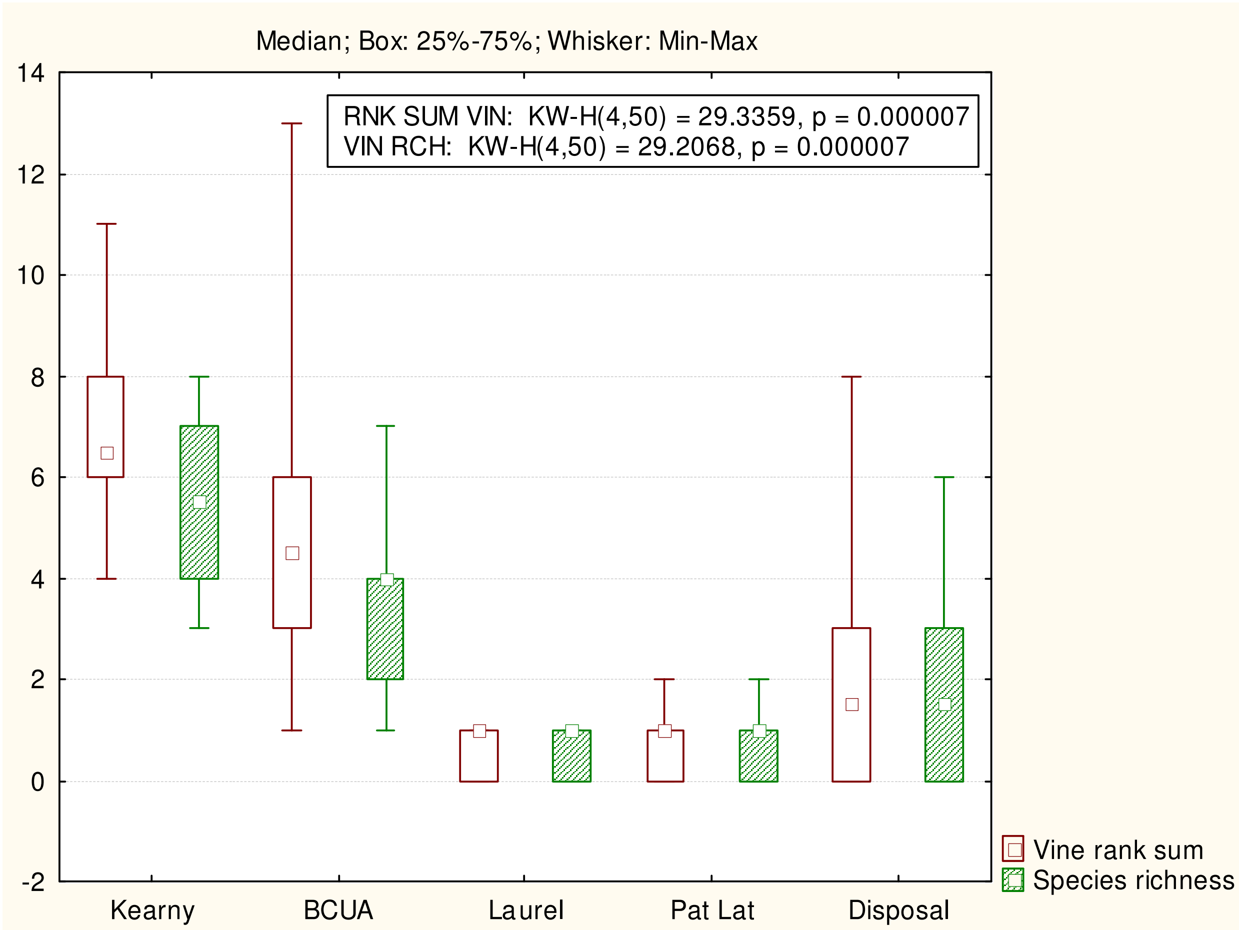

Figure 7. Rank sums and species richness of vines (woody and herbaceous vines combined) per 100 m segment on five transects in the Hackensack Meadowlands in early summer 2006. Statistics are from the Kruskal-Wallis ANOVA by ranks (null hypothesis of no difference among transects). See Table 1 for details of transect locations.

In addition to the numbers of species *per se*, it is informative to look at the "quality" of the butterfly fauna recorded on our transects. All the butterflies we recorded are common species with two exceptions. The long dash was described by Gochfeld and Burger (1997) as "generally uncommon" and is tracked by the New Jersey Landscape Program, indicating potential conservation concern. The little glassy wing was described as "Widespread throughout; usually not common but sometimes locally and briefly abundant" (Gochfeld and Burger 1997). The common buckeye (1 off-transect observation) is uncommon in northeastern New Jersey (Gochfeld and Burger 1997). All the butterflies we recorded on the transects were ranked by Cech and Tudor (2005) as "generalists" based on a combination of habitat and host plant affinities, except for the long dash, broad-winged skipper, and wild indigo duskywing which were ranked as "medium generalists" (the summer azure was not ranked, but would probably be considered a generalist).

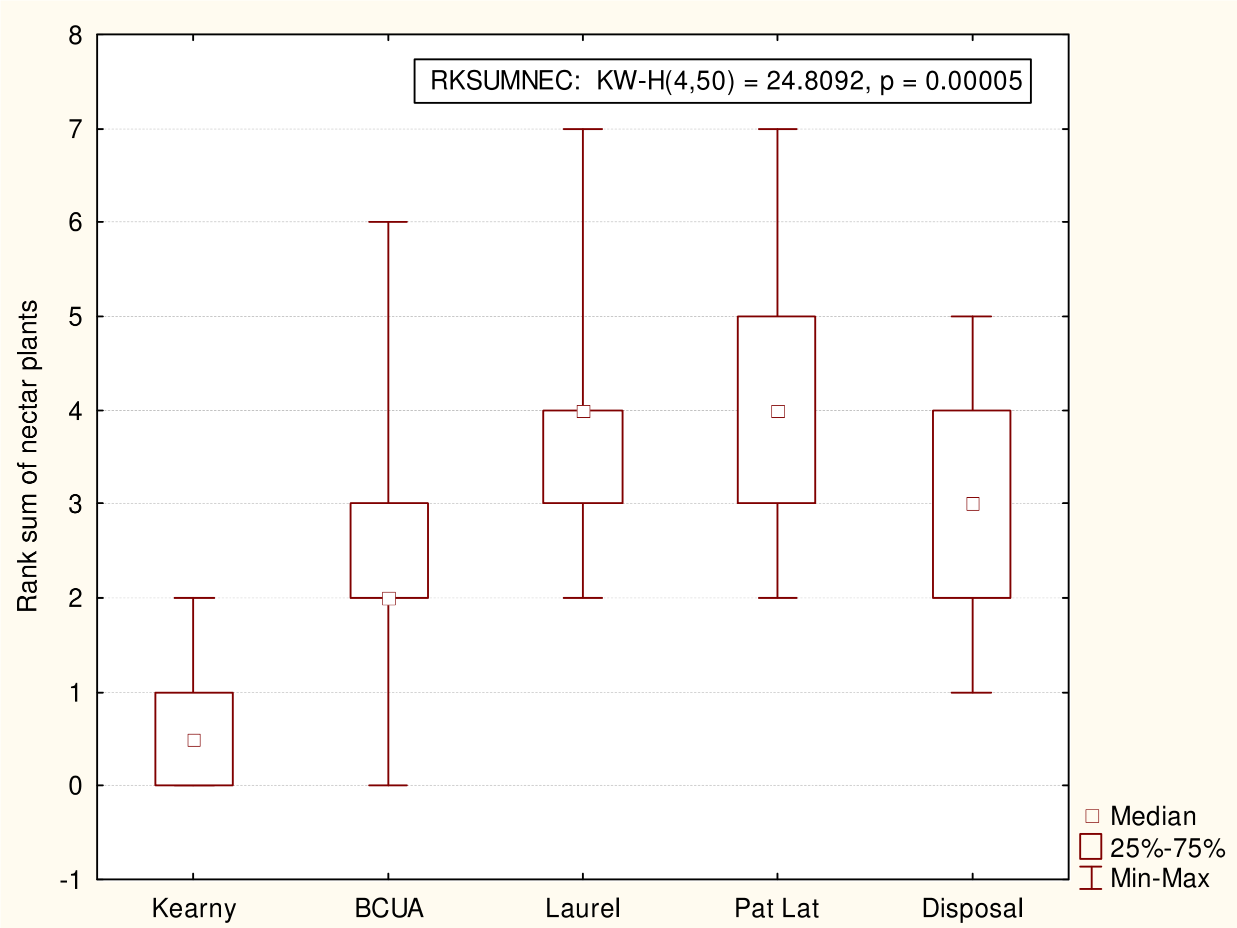

Figure 8. Rank sums of nectar plants per 100 m segment on five transects in the Hackensack Meadowlands in early summer 2006. See Table 1 for details of transect locations.

Only one of the 21 true butterflies and skippers recorded on the transects is an introduced species, the cabbage white (*Pieris rapae*), but this species accounted for 37% of on-transect individuals in our surveys. One other introduced species, European skipper, was only recorded off-transect (1 individual). Virtually the entire northeastern butterfly fauna is regarded as native to the region. Cabbage whites are unlikely to compete for food with other Meadowlands butterflies, as the other species we recorded do not feed on mustards (Brassicaceae; Table 6). Even other mustard-feeding pierids barely overlap with the cabbage white at the host plant species level (Gochfeld and Burger 1997, Cech and Tudor 2005). It is not known whether other northeastern white species mis-mate with cabbage whites (Gochfeld and Burger 1997), if there is food plant competition between cabbage whites and insects other than butterflies, or if Meadowlands cabbage whites are likely to compete with other insects for nectar. That we found no correlation between nectar plants and butterflies suggests that Meadowlands butterflies are not competing for a scarce nectar resource, at least in early summer.

Table 6. Water quality measurements at three butterfly-odonate transects, Hackensack Meadowlands, 2006. Measurements were made with a Hydrolab Surveyor 4 portable water quality probe at representative locations close to transects. Variables are water temperature (Celsius), dissolved oxygen (per cent saturation), dissolved oxygen (parts-per-million), specific conductance (millisiemens), salinity (parts-per-thousand), and pH. See Table 1 for details of transect locations.

Transect	Habitat	Date	Time EDT	Temp C	DO sat %	DO ppm	Cond mS	Sal ppt	pH
Disposal	Pool W of road	31-May	1010	22.0		5.5	1.60	0.80	8.10
	Flowing ditch W of road	31-May	1020	21.5		6.6	0.80	0.42	8.10
Pat Lat	Puddle on road 1	01-Jun	945	22.7	17	1.1	0.73	0.38	7.85
	Puddle on road 2	01-Jun	1020	28.4	44	2.8	0.61	0.31	7.25
	Puddle on road 3	01-Jun	1025	23.6	34	2.4	0.43	0.22	7.45
	Puddle on road 4	01-Jun	1040	29.7	19	1.2	0.41	0.21	7.50
	Puddle on road 5	01-Jun	1050	31.8	14	0.8	0.41	0.20	7.20
	Puddle on road 6	01-Jun	1120	33.6	10	0.6	0.27	0.13	6.95
	First (small) channel	01-Jun	1000	23.4	21	1.4	1.24	0.65	7.40
	Second (large) channel	01-Jun	1100	23.0	22	1.6	1.61	2.25	6.73
BCUA	Mehrhof Pond near N gate	01-Jun	1315	26.8	68	4.7	0.70	0.36	7.62

"Waste areas" or "waste ground" (i.e., human-altered ecosystems generally lacking topsoil, dry, and characterized by hardy, tolerant species; see Kiviat and Stevens [2001]) are important butterfly habitats on the U.S. East Coast (Cech and Tudor 2005). Most upland habitats in the Meadowlands are waste areas. All of the butterfly species we recorded use common native or introduced plants as larval hosts (Table 6), and these plants generally abound in the waste areas of the Meadowlands. The many species of sedge-feeding skippers (see Gochfeld and Burger 1997) were absent from our surveys, presumably because the *Carex* sedges are scarce in the Meadowlands. We recorded none of the three species of hackberry-feeding butterflies despite the presence of a number of large hackberry trees (*Celtis occidentalis*) on the southern portion of the Disposal transect and fewer hackberries elsewhere on our transects. One hackberry-feeder, tawny emperor, was reported from DeKorte Park (Anonymous 2000). We were surprised not to see more broad-winged skippers, the larvae of which feed on common reed; our surveys were probably performed a little before peak flights of this species. Several species of butterflies recorded historically from the Hackensack Meadowlands or the Newark area did not occur in our 2006 surveys: zebra swallowtail, bronze copper, Edwards' hairstreak, silvery checkerspot, Harris checkerspot, and dun skipper (Gochfeld and Burger 1997).

Except for one species, the common green darner (only recorded off-transect), all the dragonflies we recorded belong to the family Libellulidae. These species are associated with standing water (Nikula et al. 2003). A few of the libellulids are tolerant of brackish water, e.g., Needham's skimmer and eastern amberwing (Donnelly 1992), although the upper limits of salinity tolerance are not known. Stream-dependent species, e.g., the gomphids, were absent from our surveys. Streams in the Meadowlands are either impounded by tide gates thus pond-like (e.g., Losen Slote, near our BCUA and Paterson Lateral transects), salinized, culverted, or very small (such as the apparently spring-fed stream ca. 30 m west of our Disposal transect). The powdered dancer (*Argia moesta*) breeds in streams and in lakes with rocky shores (Lam 2004); the riprapped north shore of Mehrhof Pond near the BCUA transect presumably is suitable larval habitat. Abundance of damselflies (mostly bluets [*Enallagma* spp.] and forktails [*Ischnura* spp.]) on only 2 of the 5 surveys was probably related to the availability of large bodies of fresh or nearly fresh water, with habitats having low hydrodynamic energy (i.e., low turbulence), near those 2 transects. Those transects are also land-dominated compared to the other 3 transects (Francisco Artigas, MERI, personal communication). The species of forktails and bluets that predominated on our surveys are generally associated with quiet fresh water (Nikula et al. 2003, Lam 2004). Orange bluet (n = 29) was tied (with Needham's skimmer) as the second most abundant odonate on our surveys overall, and familiar bluet (n = 21) was the fourth most abundant odonate. Familiar bluet is a very widespread and common species sometimes breeding in brackish water (Lam 2004), and was very abundant and tolerant of sewage loading in Catling's (2005) study. Rambur's forktail also breeds in brackish water (Lam 2004).

Needham's skimmer is tracked by the New Jersey Landscape Program, indicating potential conservation concern. This species was a fairly numerous dragonfly on our counts, appears common in the Meadowlands, and was previously observed by Kiviat at Paterson Lateral, Mill Creek Point, and the mouth of Bellman's Creek. Dunkle (2000) stated that Needham's skimmer is associated with brackish, mineral-rich, or fertilized waters range-wide. The big bluet is also tracked by the Landscape Program; we saw two individuals on-transect at Kearny. Big bluet is ranked S2S3 by the New Jersey Natural Heritage Program. The most abundant odonate on our transects was blue dasher (Table 3). Blue dasher is a common dragonfly associated with a wide variety of aquatic habitats (Dunkle 2000).

Odonate larvae are generally sensitive to high salinity, low dissolved oxygen, high turbidity, and low or high pH (Roback 1974, Corbet 1999, D'Amico et al. 2004). Salinities in various habitats on and near the transects before the surveys were as high as 2.25 ppt although all but one value were 0.8 ppt or lower. Dissolved oxygen was as low as 0.6 ppm and oxygen saturation as low as 10% (Table 5). Most water quality values recorded were probably within the range of tolerance of the odonates found on the surveys, but the most brackish and the most hypoxic waters would exclude some species. Roback (1974) listed only one odonate (fragile forktail) found in waters with DO < 4 ppm. We did not measure salinity in, for example, the brackish tidal waters east of the Disposal transect which were presumably too saline for the larvae of most odonates. We observed mated pairs or ovipositing females, including: spot-winged glider (mated pair flying low over puddles on Paterson Lateral pipeline road), probable black saddlebags (ovipositing, Paterson Lateral puddle), Needham's skimmer (ovipositing, Paterson Lateral puddle), and familiar bluet (mated pair at BCUA).

We found negative correlations of dragonfly abundance and species richness with woody plant rank sums (a surrogate for woody vegetation volume or biomass). Brown (2006) stated that at the levels of township and sub-watershed in Rhode Island, there was a strong correlation between species diversity of odonates and per cent forest cover. The difference between our findings and Brown's may be due to the much larger scale of her study or to the influences of other factors correlated with forest cover. Brown (2006) also found a negative correlation between odonate diversity and per cent development or roads, suggesting that habitat fragmentation or less suitable water quality in developed areas may be more important than forest cover *per se*.

Kearny, Paterson Lateral, and parts of the Laurel and BCUA transects were in use by off-road vehicle (ORV) riders. No ORVs drove through while we were conducting the insect surveys; however, ORVs were present during reconnaissance and flora surveys, especially at Kearny. We suspect that some damage occurs to the vegetation habitat on the transect route at Kearny. At Paterson Lateral, however, ORVs (motorcycles) are maintaining the rainpool habitat on the dirt road for odonates and a rare species of clam-shrimp (see Schmidt and Kiviat, submitted).

Nectar abundance is an important factor in the ability of a landscape to support a butterfly fauna (e.g., Saarinen et al. 2005). Most of the nectar plants we observed butterflies visiting were common, weedy, introduced species typical of roadside and fill habitats in the Meadowlands. The endangered Karner blue butterfly in Indiana selected native and introduced nectar plants in proportion to their representation in the local species list, and one of the 10 most frequently selected nectar plants was an introduced species, white sweet-clover (Grundel et al. 2000). The lack of a clear relationship between butterfly abundance or species richness and nectar plant abundance suggests nectar plants are generally not in short supply in the Meadowlands in early summer.

The reported host plants (Table 6) of butterflies recorded in our surveys are diverse and include many introduced plant species as well as native species. Most of these host plants are common, urban-tolerant taxa, and many are common at the transects and elsewhere in the Meadowlands. Inasmuch as most of the butterflies we recorded are urban-tolerant, it would be appropriate to plant or encourage these host plants and nectar plants on the development sites and restoration sites of the Meadowlands where such plants will not interfere with other ecological objectives. Switching of native butterflies from native to introduced host species has been well-documented; for example, Shapiro (2002; also see Thacker 2004, Pyle 2006) found that more than 40% of the mostly native, urban butterfly fauna of Davis, California, depended entirely on introduced species of larval host plants. It is also well known that native North American butterflies use certain introduced nectar plants heavily (e.g., Pyle 2006). We do not argue that introduced plants should be favored over native plants, but rather that introduced plants that thrive in urban environments like the Meadowlands can be valuable to native biota, including charismatic taxa like the butterflies.

Insect variables (total numbers and species richness) were similar across the five transects for butterflies and dragonflies but dissimilar for damselflies. Catling and Brownell (2001) found substantial variation in damselfly diversity among 41 gravel pit ponds in Ontario, and Bried and Ervin (2005) found substantially different species lists of odonates among four wetlands in Mississippi. Our plant variables were different across transects for nectar plants, vines, shrubs, and trees. This contrast between insect and plant distribution suggests strongly flying insects are able to exploit different sites similarly despite floristic differences. It is likely that the ability of butterflies and odonates to fly from one plant or plant community to another allows the insects to adjust or "stabilize" their communities at a large spatial scale on the fragmented urban landscape. The fairly high plant diversity, and abundance of potential host plants and nectar plants, at the transect sites must contribute to the ability of these sites to support butterfly diversity. Dennis et al. (2006) emphasized the importance of the pattern of vegetation on the landscape and the permeability of the landscape to butterfly movements. A Colorado grassland study suggested that urbanization *per se* may not be an important predictor of butterfly species richness or composition (Collinge et al. 2003). Conserving butterfly diversity may require the occurrence of diverse vegetation patches in a mosaic, and this suggests that land management in the Meadowlands should provide for a diversity of wild vegetation on uplands as well as wetlands. The kinds of "scruffy" uplands and wetland edges sampled on our transects are often considered unsightly or undesirable, but are important habitats for butterflies (Cech and Tudor 2005) and odonates as well as plants, songbirds, and many other organisms.

Butterfly and odonate populations are related to plants used for egg-laying substrates, larval hosts, nectar sources, perches, territory boundary markers, and shelter; soil characteristics and water quality; environmental contaminants and pesticides; predators, prey, and parasites; barriers to movement across the landscape; and microclimate (e.g., Takamura et al. 1991, Dover et al. 1997, Bried and Ervin 2005, VanReusel et al. 2007). Climate change is affecting these faunas along with other organisms. In Europe, for example, 63% of 35 species of non-migratory European butterfly species shifted their ranges northward and only 3% shifted southward, during the 1900s (Parmesan et al. 1999). More than the usual numbers of southern butterfly species have wandered northward into the New York City region during especially mild years (e.g., Tudor 1992). The butterfly-odonate survey method we tested in 2006 has good potential for long-term monitoring of this charismatic and ecologically important component of the Meadowlands biota. Changes in butterfly and odonate numbers recorded in such a monitoring program should reflect changes in local conditions as well as large-scale climate and population processes.

Assessment of Methodology

A one-year, single sampling period, five-transect pilot of a strip transect method for combined surveys of butterfly and odonate adults performed well in an urban area, the Hackensack Meadowlands. The numbers on individual transects were high enough for analysis but not too high for accurate identification and recording in the field. The dragonfly and butterfly composite variables (numbers of individuals and species richness) did not differ significantly among transects in univariate analyses, suggesting the transects may be considered as spatial replicates for these taxa. Damselfly composite variables were different among transects. Overall the sample size (number of transects) was small and unless survey data are consistent from year to year, the ability to detect moderate changes in populations will be low. Therefore, we recommend that the surveys be continued annually using the same survey method and adding additional transects for a total of at least 10 transects. Because warm sunny weather with low wind speed is necessary for the surveys, it may not be possible to perform all surveys on consecutive days. Survey days, however, should be within the dates 21 June – 10 July if possible, with each site surveyed as close as possible to the same date each year. During the week in which we conducted surveys, most of the species of northern New Jersey are flying, thus late June – early July appears the best period for a single temporal sample. Surveys performed earlier and later in the season would detect some species that we did not record.

Table 6. Reported host plants (larval food plants) of the butterfly species recorded on surveys in the Hackensack Meadowlands, New Jersey, in early summer 2006. (Host plants per Gochfeld and Burger 1997; * taxon introduced to northeastern New Jersey; Poaceae includes both introduced and native grasses.)

Common name	Scientific name	Host plants
Monarch	*Danaus plexippus*	Milkweeds (*Asclepias*)
Silver-spotted skipper	*Epargyreus clarus*	Black locust (*Robinia pseudoacacia*)*
Wild indigo duskywing	*Erynnis baptisiae*	Crown-vetch (*Coronilla varia*)*, other legumes
Least skipper	*Ancyloxypha numitor*	Grasses (Poaceae)
European skipper*	*Thymelicus lineola*	Timothy (*Phleum pratense*)*
Peck's skipper	*Polites peckius*	Rice cutgrass (*Leersia oryzoides*), other grasses
Delaware skipper	*Anatrytone logan*	Grasses (Poaceae)
Broad-winged skipper	*Poanes viator*	Common reed (*Phragmites australis*)*
Hobomok skipper	*Poanes hobomok*	Panic grasses (*Panicum*), bluegrasses (*Poa*)*
Little glassy wing	*Pompeius verna*	Purple top (*Tridens flavus*)*
Long dash	*Polites mystic*	Bluegrasses (*Poa*)*, other grasses (Poaceae)
Northern broken-dash	*Wallengrenia egeremet*	Switchgrass (*Panicum virgatum*), other panic grasses
Eastern tailed blue	*Everes comynta*	Various legumes (*Fabaceae*); mostly *
Summer azure	*Celastrina neglecta*	Shrubby dogwoods (*Cornus*), sumacs (*Rhus*), etc.
Red admiral	*Vanessa atalanta*	Stinging nettle (*Urtica dioica*) (presumed *), false-nettle (*Boehmeria*)
Mourning cloak	*Nymphalis antiopa*	Willows (*Salix*), poplars (*Populus*), elms (*Ulmus*)
Pearl Crescent	*Phyciodes tharos*	Asters (*Aster s.l.*)
Question mark	*Polygonia interrogationis*	Stinging nettle (*Urtica dioica*) (presumed *), false-nettle (*Boehmeria*), elms (*Ulmus*), hackberry (*Celtis occidentalis*), Japanese hops (*Humulus japonicus*)*
Common buckeye	*Junonia coenia*	Plantains (*Plantago*)*, figworts (Scrophulariaceae)
Viceroy	*Vanessa atalanta*	Willows (*Salix*), poplars (*Populus*)
Spicebush swallowtail	*Papilio troilus*	Spicebush (*Lindera benzoin*), sassafras (*Sassafras albidum*)
Eastern tiger swallowtail	*Papilio glaucus*	Black cherry (*Prunus serotina*), other woody plants
Black swallowtail	*Papilio polyxenes*	Queen Anne's lace (*Daucus carota*)*, other Apiaceae (probably *)
Cabbage white	*Pieris rapae*	Mustards (*Brassicaceae*, native and introduced)
Orange sulfur	*Colias eurytheme*	Various legumes (native and introduced)

Clouded sulfur	*Colias philodoce*	White clover (*Trifolium repens*)*, related legumes*

(Table 6, continued)

Common wood nymph	*Cercyonis pegala*	Purple top (*Tridens flavus*)*, other grasses (Poaceae)
Little wood satyr	*Megisto cymela*	Grasses (Poaceae)

The taxonomic ability of the surveyors is critical, and photographs or voucher specimens should be taken when field identification is uncertain. It would be useful to repeat surveys on selected transects either seasonally or for temporal replication in order to better understand the statistical properties of this type of data. There is always the risk that enough consecutive days of suitable weather will not occur during a planned survey period, thus it is important to begin the surveys a few days earlier than what might be the ideal time. In our data, correlations between start time of transect segments, and the abundance and richness of odonates and butterflies, were not significant, suggesting that the visible fauna did not change through the 100 min counts and segments were equivalent in time. Variation in weather, and differences in butterfly seasonality (phenology), from year to year affect Fourth of July Butterfly Counts in any one year (Swengel 1990) but presumably average out in long time series.

Conclusions

We successfully tested a time- and space-constrained transect method for monitoring adult butterflies and odonates at 5 sites in urban areas of the Hackensack Meadowlands, New Jersey, during a single survey period in early summer 2006. We detected 21 species of butterflies and 22 species of odonates on the transects, and an addition four species of butterflies and two species of odonates off-transect during the surveys. Most of the butterflies are species that are common in northeastern New Jersey; the larvae of most of these butterflies feed on common native or introduced plant species in open, weedy, upland habitats. Three species, the long dash, little glassy wing, and common buckeye, are uncommon in northeastern New Jersey. All of the odonates are species associated with non-flowing waters and adjoining upland habitats, and several species are known to be tolerant of slightly brackish water. Two of the odonates are considered uncommon in New Jersey, Needham's skimmer and big bluet. We consider the variety of butterfly and odonate species reasonable for urban areas given the season and habitats surveyed.

Acknowledgments

Ai Wen and Josh Stout assisted in the reconnaissance and marked the transects. Alex Martí collected the GPS data and prepared the transect maps and I thank Dom Elefante for this service. Alana Buonaguro and Amie Worley managed the data with assistance from Nicole Rhodes. Ken Soltesz identified or verified odonate specimens. Brett Bragin helped with site selection. Joseph Sarnoski loaned and calibrated the sonde; Stuart Findlay and Bob Schmidt helped with interpretation of water quality. Christine Hobble and Francisco Artigas were our liaisons with MERI-NJMC. We thank the Bergen County Utilities Authority for opening their gates for us at odd hours. We appreciate training provided by the New York Dragonfly and Damselfly Survey. Charles Canham gave statistical advice. Brett Bragin, Francisco Artigas, and Christine Hobble commented on drafts of this paper. This project was funded by the Meadowlands Environmental

Research Institute of the New Jersey Meadowlands Commission. This is Bard College Field Station – Hudsonia Contribution 103.

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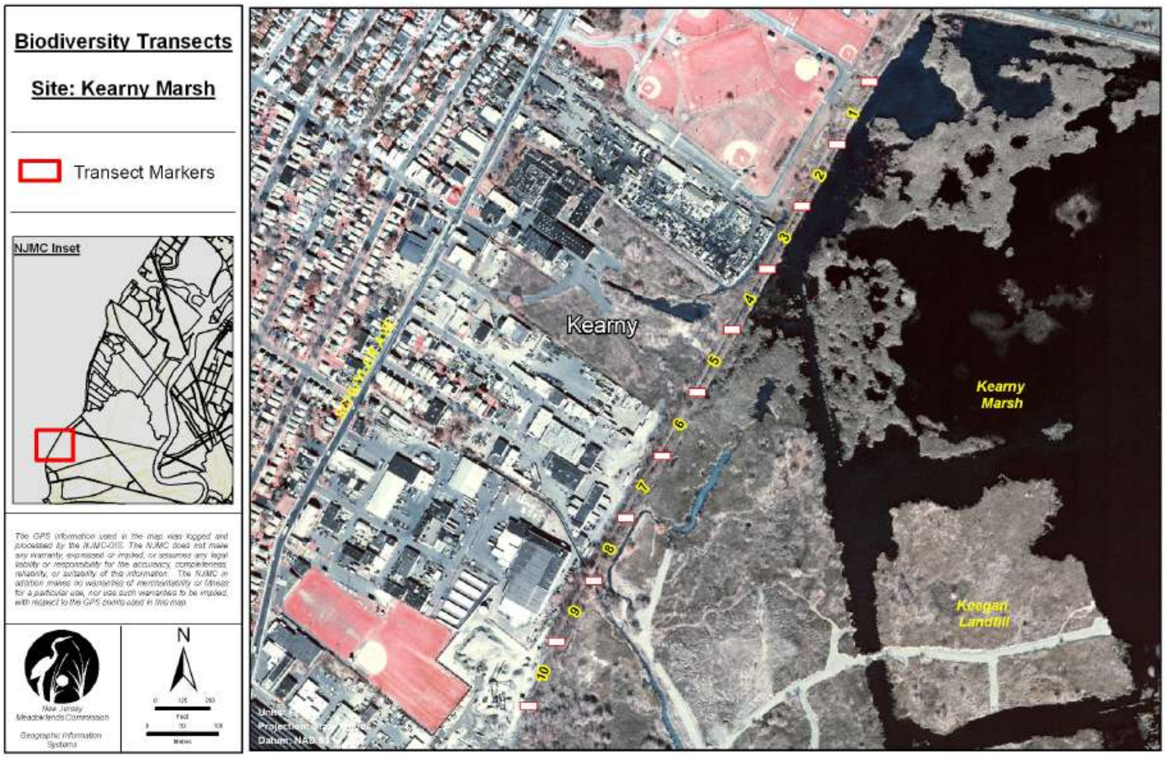
Appendix 1 (following five pages). Large-scale maps of the five butterfly-odonate transects shown in Figure 1. The tenth (last) segment of the Laurel Hill transect is longer than 100 m because we omitted a bare area used as an equipment turnaround.


Biodiversity Transects
Site: Kearny Marsh
Transect Markers
NJMC Inset
The GPS information used in the map was logged and processed by the NJMC-GIS. The NJMC does not make any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, reliability, or suitability of this information. The NJMC in addition makes no warranties of merchantability or fitness for a particular use, nor use such warranties to be implied, with respect to the GPS points used in this map.
New Jersey Meadowlands Commission
Geographic Information Systems
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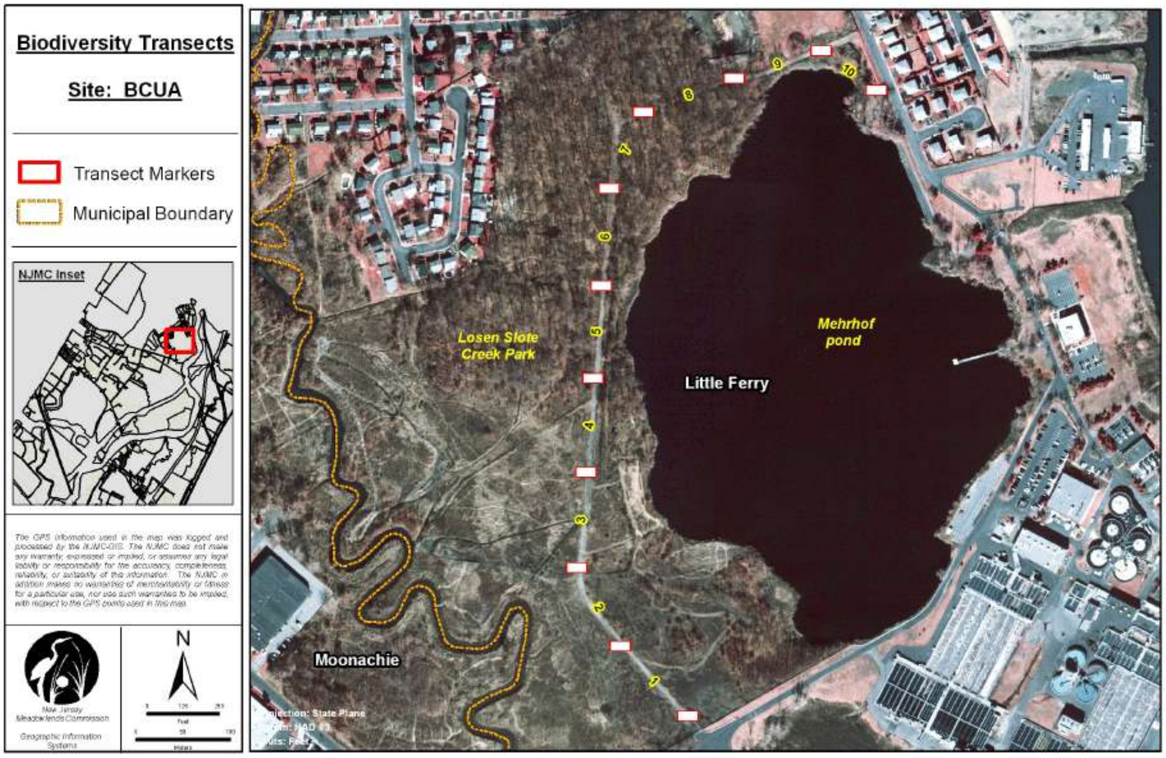
Biodiversity Transects
Site: BCUA
Transect Markers
Municipal Boundary
NJMC Inset
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New Jersey Meadowlands Commission
Geographic Information Systems
N
Feet
Meters
Losen Slote Creek Park
Mehrhof pond
Little Ferry
Moonachie
1
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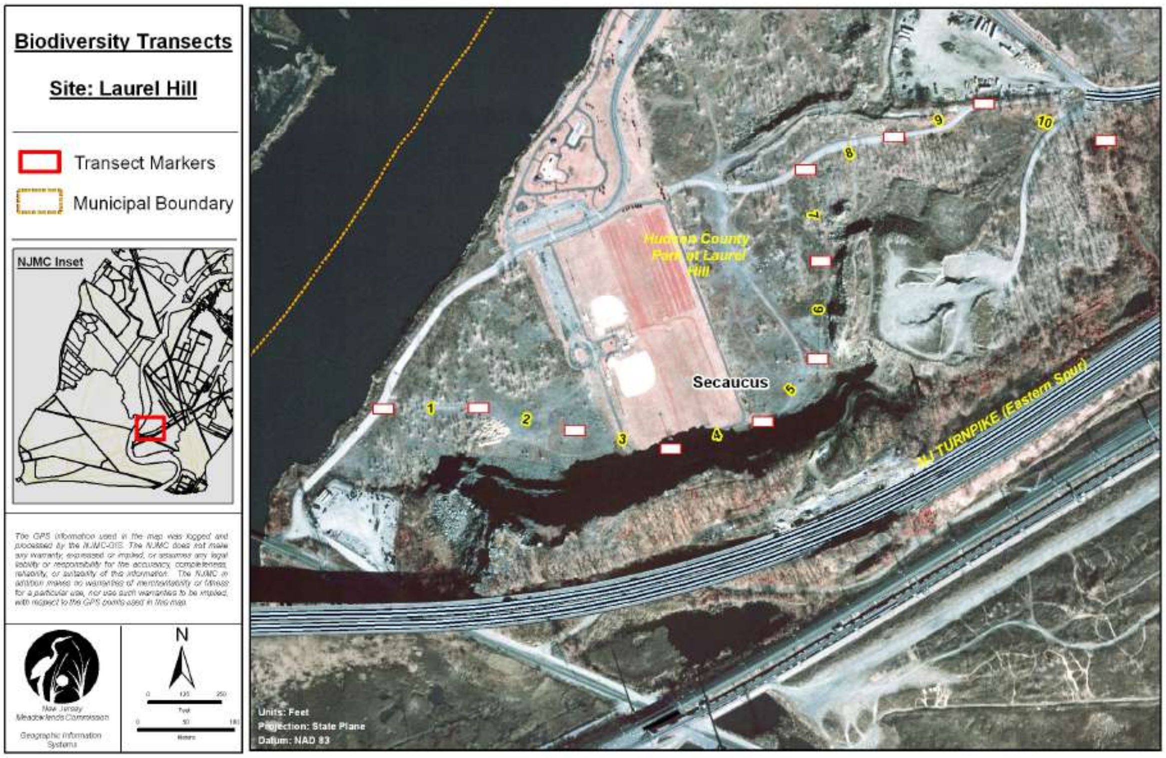
Biodiversity Transects
Site: Laurel Hill
Transect Markers
Municipal Boundary
NJMC Inset
The GPS information used in the map was logged and processed by the NJMC-GIS. The NJMC does not make any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, reliability, or suitability of this information. The NJMC in addition makes no warranties of merchantability or fitness for a particular use, nor are such warranties to be implied, with respect to the GPS points used in this map.
New Jersey Meadowlands Commission
Geographic Information Systems
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Units: Feet
Projection: State Plane
Datum: NAD 83
Hudson County Park at Laurel Hill
Secaucus
NJ TURNPIKE (Eastern Spur)
1
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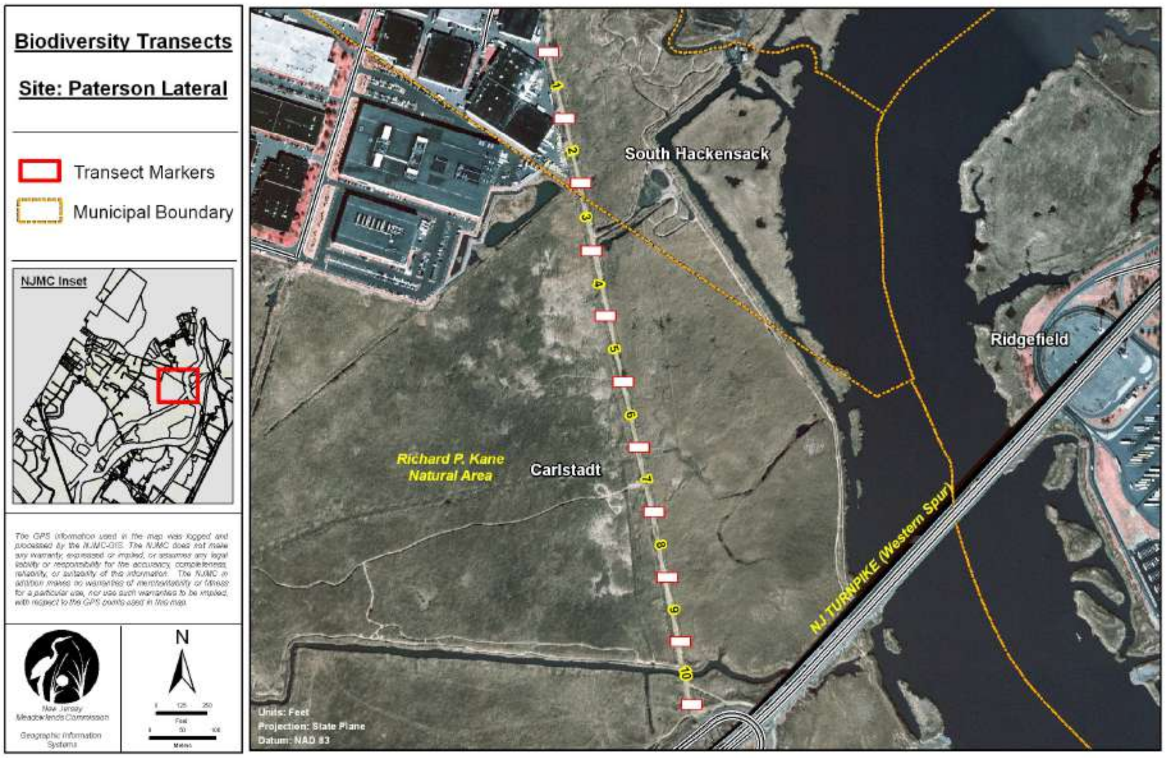
Biodiversity Transects
Site: Paterson Lateral
Transect Markers
Municipal Boundary
NJMC Inset
N
Feet
South Hackensack
Ridgefield
Richard P. Kane Natural Area
Carlstadt
NJ TURNPIKE (Western Spur)
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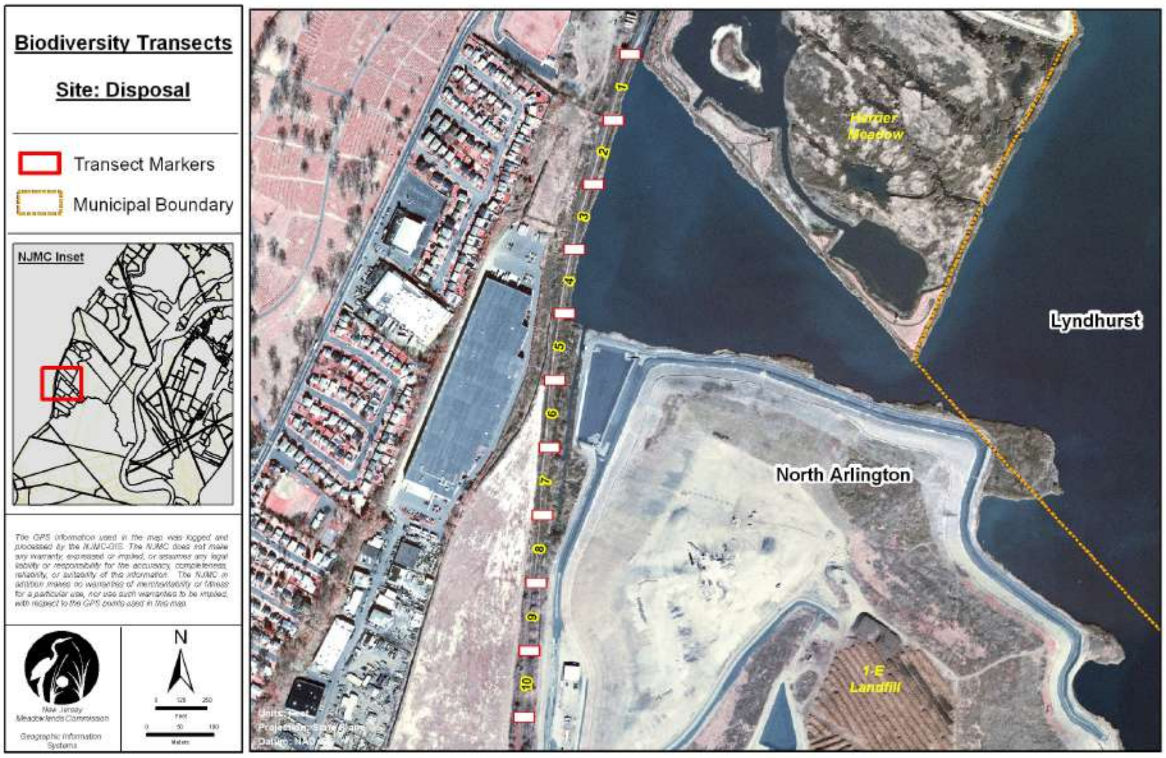
Units: Feet
Projection: State Plane
Datum: NAD 83



Biodiversity Transects
Site: Disposal
Transect Markers
Municipal Boundary
NJMC Inset
North Arlington
Lyndhurst
Harrier Meadow
1-E Landfill
N

Monitoring Fishes in the Meadowlands

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Monitoring programs can be done for a variety of reasons. Monitoring can detect faunal changes associated with purposeful landscape alterations (positive or negative), changes in habitat quality (water quality in this case), or changes associated with larger scale phenomena (regional, global). Monitoring may, in fact, detect all of these kinds of changes (and others) simultaneously and thus it may be difficult to interpret the observations.

Monitoring is most useful when the kinds of environmental conditions of interest or concern are clearly identified and strong links between the variable and the population being monitored are established. In the case of the Meadowlands, there seem to be two current efforts to modify the environment that would be useful to monitor with fishes: long term efforts to improve water quality and efforts to restore marsh vegetation.

Current State of Knowledge

A recently completed report (Bragin et al., 2005) described a comprehensive survey of fishes in tidal brackish water of the Hackensack River. This was a multigear survey with monthly sampling the first year and quarterly sampling the second year, in 1987/88 and again in 2001/03. Sampling in this program was extensive and field and analytical time for the program was probably expensive. As a monitoring program, the magnitude of sampling in time and space and the interval between samples makes this effort a reasonable way to assess long-term water quality improvements if continued and the data already gathered can possibly be interpreted to document such improvements.

Populations of mobile organisms (like fishes) in estuaries are quite variable from year to year. It may be that the best sampling regime one could have to link a change in the ecosystem to fish population fluctuations would be a time series with sampling being more frequent (ideally) than the lifespan of the organisms being studied. The current efforts in the Meadowlands, while showing encouraging changes, are too infrequent to discern real changes from possibly random effects.

It might be possible to do a set of power analyses that would allow restructuring of the program to be more efficient. Questions such as the following may be addressable: Are all the gears equally informative in detecting effects of increased water quality? Is sampling at some stations more informative than others? Is sampling in all months necessary? It might be possible to design a streamlined sampling program based on data already available that would retain the ability to monitor fish populations and their responses to water quality changes at reduced cost.

It is challenging to sort out changes in the fauna due to environmental changes in the Hackensack River as opposed to changes that may be occurring in the larger aquatic system. From Table 16 in Bragin et al. (2005), there were 14 fishes that increased or decreased at least an order of magnitude in abundance (measured by total numbers caught) between the two studies. Coincidentally, half increased and half decreased. Of the species that changed two orders of magnitude in abundance, three increased (gizzard shad, striped bass, and white perch) and three decreased (Atlantic tomcod, bay anchovy, and pumpkinseed). Some of these changes are symptomatic of the larger ecosystem. Gizzard shad increased dramatically in the Hudson River in the same time frame (Daniels et al. 2005), striped bass young of year were at high levels in the Hudson River in 2004 (Striped Bass Technical Committee 2004), and Atlantic tomcod populations reached the lowest levels seen in 27 years in the Hudson estuary in 2002 (Daniels et al. 2005). Changes in bay anchovy, pumpkinseed, and white perch populations have no correlation in the Hudson River as far as I know. The presence, in 2001-3, of large numbers of Atlantic silverside in the Hackensack River may be a result of the increased abundance of this species in the larger New York Harbor/Hudson River ecosystem (Hurst et al. 2004). The fact that the water quality in the Hackensack River can support this relatively “fussy” species is not in dispute, but changes in their abundance in these surveys may not be due to factors working in the Hackensack alone.

The most abundant fishes in the trawl collections in the Hackensack River in 1987/88 were somewhat similar to those from trawl collections Woodhead (1987) made in the lower Hudson River in 1984/86 (Table 1). Notably, however, hogchoker was not present in the Hackensack in trawl samples (and is very scarce in the 2001/03 samples altogether) but was the second most abundant species in New York Harbor. In the more recent Hackensack River collections, several species that were relatively common in 1987/88 were considerably rarer or absent (Table 1). Five of the species that were rare or absent in the most recent surveys (some of which were rare or absent in both surveys) were benthic fishes (Atlantic tomcod, discussed earlier, and four flounder species). Since the Hackensack and Hudson River are contiguous, it may be an interesting avenue of research to ask why differences like this one exist.

Changes in the larger ecosystem may not be the only confounding factor affecting fish populations in the Hackensack River. Climate and weather pattern changes and things like subtle hydrological changes in the river can also conceivably influence fish population dynamics.

The data set reported by Bragin et al. (2005) is valuable and it can possibly be interpreted as documenting effects of improved water quality in the tidal Hackensack River. This monitoring program should be continued but I would suggest that analyses should be done to improve its efficiency and that studies be done to investigate interactions between the Hudson-New York Harbor and the Hackensack River. Whitfield and Elliott (2002) have provided a useful summary of similar long-term monitoring programs, primarily outside of North America, and various metrics that have been applied to detect changes in estuarine fish communities.

Table 1. Species ranked by abundance in three trawl surveys; the lower Hudson River in 1984/86 (Woodhead 1987) and the Hackensack River in 1987/88 and 2001/03 (Bragin et al. 2005). Fishes are ranked by abundance in the Hudson River and abundance ranks in the Hackensack surveys are indicated in the appropriate column. An "x" indicates presence but not in the top eleven ranks. A blank space indicates absence from the trawl collections.

Species	Hudson 1984/86	Hackensack 1987/88	Hackensack 2001/03
Bay anchovy	1	2	8
Hogchoker	2		
Atlantic tomcod	3	3	x
White perch	4	9	1
Winter flounder	5	10	x
Striped bass	6	x	2
Windowpane	7	x	
Weakfish	8	6	5
American shad	9	12	
Alewife	10	8	7
Summer flounder	11		x

Monitoring Tidal Wetland Functions Using Fishes

Estuaries and their associated tidal wetlands have several well-documented ecological functions that involve fishes. Thus monitoring these fishes is an approach to assessing changes in ecological functions. For instance, shallow inland estuaries are nursery areas for a variety of marine and diadromous fishes. Bragin et al. (2005) and others (e.g. Neuman et al., 2004) have documented the presence of juveniles of species like bluefish, alewife, and striped bass residing and feeding in the low salinity tidal creeks in the Meadowlands. Monitoring this aspect of estuarine functions could be a low intensity more frequent quantitative sampling program compared to Bragin et al.'s (2005) inventory. Other ecological functions in the Meadowlands have not yet been well documented but monitoring them would potentially provide a more complete picture of the ecosystem.

In addition to providing nursery habitat for resident and migratory fishes, many of these species seek out low salinity estuaries for spawning. This nursery function is therefore not limited to the larger juveniles but is also important in nurturing developing larvae. The presence and magnitude of fish eggs and larvae in the Meadowlands may be a better indicator of water quality than the presence of (presumably) more stress-tolerant older juveniles (a point that can be debated) and changes in presence and magnitude of eggs and larvae over years can be a good indicator of changing environmental conditions. A larval fish monitoring program would probably use less field time but does require more laboratory time and identification skills than working with larger fishes. Collecting larval fishes would also answer some species-specific questions of interest, for instance Atlantic tomcod are present in the Hackensack (Bragin et al. 2005) but documentation of spawning in that area would be a significant observation since there are no recent reports of this species spawning south of the Hudson River (Stewart and Auster 1987).

The New Jersey Department of Environmental Protection officially lists only the federally endangered shortnose sturgeon (*Acipenser brevirostrum*) in the state, although the list of species posted on their website states that American shad and rainbow smelt may be threatened. The National Marine Fisheries Service lists three anadromous herrings as of special concern; American shad, alewife, and blueback herring (and similarly lists rainbow smelt). Only one individual rainbow smelt was reported in the Hackensack River in the 1987/88 survey and none more recently. This species has probably become extinct in the Hudson River since its population crash in 1996 (Daniels et al. 2005). It might be very useful to determine if these three anadromous herrings are spawning in the Hackensack River, considering their special concern status with the NMFS.

Another role that fishes play in tidal marsh ecology is the transformation of detrital biomass into animal biomass and its export into tidal creeks. Mummichog feed on small macroinvertebrates on tidal marsh surfaces and their movements on and off the marshes transport this energy into areas where predators can feed on them (Valiela et al. 1977). Grass shrimp (*Palaemonetes*) feed more directly on marsh detritus and also transport this energy into tidal creeks (Welsh 1975). My observations of the shallow marshes at low tide in the Meadowlands indicate that the populations of these two organisms are huge (as are blue crab). Feltes (2003) and Learn et al. (2004) corroborated my superficial observations by collecting large numbers of these species (in the impounded wetlands) and also reported large numbers of inland silverside (*Menidia beryllina*). It is difficult to monitor very large populations because the sampling effort necessary to detect all but massive changes is prohibitive. However, given the significant role these species should have, monitoring may be of value. Instead of monitoring change in population size, one could estimate annual growth rates for these several important organisms and any significant changes in growth rates would probably signal a concomitant environmental change.

Current efforts to restore emergent marshes from a *Phragmites*-dominated habitat to a more diverse habitat including *Spartina* can also be monitored using fishes. There are considerable data on changes that occur in use of emergent marshes by tidal marsh fishes, primarily *Fundulus heteroclitus* (e.g. Wozniak et al. 2006, Fell et al. 2006). Quantitative sampling of fishes and macroinvertebrates on marsh surfaces across restored and unrestored marshes could be used to assess restoration goals and temporal sampling could track changes in habitat use as restoration efforts continue within a marsh. Not all studies have shown that *Phragmites* provides poorer habitat for mummichog (Fell et al. 1998) but generally *Spartina alterniflora* habitat is as good as or better (by the criterion of fish density) habitat for mummichog (Able and Hagan 2000, e.g.). A study in Mill Creek in the Meadowlands did show that mummichog larvae and small juveniles (<20 mm TL) were significantly more abundant in *Spartina* marshes compared to *Phragmites* marshes, primarily because of differences in microtopography (Raichel et al. 2002). Woolcott (2005) sampled nekton in *Phragmites* and *Spartina* marshes in the Meadowlands with minnow traps and flume nets. He found that subadult and adult mummichog significantly preferred *Spartina* marshes. Differences in the results of these two studies may be explained by differences in sampling gear (pit traps and minnow traps vs. flume nets and minnow traps). Despite the variation seen in similar studies, it seems that *Spartina* marshes support larger numbers of mummichog in the Meadowlands. (An analysis of the literature comparing fish communities in *Phragmites* and *Spartina* marshes is in Kiviat 2006.) In addition to large numbers of mummichog, Feltes (2003) and Learn et al. (2004) documented large numbers of inland silverside in waters adjacent to the vegetated shallows. If the latter is seasonally resident in these areas and remains abundant today, it might be worth asking if the emergent plant communities have significant interactions with this fish.

It is possible that *Fundulus luciae* inhabits these areas. This is a very cryptic species that only recently was documented from a tidal marsh surface in the Hudson River and in Lincoln Park in the Hackensack River not far from the Meadowlands District (Yozzo and Ottman 2003). If present, monitoring this species would also track changes in tidal marsh functions.

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