



Inventory of Odonata (Dragonflies and Damselflies) at Gateway National Recreation Area

Natural Resource Technical Report NPS/NCBN/NRTR—2010/296



ON THE COVER

Swamp Darner (*Epiaschna heros*) at Gateway National Recreation Area .
Photograph by: Jackie Sones.

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Nina Briggs, Eric G. Schneider, Jackie Sones, Kristen Puryear

Rhode Island Natural History
P.O. Box 1858
Kingston, Rhode Island 02881

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Abstract

In order to expand knowledge of odonate biodiversity and to make recommendations for management, we conducted a comprehensive baseline inventory of dragonflies and damselflies (Class Insecta, Order Odonata) at Gateway National Recreation Area (GATE). During 2004 and 2005 we conducted a checklist inventory at sites where odonates could potentially breed, as well as at potential migratory and foraging sites. Checklist walks are unrestricted, complete searches that provide an efficient means for initial determination of species presence. During the combined 2004 and 2005 field seasons, 37 species of odonates were documented across 38 sites surveyed. Two New York state listed species were observed, Rambur's forktail (*Ischnura ramburii*) and Needham's skimmer (*Libellula needhamii*). Of the 4,671 individuals sighted during 2004 and 2005, 353 were collected as voucher specimens, representing 35 of the 37 species recorded. The most abundant odonate species at GATE were familiar bluet (*Enallagma civile*), blue dasher (*Pachydiplax longipennis*), citrine forktail (*Ischnura hastate*), and swamp darter (*Epiaeschna heros*). GATE is located within the odonate migration corridor and offers critical habitat for migrating odonates. Migrating odonates were observed during both years of this study in the Jamaica Bay Unit at Fort Tilden and at Breezy Point. The Jamaica Bay Unit showed the greatest species richness of the three Park Units at GATE. In particular, Big John's Pond and West Pond at Jamaica Bay Wildlife Refuge contained permanent water and supported considerable odonate activity, including two state-listed species, Rambur's forktail and Needham's skimmer. The Staten Island Unit generally lacks permanent water and abundant habitat that can be used for breeding by odonates. Nonetheless, sites containing permanent water, such as Freshwater Pond and Peeper Road, provided good foraging and breeding habitat for a suite of odonate species, including two state-listed species, Rambur's forktail and Needham's skimmer. The Sandy Hook Unit contains several unique coastal habitats, including sand dunes, salt and freshwater marshes, and freshwater ponds that provided valuable foraging, breeding, and migratory habitats for odonate species. Of particular importance to breeding odonates were freshwater ponds such as Newest, North, and Exclamation Point Pond. Overall, GATE contains several marshes and coastal ponds that are appropriate for odonate reproduction, as well as several sites that offer good foraging and critical migration habitat.

Keywords: biodiversity, damselflies, dragonflies, Gateway National Recreation Area, insect, inventory, Jamaica Bay Unit, migration, odonate, Sandy Hook Unit, Staten Island Unit

Executive Summary

For the National Park Service to effectively maintain the existing dragonfly and damselfly (Class Insecta, Order Odonata) diversity of Gateway National Recreation Area (GATE) baseline knowledge of the present odonates assemblage is critical, including habitats within the park that support odonates and the abundance and viability of selected odonate species at such sites. To help meet this goal, we focused on three main objectives. The first objective was to conduct a comprehensive baseline inventory of adult odonates. The second objective was to document status, distribution, and relative abundance of rare species found within the park. The third objective was to document odonate migration events and behavior.

Potential survey sites containing breeding, feeding, and migrating habitats were identified by examining aerial photos, topographic maps, wetland maps and records of odonates provided by NPS staff, and consultation with local amateur odonatists. Databases and museum collections were also researched for historic records. Each site was surveyed using the checklist technique, which entails actively searching out odonates so that they could be caught and identified. Male and female vouchers were taken whenever possible at each site. Individuals that evaded capture but could be confidently identified in flight were recorded as sight records on field data sheets. Surveys were conducted once a month during the flight season, from May through September in 2004 and 2005.

Thirty-seven odonate species were recorded across 38 sites surveyed at GATE during 2004 and 2005. Two of these species are state listed in New York, Needham's skimmer (*Libellula needhami*) and Rambur's forkail (*Ischnura ramburii*). Of the three National Parks in New York and New Jersey surveyed for odonates during 2004 and 2005 (Fire Island National Seashore, Sagamore Hill National Historic Site, and GATE), GATE showed the greatest species richness and number of sites with odonate species. The most abundant odonate species at GATE were familiar bluet (*Enallagma civile*), blue dasher (*Pachydiplax longipennis*), citrine forkail (*Ischnura hastata*), and swamp darner (*Epiaeschna heros*). Overall, GATE contains several marshes and coastal ponds that contained permanent water and emergent vegetation and supported odonate breeding. In addition to supporting breeding odonates, several sites at GATE offered good foraging habitat and cover for migrating odonates.

Due to its location within the odonate migration corridor and especially considering the level of development in the surrounding landscape, GATE offers critical habitat for migrating odonates. Migrating odonates were observed during both years of this study in the Jamaica Bay Unit at Fort Tilden and at Breezy Point. On several occasions researchers observed odonates funneling over the dunes at Fort Tilden Fishlot en route to Breezy Point Swales. During much of the migratory period, Breezy Point Swales was teeming with migratory odonates and generally offered excellent foraging habitat and cover to migrating odonates. At the Sandy Hook Unit, Newest Pond and Spermaceti Cover Inner Salt Marsh also supported migratory odonates, offering good foraging habitat and cover during the migratory period. Given the location of the Sandy Hook Unit, it's possible that some of the migratory odonates observed at Breezy Point migrated over the ocean and stopped-over at Sandy Hook before continuing on. Specific results will be presented for each Park Unit (Jamaica Bay Unit, Staten Island Unit, Sandy Hook Unit) below.

The Jamaica Bay Unit showed the greatest species richness of the three Park Units at GATE and contains several areas with critical or rare habitat, such as coastal ponds, dunes, and swales, which not only support odonate breeding, but also provide foraging areas, cover, and habitat for migrating odonates. For example, both Big John's Pond and West Pond at Jamaica Bay Wildlife Refuge (JBWR) contained permanent water and emergent vegetation that supported considerable odonate activity, even when water levels were low. In addition, these sites provided breeding habitat for two state-listed species, Rambur's forktail and Needham's skimmer. As mentioned above, the dunal system and beach at Fort Tilden Fishlot and, in particular, Breezy Point Swales offered excellent foraging habitat and cover to migrating odonates.

The Staten Island Unit contains generous open space amongst a heavily developed landscape, but generally lacks permanent water and abundant habitat that can be used for breeding by odonates. However, sites that contain permanent water such as Freshwater Pond and Peeper Road provided good foraging and breeding habitat for a suite of odonate species, including two state-listed species, Rambur's forktail and Needham's skimmer. In addition, the dunes and beach at Miller's Field provided foraging and potential migration habitat for several odonate species.

The Sandy Hook Unit contains several unique coastal habitats, including sand dunes, salt and freshwater marshes, freshwater ponds, and shrub thickets, that provided valuable foraging, breeding, and migratory habitats for odonate species. Of particular importance to breeding odonates were freshwater ponds with permanent water such as Newest, North, and Exclamation Point Pond. As noted above, Newest Pond and Spermaceti Cover Inner Salt Marsh provides critical habitat used by many migrating odonates.

In general, current management practices at most survey sites appear to have either a neutral or beneficial effect on odonate populations at GATE. The most serious threat to odonate populations and habitat appears to be the abundance of common reed (*Phragmites australis*) at many odonate survey sites, including JBWR Big John's Pond, Peeper Road at Great Kills Park, and Exclamation Point Pond and North Pond at Sandy Hook. In fact, nearly all of the permanent and temporary water used by odonates at GATE were surrounded, to some degree, by common reed. Common reed out competes native plants, changes invertebrate abundance and assemblages, affects site hydrology, and can reduce diversity of damselfly species.

We recommend that in addition to continuing odonate surveys at several of the most productive sites, including JBWR Big John's Pond and Peeper Road and Freshwater Pond at Great Kills Park, that common reed be monitored and if deemed necessary, managed for at Peeper Road and Freshwater Pond at Great Kills Park. In addition, we suggest that monitoring for migration events at Fort Tilden Fishlot at the Jamaica Bay Unit.

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Introduction

Although several lists of odonate (Class Insecta, Order Odonata) species have been compiled (Calvert 1895, 1897; Davis 1898, 1913; Donnelly 1992) counties in the New York metropolitan area have not been adequately sampled for odonates. Calvert (1895, 1897) was the first to publish a list of odonates known to occur in New York State. Davis (1898) wrote a preliminary list of the odonates of Staten Island. A second paper by Davis (1913) lists 117 species of odonate recorded in the vicinity of New York City and includes all previous odonate lists. The most recent summary of odonates in New York (Donnelly 1992) listed 175 species in the state with 79 species in Suffolk County, 11 species in Nassau County, and 69 species in the New York City area (with 19 species in Queens County, 8 species in Kings County, and 59 species in Richmond County). In New Jersey, the New Jersey Odonate Society has an ongoing odonate survey. At present, 183 species have been documented in New Jersey, including 53 species in Monmouth County.

For the National Park Service and GATE to effectively to meet their responsibilities, including maintaining the distinctive biological diversity of GATE, it first must identify what habitats within the park support odonates, inventory sites containing these habitats for adult odonates, and document the abundance and viability of selected odonate species. Odonates are well suited to inventories because they are a relatively small group of insects, and most adults can be readily identified in the field. Odonates begin their life cycle as aquatic insects and therefore may also provide valuable information about water quality and ecological management issues.

The first objective of this project was to conduct a baseline inventory of adult odonates at GATE. The second objective was to document the occurrence of any rare species of odonates at GATE. Twenty-seven species are state listed in New York (NYNHP 2006) and 21 species are state listed in New Jersey (NJODES 2006). Several of the state listed species carry a S1 or S2 status¹ because their populations are declining, in part due to loss and degradation of habitat (NJODES 2006, NYNHP 2006). If rare odonate species are present in the park, information such as breeding status, population estimates, and habitat requirements could be used to improve management of habitat for these species.

The third objective of this project was to document odonate migration events and migration behavior. Recent technological advances have improved our ability to investigate odonate migration and behavior, greatly improving our knowledge such phenomena (Moskowitz et al. 2001, Wikelski et al. 2006). Historically, migration was thought to be a dispersal mechanism (Johnson 1960). Recent work shows that migration is not limited to dispersal and is strongly correlated with cold front passages (Russell et al. 1998, Wikelski et al. 2006). In addition, large

¹ A S1 rank means the NY Natural Heritage Program has determined that there are only “...five or fewer occurrences, very few individuals...or factors making it very vulnerable in New York State” (NYNHP 2006). A S2 rank means that there are only “...6-20 occurrences, few remaining individuals...or factors making it very vulnerable in New York State” (NYNHP 2006).

swarms of migrants are influenced by topographic leading lines such as coastlines (Russell et al. 1998, Wikelski et al. 2006). For example, odonates appear to move along and follow the coast line after a cold fronts passes (Russell et al. 1998). Due, primarily, to its location along the Atlantic seaboard, GATE is located within the odonate migration corridor (Shannon 1935, Mulberry Wing 2006).

Study Area

Gateway National Recreational Area (GATE) is a 10,644 ha (26,610 acre) National Park located along the Atlantic coastline on Long Island, Staten Island, and Sandy Hook, New Jersey. It is comprised of three Park Units: the Jamaica Bay Unit, the Staten Island Unit, and the Sandy Hook Unit (Figure 1). For simplicity, we discuss each Park Unit separately in this report. At each Park Unit, a distinctive mix of coastal habitats could potentially support odonate populations. Characteristic habitats include freshwater ponds, fresh- and saltwater marshes, primary and secondary dunes and associated swales, beach, and coastal upland shrub habitat. Each habitat can be utilized in different ways by odonates, such as for reproduction, cover, foraging, or migration.

Beaches and primary dunes are migration corridors for odonates (Shannon 1935, Russell et al. 1998). Odonate migration can occur in both spring and fall, but fall migrations are most pronounced and best understood. Along the northeastern U.S. coast, fall migrations often occur between late July and mid October following the passage of cold fronts which push odonates from the north to the southwest (Russell et al. 1998). It's also believed that major topographic features, such as beaches and dunes, concentrate insects as they migrate (Moskowitz et al. 2001).

Interdunal swales can be important foraging and, for a limited but distinctive set of species, breeding habitat for odonates. Water bodies at interdunal swales are characterized by fishlessness, seasonality, sandy substrate, sun and wind exposure, and vegetation such as rush (*Juncus ssp.*), bayberry (*Myrica pensylvanica*), and myrtle (*Myrtaceae spp.*), which provide good sites for oviposition, emergence, and perching. Many species of odonates benefit from high prey densities at interdunal water sources and a few species can use the temporary waters as breeding habitat. Typical species include wandering glider (*Pantala flavescens*), spot-winged glider (*Pantala hymenaea*), familiar bluet (*Enallagma civile*), and citrine forktail (*Ischnura hastata*).

In general, coastal fresh water ponds provide the most permanent environment for odonates and typically show the greatest abundance and diversity of odonate species (McClure 2001). While species that use permanent freshwater ponds, in general, can take advantage of coastal ponds, some species of conservation importance such as Needham's skimmer (*Libellula needhami*) and Rambur's forktail (*Ischnura ramburii*) are typically associated with these habitats.

Salt marshes with well developed salt pannes typically have high invertebrate diversity and density among barrier island habitat types. Of the 4 types of pannes found in salt marshes (e.g., deep perennial, shallow perennial, temporal, and vegetative panes) temporal pannes exclude fish and thus, have the greatest diversity of invertebrates (Wilson 2005). Salt marshes, in general, offer important foraging areas for many odonate species, especially during fall migration, and may provide breeding habitat for certain species such as seaside dragonlet (*Erythrodiplax berenice*), familiar bluet (*Enallagma civile*) and Rambur's forktail.

For this study, survey sites were selected based on their potential to support odonate breeding habitat, their position relative to likely migration routes, and recommendations from park service personnel (see Methods for more detail). Some sites that were surveyed in 2004 did not appear to support odonates, and were therefore not resurveyed in 2005 in order to concentrate field time at likely odonate habitats. All survey sites and activities by year are summarized in Table 1. The

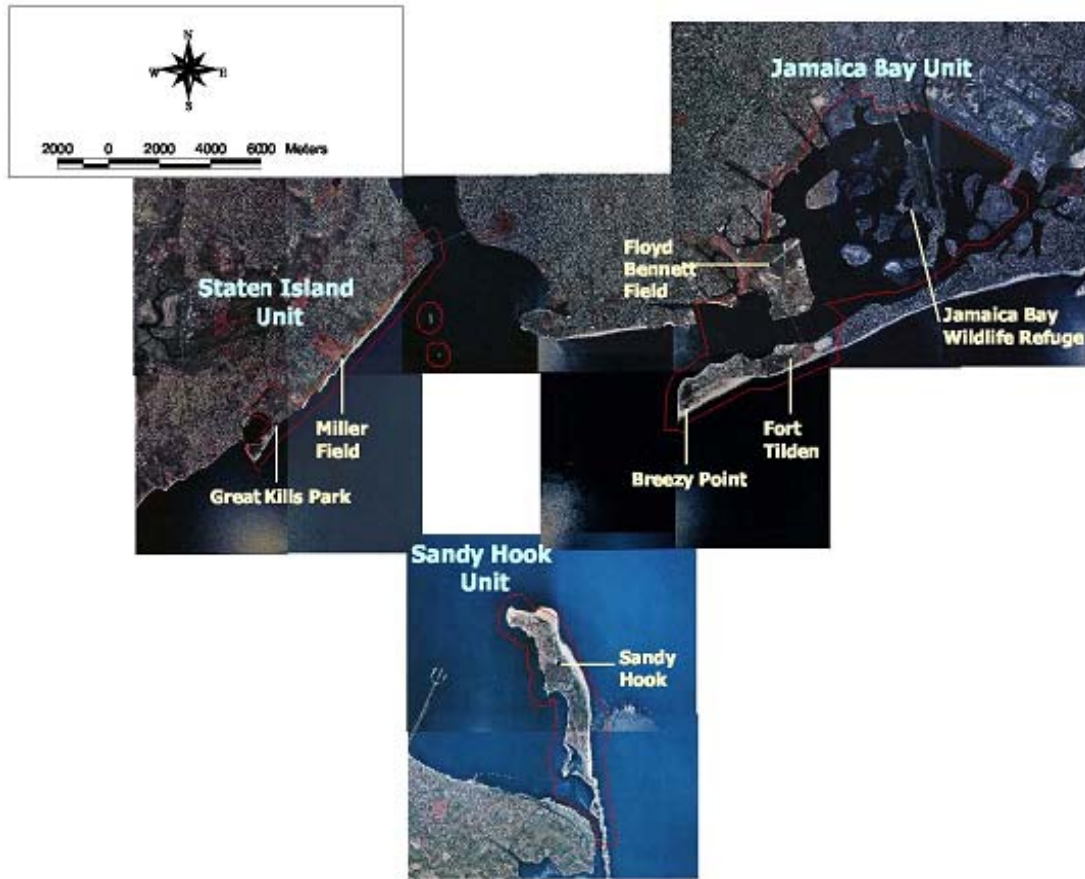


Figure 1. Map of odonate inventory survey sites at GATE in 2004.

following paragraphs describe Park subunits and each survey site in detail. Note that each odonate survey site was assigned natural community classifications based on both the National Vegetation Classification Standard (NVCS)(FGDC 1997) and the New York Natural Heritage Program (NYNHP) classifications (Edinger et al. 2002) (Appendix A). In this report, we discuss habitat classifications using NVCS and only refer to NYNHP classifications when habitat at a given site was not recognized by NVCS. Photographs of survey sites are contained in Appendix B.

Jamaica Bay Unit

The Jamaica bay Unit is comprised of four Park subunits: Jamaica Bay Wildlife Refuge (JBWR), Fort Tilden, Breezy Point, and Floyd Bennett Field. These subunits are located in Kings and Queens Counties, New York, and thus New York regulatory regimes apply to all of them. Although these subunits span two counties, they are all in relatively close in proximity to each other (Figure 2). Therefore, it is likely that historical records from a given county could potentially apply to the other. Although the habitats in these subunits show some ecological diversity, the habitats of greatest value for odonate study and management are those which typify North Atlantic barrier islands. These habitats are found primarily at Breezy Point and JBWR.

Table 1. Sites surveyed for odonates at Gateway National Recreation Area, New York and New Jersey, during 2004-2005. Sites that were surveyed in a given year are noted with an X. Rational is provided for sites that were not resurveyed. Park subunits are abbreviated as: Breezy Point (BP), Floyd Bennett Field (FB), Fort Tilden (FT), Jamaica Bay and Wildlife Refuge (JBWR).

Park Unit / Subunit / Site Name	Year(s) surveyed		Rational if not resurveyed
	2004	2005	
Jamaica Bay Unit			
BP: Saltmarsh	X	X	
BP: Swale	X	X	
FBF: Community Garden		X	
FBF: Culvert	X	X	
FBF: Rag Pond	X	X	
FT: Fishlot	X	X	
FT: House		X	
FT: Pond	X	X	
JBWR: Big John's Pond	X	X	
JBWR: Blind Pond	X	X	
JBWR: East Pond	X	X	
JBWR: Fire Break	X	X	
JBWR: Saltmarsh	X	X	
JBWR: West Pond	X	X	
JBWR: West Pond Marsh North #2	X	X	
JBWR: West Pond Marsh South #1	X	X	
Sandy Hook Unit			
Exclamation Point Pond	X	X	
Horseshoe Marsh	X		Lack of odonate habitat
K-Lot Field	X	X	
Newest Pond	X	X	
Nike Pond	X		Inaccessible
North Pond	X	X	
Plum Marsh	X		Breeding habitat appropriate for one species, which was found in 2004
Round Pond	X	X	
Spermaceti Cove Inner Salt Marsh	X	X	
Spermaceti Cove Outer Salt Marsh	X		Lack of odonate habitat
Staten Island Unit			
Ballfield	X		
Blue Dot Trail Drainage Opening	X	X	
Cliff Edge	X	X	
E Lot Ditch	X		No standing water remained
Education Center Pond	X	X	
Freshwater Pond	X	X	
Peeper Road	X	X	
Pipe Road	X	X	
Pipe Road Drainage	X		No standing water remained
Promenade Marsh	X	X	
Miller Field: Dune/Beach	X	X	
Miller Field: Field	X	X	
	36	26	

Jamaica Bay Wildlife Refuge

JBWR is the largest subunit within GATE at 3,705 ha (9,155 acres) and contains 12 sites that were surveyed for odonates: Big John's Pond, Bird Blind Pond, East Pond, Fire Break Road, Salt Marsh, Visitor Center, West Pond, and West Pond Marsh South and North (Figure 2).

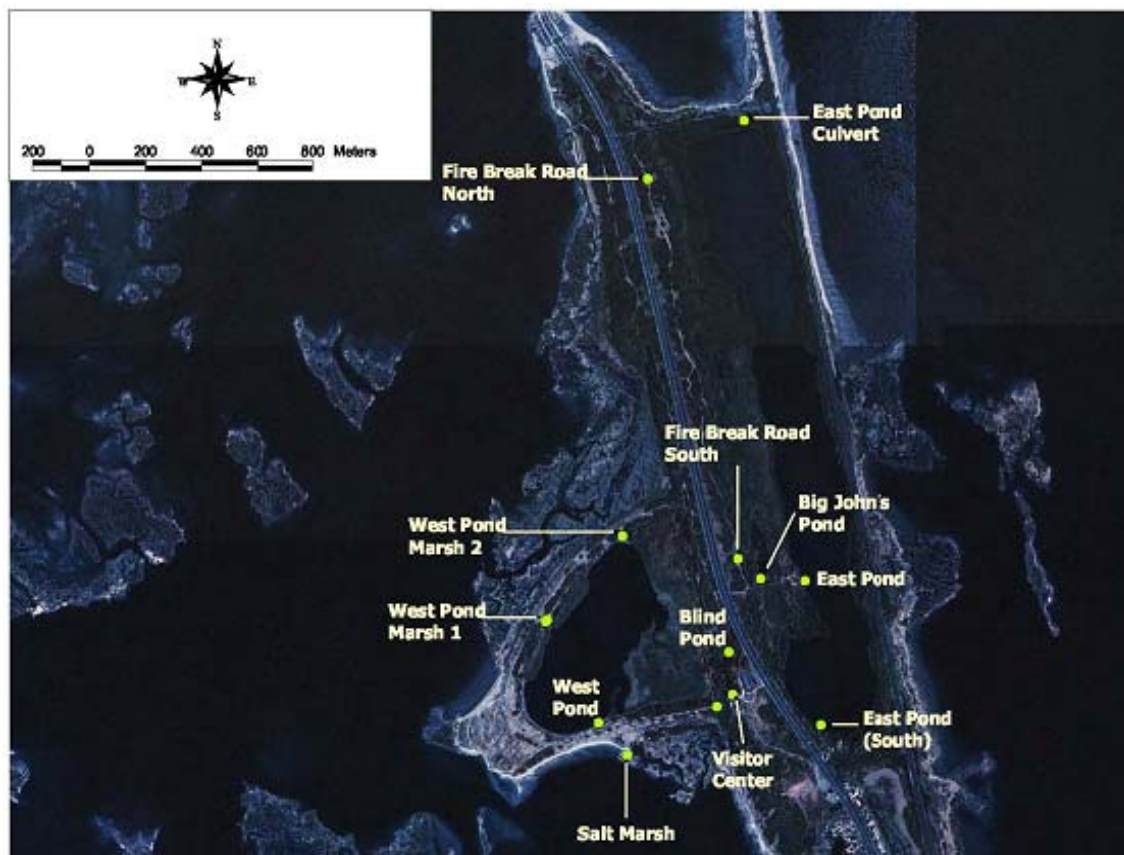


Figure 2. Map of odonate survey sites in Jamaica Bay Wildlife Refuge, GATE 2004.

Big John's Pond: Big John's Pond is a marsh that is 10 m (30ft) in diameter and virtually surrounded by eastern reed (FDGC 1997). The north and west edge support other emergent vegetation, such as rush and there is an organic mat on the water composed of algae (undetermined species) and other organic detritus. Wide variation in water level was observed between 2004 and 2005.

Bird Blind Pond: Bird Blind Pond is a small, 3 m (10 ft) diameter, man-made pond fed by a hose. The pond surface is covered in pondweed (*Lemna minor*), and has very little emergent vegetation. The area to the east of the pond is mowed, to the west there is a dense stand of eastern reed. This pond is potential foraging habitat or cover, but presents limited potential as breeding habitat and contained no exuvia.

East Pond: East Pond is a large, 49 ha (120 acre) in diameter artificial impoundment connected to the ocean by a culvert. Water levels at East Pond are managed to expose mudflats for bird habitat, a physical characteristic that may prevent odonate reproduction. The pond is surrounded

by a dense stand of common reed (*Phragmites australis*), also referred to as eastern reed, and has mallow (fam. *Malvaceae*) growing on the mudflats. Blue-green deposits of unknown origin were seen in the water and surrounding mudflats.

Fire Break Road: The fire break road is a mowed path that runs between East Pond and Cross Bay Boulevard. There is evidence of human use and disturbance; there are no aquatic features. The site was chosen for potential feeding/shelter sites.

Salt Marsh: This extensive salt marsh borders the south and east sides of West Pond. Within the salt marsh there are intertidal mudflats, as well salt pannes and pools.

Visitor Center: The Park Visitor Center contains open mowed lawn and path areas adjacent to West pond. These upland areas were selected for their potential to serve as feeding habitat, within the dense graminoid vegetation and woody plants that line the path.

West Pond: West Pond is an artificial estuarine impoundment that contains a 22 ha (54 acre) open water pond. The eastern edge of the pond has a broad stand of eastern reed, and the western edge is mowed regularly to allow birdwatchers visual access to the shoreline bird habitat. The mowed shore has dense graminoid/herbaceous vegetation.

West Pond Marsh South and West Pond Marsh North: These shallow emergent marshes are located along the western edge of West Pond. They did not contain open water on the days they were surveyed.

Floyd Bennett Field

Floyd Bennett Field is a 579 ha (1448 acre) former naval air station (Figure 3). There is an ongoing grassland restoration project at this subunit, targeting grassland bird species. Four sites were surveyed for odonates within Floyd Bennett Field: Community Gardens, Culvert Marsh, North Forty Trails, and Return-A-Gift Pond (hereafter, RAG Pond).

Community Gardens: These public gardens are located across from the grassland restoration site. Although a road bisects the habitat, the Community Gardens together with adjacent open grasslands offered a potential feeding area for odonates.

Culvert Marsh: The Culvert Marsh extends under a runway-access road in the northeastern portion of Floyd Bennett Field. It is surrounded by dense poison ivy (*Toxicodendron radicans*) and common reed. This small marsh, 1 m (3 feet) wide, had no obvious water source.

North Forty Trails: These mowed trails meander through eastern reed marsh (FDGC 1997) in the northern portion of Floyd Bennett Field. This area contains a mix of deciduous trees and upland shrubs interspersed within the marsh and appeared to offer potential feeding and foraging habitat.

RAG Pond: This site contains a small, 100 m², man-made marsh surrounded by common reed. Common reed is the dominate vegetation and no other emergent vegetation was seen in the pond. During the 2005 survey a thick layer of pondweed (*Lemna minor*), covered the entire surface of the pond. We observed large fluctuations in water levels between surveys conducted during 2004 and 2005.



Figure 3. Map of odonate survey sites at Floyd Bennett Field, GATE 2004.

Breezy Point

Breezy Point is the extreme western tip of the Rockaway Peninsula on Long Island. The subunit is surrounded by ocean to the north, south, and west, and is bordered by intensive development to the east. Breezy Point is composed of a series of dunes and swales and a salt marsh, as well as open sandy beach. Odonate surveys were conducted on the northern edge of at the dune and swale survey sites. Surveys were also conducted at the salt marsh, located in the southern third (Figure 4)

Dune: Located at the north end of the Breezy Point subunit, the dunes are sandy but vegetated and are assumed to be largely stable. Because the dunes are elevated relative to their surroundings, they appeared to contain good habitat for foraging and migration.

Salt Marsh: This large salt marsh appears to be a North Atlantic High Salt Marsh (FDGC 1997) and contains halophytic vegetation indicative of saline soils. Water levels were observed to vary greatly from 2004 and 2005. In 2004, the marsh was dry early in the season and inundated later in the summer. In 2005, the salt marsh was dry, both early and late in the season, when surveyed.

Swale: This area of Northeastern Atlantic Brackish Interdunal Swale (FDGC 1997) is substantially wetter compared to other areas within the dunal system. There is a layer of dense shrubs at the edge of the swale interspersed with eastern reed. Dense graminoid and herbaceous vegetation are found at the bottom of the swale. Water levels were observed to vary from 2004 to 2005.



Figure 4. Map of odonate survey sites in Breezy Point Tip, GATE 2004.

Fort Tilden

Fort Tilden is a large parcel of mixed use land located on the Rockaway Peninsula that is bounded by the Atlantic Ocean to the south and the Rockaway Inlet to the north (Figure 5). The landscape contains a mix of gardens, open fields, and dunes that are fragmented by dune trails and roads. This subunit contains three sites that were surveyed for odonates: Fort Tilden Fisherman's Lot (hereafter, Fishlot), Fort Tilden House, and Fort Tilden Pond.

Fort Tilden Fishlot: This site consists of a paved path and road which are situated at the southern edge of Fort Tilden. This has been a site that was used in the past to document odonate migration (Walter 1998). Because of its location, odonates are funneled along the coast during fall migrations.

Fort Tilden House: This house is located in the Southwest-section of Fort Tilden, approximately 250 m from the beach and the Atlantic Ocean. It is located on a 20 x 100-m lot with lawns that are regularly mowed. Along the south side of the house is a 100 x 50 m swathe of mixed age deciduous trees and shrubby undergrowth divided by a paved foot path. Due to its proximity to the ocean, it was found to be a good migratory and feeding area.

Fort Tilden Pond: This is a small, 3 m (9.5 ft) diameter, eastern reed marsh at the bottom of a dune swale. The water surface is covered with a thick layer of pondweed. Although the reeds are tall, the site is open to the sky. Water levels did not vary from 2004 to 2005.



Figure 5. Map of odonate survey sited in Fort Tilden, GATE 2004.

Staten Island Unit

This Park unit is located on Staten Island, Richmond County, New York and contains two Park subunits: Great Kills Park and Miller Field. These subunits are located along the southeast facing shore and separated from each other by urban and suburban development (Figure 6). New York regulatory regimes apply to both subunits. Unlike subunits at the Jamaica Bay Unit, Staten Island subunits provide little or no typical barrier island habitat resources; however, this subunit does contain two productive breeding habitats. This site also offers foraging and potential migration habitat for odonates due to their location.

Great Kills Park

Great Kills Park is a public park with a mix of fields, wetlands, nature trails, and boat slips. We surveyed 11 sites at the subunit for odonates: Ballfield, Blue Dot Trail Drainage Bridge, Blue Dot Trail Drainage Opening, Cliff Edge, Education Center Pond, E Lot Ditch, Freshwater Pond, Peeper Road, Pipe Road, Pipe Road Drainage, and Promenade Marsh.



Figure 6. Map of odonate survey sites in Great Kills Park, GATE 2004.

Ballfield: This site contained several athletic fields located in the west corner of the Great Kills Park. These fields were mowed and offered potential foraging habitat and a location to observe migratory behavior.

Blue Dot Trail Drainage Bridge: This site, located at the far-west corner of the park, contains a small bridge that crosses a tidally influenced stream. The stream is influenced by Great Kills

Harbor, which lies approximately 125 m to the south. During our surveys water levels were low and there was little or no flow. We found little emergent vegetation and the stream bed was muddy.

Blue Dot Trail Drainage Opening: This is a 2 m² section of the 800 m drainage system located near the north-west edge of Great Kills Park. This ditch is bordered on the east by Hylan Boulevard, to the west by mixed deciduous forest. This portion of the drainage system supports an eastern reed marsh (FDGC 1997). Because of the slow and intermittent flow of the water in the ditch, it was of questionable quality for odonate breeding.

Cliff Edge: This is a 350 m long area atop coastal escarpment located on the eastern edge of Great Kills Park, facing Lower New York Bay. The active beach is located approximately 3 m below the cliff edge. This site has no associated fresh water, but has good potential for migrating and foraging odonates.

Education Center Pond: This small, 5 m (15 ft), artificial pond was maintained for education program demonstrations. Although habitat quality appeared generally good during 2004, during 2005 habitat quality was obviously degraded. For example, during 2005 we observed turbid water, less emergent vegetation and greater disturbance of pond-side soil and vegetation compared to 2004. We attributed these negative affects to abundance of ducks present in 2005.

E Lot Ditch: The E Lot Ditch is approximately 100-m long, 1-m wide drainage ditch running north-south just inland of the east shore of Great Kills Harbor. This impoundment is bounded by a parking lot and has intermittent standing water.

Freshwater Pond: This is eastern reed marsh (FDGC 1997) is approximately 7 m (21 ft) in diameter and is located in the eastern-central area of the park. It is surrounded by common reed, but the shores of the pond have abundant rush. This site appeared to have very good habitat for odonates. The presence of rush suggests that water levels typically fluctuate; however, levels appeared unusually low in 2005.

Peeper Road: This large eastern reed marsh (FDGC 1997) was approximately <0.5 ha (1.2 acre) in extent with open water within the bounds of the marsh. The open area supports a suite of rushes and sedges that provided potential perches and cover for odonates. During 2005, we observed considerable variation in water levels.

Pipe Road: Pipe Road is a grass/dirt road located to the north of Pipe Road Drainage. Pipe Road runs parallel to Pipe Road Drainage and contains a mix of short and tall graminoid vegetation. This site appeared to offer foraging habitat in close proximity to potential breeding habitat in the Pipe Road Drainage.

Pipe Road Drainage: This is a drainage ditch which supports an eastern reed marsh (FDGC 1997). This site was selected because it appeared to offer potential odonate breeding habitat. However, during 2004 we observed a lack of both water flow and odonate activity and thus, determined that this site had little potential to support odonate breeding.

Promenade Marsh: This is a small, <200 m², wet grassy area located between a dirt parking lot and a seawall. We believed that the site offered potential habitat for odonate breeding. In

retrospect, the site contained suitable cover for small odonates, but there was probably not enough water to support odonate breeding.

Salt Marsh: This is a marshy area immediately behind the beach. It may be a remnant of a larger marsh, now eroded by the ocean. There are some salt pannes or pools; however, their small size and proximity to the active shoreline made them unlikely to support breeding odonates.

Miller Field

Miller Field is a former air field that has been converted into athletic fields. It is closely surrounded by development on three sides and by the sea to the southeast. Two sites were surveyed for odonates: Dune/Beach and the Athletic Field.

Dune/Beach: This site contains a beach and dunal system that runs approximately 500 m from the southwest to the northeast and separates the athletic fields from the ocean. This site was selected because it is a west facing dune, which offers potential migration and feeding sites for odonates.

Athletic Field: The Athletic Field site was a former airfield that was converted into multiple athletic fields (Figure 7). The grounds are mowed regularly and the grass is maintained for athletic events. This site was chosen as a possible feeding and foraging area and offers a location to observe migratory behavior.

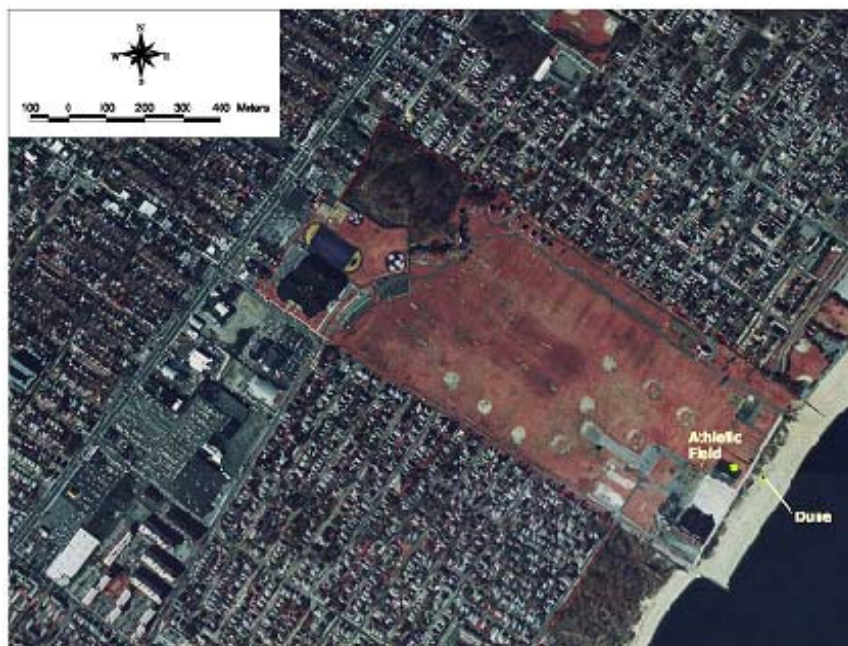


Figure 7. Map of odonate survey sites at Miller Field, GATE 2004.

Sandy Hook Unit

This Park unit is located in Monmouth County, New Jersey and subject to New Jersey regulatory regimes. Sandy Hook is a barrier beach spit approximately 9 km (5.6 mi) long and 827 ha (2,044

acre) in area (Figure 8, 9). Sandy Hook has a good representation of habitats typical of barrier islands/beaches, including sandy beaches and salt marshes on the west side of the spit, beaches on the east side, and a handful of freshwater ponds in the interior and on the point. (Figures 8, 9). Sandy Hook is approximately 12 km (by sea) from Breezy Point and likely participates in odonate migratory events with the other Park Units. There are no Park subunits at Sandy Hook; however, for the purposes of this report we will refer to a subunit called Sandy Hook. Odonate surveys were conducted at the following sites at Sandy Hook: Exclamation Point Pond, Fisherman's Trail, Horseshoe Cove Salt Marsh, K Lot Field, Newest Pond, Nike Pond, North Pond, Plum Island Salt Marsh, Round Pond, and Spermacetti Cove Inner and Outer Salt Marsh.

Sandy Hook

Exclamation Point Pond: This small, 10m (30 ft) in diameter eastern reed marsh (FDGC 1997), is located near the northern tip of Sandy Hook. It is surrounded by a wide band of common reed, poison ivy, and marsh mallow. This band of vegetation makes the pond nearly inaccessible. We observed algal-like floating vegetation and consistent water levels during 2004 and 2005 surveys.

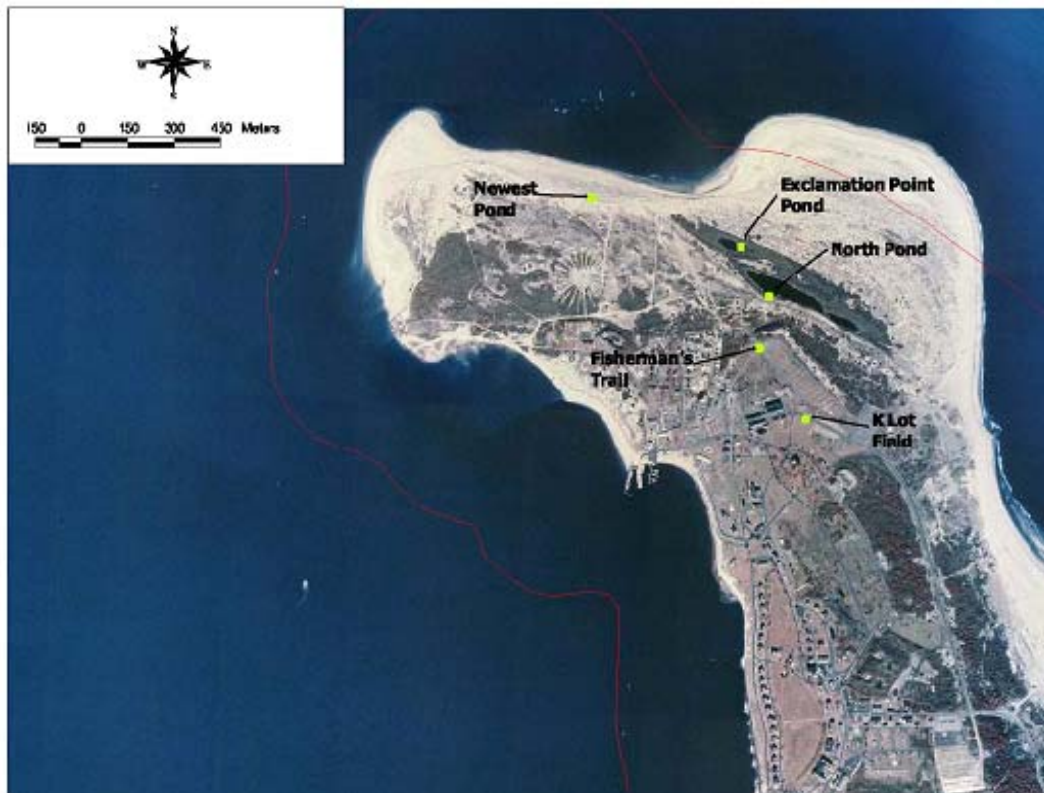


Figure 8. Map of odonate survey sites in Sandy Hook (North), GATE 2004.



Figure 9. Map of odonate survey sites in Sandy Hook (South), GATE 2004.

Fisherman's Trail: This site consists of a 250-m long segment of a sandy foot trail through a maritime holly forest (FDGC 1997). The trail, at points, winds past an eastern reed marsh (FDGC 1997). This site was selected because it offers potential foraging habitat.

Horseshoe Cove Salt Marsh: This is a large salt marsh located on the western edge of the spit. It encompasses both high salt marsh and low salt marsh habitats. There is a tidal creek, but salt marsh pools and pannes did not appear to offer suitable breeding habitat for seaside dragonlet.

K Lot Field: This is a successional old field approximately 1 ha (2.5 acre) in size. This site was selected for its potential as foraging habitat. There is no water associated with this site.

Newest Pond: This is a freshwater pond approximately 100 x 30 m in size located on the lee side of the active dune at the northern edge of Sandy Hook. There is little emergent vegetation at the shore of the pond, but an algal-like floating mat was observed. Water levels were similar during 2004 and 2005 surveys. If this pond becomes more established, this site could be a potentially important site for odonates.

Nike Pond: This 100 m in diameter pond is surrounded by an eastern reed marsh (FDGC 1997) that was formed by water retained in the footprint of an old military installation. There was little to no emergent vegetation apparent. This pond is surrounded by dense common reed and poison ivy, making it virtually inaccessible.

North Pond: This is a large, oblong pond approximately 300 m (0.2 miles) in length located near the tip of the Sandy Hook spit. The pond has a sandy bottom covered in a thin organic layer and is surrounded by dense common reed and poison ivy with openings along the southern edge. Algal-like floating vegetation was present in the summer that odonates oviposited on.

Plum Island Salt Marsh: This marsh is located on a spit that off the main barrier beach on the southwest side of Sandy Hook. It has both high and low salt marsh, but the salt pannes are not well established. The north side of the marsh is subject to wave action from the cove.

Round Pond: This pond is found within a maritime holly forest (FDGC 1997) that generally provides shade for the pond. The pond is 20 m in diameter and ringed by common reed. The surface of the pond is completely covered with a thick layer of pondweed. This site is both hard to access and was unproductive for odonates in 2004 and 2005.

Spermacetti Cove Inner Salt Marsh: This 100 m² portion of Spermacetti Cove Salt Marsh has well developed high and low salt marsh with salt pannes. It is bordered on the west by marsh elder (*Iva frutescens*) and to the east by poison ivy. It is protected by dunes and not subject to direct wave action. The salt pannes support breeding seaside dragonlet and Rambur's forktail. In general, this is a good foraging site for a suite of dragonflies.

Spermacetti Cove Outer Salt Marsh: This west facing section of Spermacetti Cove is a 1.4 km long salt marsh with both high and low salt marsh. There is potential foraging/migratory habitat; however, there was no sign of odonate reproduction in this part of the marsh as the salt pannes appear to be relatively frequently inundated.

Methods

Site Selection and Documentation

Potential breeding, feeding, and migrating sites were identified using 3 approaches. Aerial photos and USGS topographic maps were analyzed for landscape features that could provide odonate breeding, feeding, or migration habitat. In addition, wetland maps provided by NPS staff were reviewed, and local amateur odonatists were consulted for their knowledge of the odonate habitats and fauna within GATE.

Once the potential odonate sites were identified, each site was visited and its location recorded using a hand-held Garmin V GPS unit. To maximize the accuracy of GPS readings, Garmin GPS units were set to the 3D Differential mode. At sites where the canopy was too dense for the 3D mode to operate, the precision of the GPS reading was noted on NPS approved field data forms.

In the field, sites were assigned natural community classifications based on both the National Vegetation Classification Standard (NVCS)(FGDC 1997) and the New York Natural Heritage Program (NYNHP) classifications (Edinger et al. 2002) (Appendix A). In this report, we discuss habitat classifications using NVCS and only refer to NYNHP classifications when habitat at a given site was not recognized by NVCS (e.g., mowed lawn) (see Appendix A).

Potential Species Lists

A checklist of species likely to be found at GATE (Appendix C) was generated using a four-step process. First, RINHS odonate specialists compiled a list of potential species that they would expect to find at GATE based on their experience in habitat similar to that identified during the site selection process. Second, published lists of odonates in the Northeast (Calvert 1903, Montgomery 1933, Walker 1953, Carpenter 1991, Donnelly 1999) were referenced for additional potential species based on habitat preference and distribution. Third, Park Service staff were consulted for their observations of odonates and knowledge of potential odonate habitat. Fourth, historical collections and biological repositories (e.g., American Museum of Natural History, Staten Island Museum, Smithsonian Museum of Natural History, and Yale University) were searched for any odonate species documented within Kings, Queens, and Richmond County in NY and Monmouth County NJ or, when possible, within the Park itself (e.g., Park records for Breezy Point and JBWR at the Jamaica Bay Unit and the Sandy Hook Unit). All potential species were then compiled into a list, see Appendix C.

Field Surveys

Given that dragonflies are most active when temperatures are warm (Walker 1953, Carpenter 1991), site visits were made on sunny days when the temperature was at least 20°C. Site visits were conducted during the third week of each month, weather permitting. In 2004, sites were visited on five consecutive months (May, June, July, August, and September). In 2005, sites visits were in June, July, and August. Cold and stormy weather during May 2005 did not permit sampling. No survey was conducted in September 2005 because odonates specialists believed it was unlikely that any new species would be recorded based on the number of new species detected during surveys in June, July, and August 2005 (see Results and Discussion).

During the survey period, weather data were recorded using a Kestral 4000 (Neilson-Tellerman) once each day. However, additional data were recorded if weather conditions changed significantly during the day. Weather variables recorded at each site were: temperature (°C), wind speed and direction, relative humidity, and barometric pressure. Weather data were recorded in field notes and then transferred to NPS approved field forms.

During the 2003 study season, one researcher (JS) visited GATE to determine site possibilities and ground truth potential habitat descriptions. During 2004 and 2005, sites were surveyed by groups of two to four researchers, including one to two odonate specialists (Table 2). All non-specialists had a working knowledge of common odonates and were trained in odonata field techniques. Field researchers netted, identified, and assisted process specimens and completed field data form. Each field data form was verified by either the project leader or the odonata specialist before leaving the field site.

Each site was surveyed for odonates using the “checklist counting technique” as described by Royer et al. (1998), which is one of the most efficient ways to initially determine species presence at a site (Royer et al. 1998). Briefly, this technique required that investigators move through a site actively looking for, identifying, and counting odonates as encountered. When odonates could be confidently identified in flight, individuals were recorded as sight records on field data sheets. When possible, a male and female voucher specimen of each species was collected from each site. Voucher specimens were caught using 1.5 m (5 ft) aerial nets. Netted specimens were placed in glassine envelopes until they could be processed. Each glassine envelope was labeled using pencil with the date, location, and genus/species information. In addition, data regarding voucher specimens were recorded on voucher cards (see Appendix D) and placed in glassine envelopes with each voucher specimen after processing.

Although most odonate species are easily identified in the field, when necessary, final determination of each species was verified using a microscope in the lab. For example, some damselflies, such as sweetflag spreadwing (*Lestes forcipatus*), southern spreadwing (*Lestes australis*), common spreadwing (*Lestes disjunctus*) cannot be distinguished from another in the field, therefore we collected several voucher specimens to determine whether a given species was in fact present at a given site.

Table 2. Researchers that visited survey sites at Gateway National Recreation Area, New York and New Jersey, during 2003-2005. No surveys were conducted during May and September 2005.

	2003	2004					2005				
	June	May	June	July	Aug.	Sept.	May	June	July	Aug.	Sept.
Researcher initials*	JS	JS, NB	JS, NB	JS, MV, NB, SJ	JS, NB, SJ	JS, NB	-	ET, NB	ET, NB	ET, NB, VB	-
* ET: Emily Troiano, JS: Jaqueline Sones, MV: Michael Veit, NB: Nina Briggs, SJ: Sarah Jennings, VB: Virginia Brown											

Voucher Specimen Processing

Specimens were processed and stored following standard procedures described by Dunkle (1990). Briefly, each specimen was placed in a glassine envelope and submerged in acetone for ~ 3 min. Specimens were then removed from the acetone and arraigned for storage with the body facing left, eyes facing up, wings placed over the back, and the legs and abdomen straightened (Dunkle 1990, Brunelle 1994). Each specimen was then put in a glassine envelope and returned to the acetone to remove lipids and water and preserve color. Larger specimens were processed in acetone for approximately 24 hours; smaller specimens were processed for 12 hours. After being removed from the second acetone treatment, specimens were dried under a light and stored in airtight containers until they could be put in insect cases in the lab.

Migration Events Monitoring

Odonate migration events are largely influenced by weather patterns, such as passing cold fronts that occur between late July and mid-October (Russell et al. 1998). The peak of odonate migration usually occurs during September (Russell et al. 1998) and therefore, sampling dates were predetermined, in part, to assure that at least one survey was conducted during a possible peak-migration period (e.g., survey conducted during the third week of the September 2004). During all field surveys, but especially those conducted during September, investigators monitored for possible migration events. For this study, a migration event was defined as a swarm or large group of dragonflies or damselflies moving together in same direction. Migration events have been documented using different approaches across the region; however, results are comparable providing that estimates contain the number of individuals moving through a specific area (e.g., 1 m²) during an interval of time (Russell et al. 1998). Therefore, in this study researchers chose to document and quantify a migration event by counting individual odonates as they fly overhead (e.g., 1 m²) using 10-min intervals, for the duration of the migration event. After a migration event had ceased, the total number of each species was quantified.

Data Analysis

Species Inventory

To quantify the status, distribution, and abundance of odonate species found within the park, data collected during field surveys were entered into an Access database and queries were run to determine the abundance and distribution of each odonate species at GATE. Outputs of each query were summarized using Excel. Biological diversity of odonate species at GATE was quantified for each survey site and Park subunit using three measures: (1) species richness, (2) Simpson's Index of Diversity, and (3) Shannon-Wiener Diversity Index. Species richness is defined as the total number of species present in a given area, such as a survey site or Park subunit. Simpson's Index of Diversity and Shannon-Wiener Diversity Index provide a measurement of diversity that accounts for the richness and evenness of the distribution of species abundances within a given area (Magurran 1988). Each measure produces a single value that increases with biological diversity, for example samples with little diversity produce a value close to 0, where as samples with greater diversity show values approaching or greater than 1.0 (Krebs 1989). We calculated Simpson's Index of Diversity as suggested by Krebs (1989) and Shannon-Wiener Index of Diversity as suggested by Zar (1999) (see Appendix E). Comparisons of species diversity between Park Units were calculated as suggested by Zar (1999) using ANOVA. Values are presented as means $\pm$ SE unless stated otherwise.

We caution against using species diversity indexes as a direct measure of conservation value for a given site, largely because we would not expect evenness of odonate abundance across all suites of species at a given site (see Discussion for more details). Thus, to help interpret the biological significance of quantitative abundance estimates for each species and better the discussion of survey site conservation value, we derived a measure called Categorical Abundance that contained three classifications: Numerous, Present, and Unusual. Using the biology and natural history of each species in its primary habitat, odonate specialists determined a range of abundance values for each classification (see Appendix F). A species was defined as “Numerous” if the population at the site is large given the biology of the species, suggesting that breeding or foraging is occurring in the habitat. A species was defined as “Present” if the population at the site is average or meets expectations given the biology of the species. A species was defined as “Unusual” if that species is either often not found in such habitat or when found is usually present in greater numbers. Using the ranges provided in Appendix F, quantitative abundance data was classified into one of the three categories noted above. We note that when a quantitative value fell in between two categories, an odonate specialist (N.B.) would determine the appropriate category based on factors that may have influenced quantitative abundances, such as weather during surveys, unique habitat characteristics, and seasonality affects.

Investigator Effort

To provide a measure of investigator effort we calculated the raw and adjusted survey effort for each site (Appendix G). Raw effort was defined as the total number of survey hours conducted by all investigators at each site. Adjusted effort was calculated by weighting the raw effort of a given researcher by their level of experience. For example, survey time committed by odonate specialists (e.g., J.S., M.V., N.B., V.B.) served as the standard by which others were weighted. Thus, the time taken by odonate specialists to conduct surveys was multiplied by a factor of 1.0. Survey time conducted by other researchers was multiplied by either 0.75 (E.T.) or 0.5 (S.J.) based on the capacity of each researcher to conduct surveys and process specimens independently. These measures of Investigator Effort may be applicable to future odonate surveys and could be used to determine the repeatability of the results presented in this report.

Results

During 2004 and 2005, 37 odonate species were identified across 38 survey sites at GATE (Table 3). Thirty-five species were recorded and identified during 2004 ($n = 7,546$ survey minutes; Appendix F) and two additional species were detected during 2005 ($n = 6,510$ survey minutes; Appendix F) (Table 3, Figure 10). Of the 37 species recorded at GATE, 23 species were dragonflies and 14 were damselflies (Table 3). During 2004 and 2005, 353 voucher specimens were collected representing 35 of the 37 species documented at GATE (Table 3).

Of the three National Parks in New York and New Jersey surveyed for odonates during 2004 and 2005 (Fire Island National Seashore [FIIS], Sagamore Hill National Historic Site [SAHI], and GATE), GATE showed the greatest species richness and number of sites with odonate species (Table 4). At GATE, Jamaica Bay showed the greatest species richness ($n = 30$), followed by Staten Island and Sandy Hook ($n = 29$ and $n = 24$, respectively) (Table 5). Species diversity varied greatly between survey sites within Park subunits (Table 5). Mean species diversity measured using Simpson's Index of Diversity and Shannon-Wiener Diversity Index (Table 6) were similar across Park Subunits ($F_{2,35} = 0.263$; $p = 0.77$ and $F_{2,35} = 0.079$; $p = 0.924$, respectively). The most abundant odonate species at GATE were familiar bluet (*Enallagma civile*) ($n = 959$), blue dasher (*Pachydiplax longipennis*) ($n = 777$), citrine forktail (*Ischnura hastata*) ($n = 711$), and swamp darner (*Epiaeschna heros*) ($n = 650$) (Table 3). Specific results will be presented for each Park Unit below.

Table 3. Odonate species recorded at Gateway National Recreation Area, New York and New Jersey, during 2004 and 2005. Abundance is presented as sight records followed by voucher specimens in parenthesis.

Common Name	ScientificName	Abundance		
		2004	2005	2004-2005
- Damselflies -				
Blue-fronted Dancer	<i>Argia apicalis</i>	2 (1)	-	2 (1)
Azure bluet	<i>Enallagma aspersum</i>	1 (1)	-	1 (1)
Familiar bluet	<i>Enallagma civile</i>	697 (36)	262 (9)	959 (45)
Big bluet	<i>Enallagma durum</i>	6 (2)	3 (1)	9 (3)
Orange bluet	<i>Enallagma signatum</i>	1 (1)	-	1 (1)
Citrine forktail	<i>Ischnura hastata</i>	706 (42)	5 (5)	711 (47)
Fragile forktail	<i>Ischnura posita</i>	62 (14)	20 (1)	82 (15)
Rambur's forktail ^a	<i>Ischnura ramburii</i> ^a	59 (19)	51 (5)	110 (24)
Eastern forktail	<i>Ischnura verticalis</i>	46 (16)	60 (5)	106 (21)
spreadwing species	<i>Lestes</i> sp.	7 (1)	-	7 (1)
Common spreadwing	<i>Lestes disjunctus australis</i>	4 (3)	-	4 (3)
Common spreadwing	<i>Lestes disjunctus disjunctus</i>	2 (2)	-	2 (2)
Amber-winged spreadwing ^{b,c}	<i>Lestes eurinus</i> ^{b,c}	1 (1)	-	1 (1)
Slender spreadwing	<i>Lestes rectangularis</i>	31 (13)	17 (10)	48 (23)
Sphagnum sprite	<i>Nehalennia gracilis</i>	3 (2)	-	3 (2)
- Dragonflies -				
Common green darner	<i>Anax junius</i>	108 (4)	91 (1)	199 (5)
Calico pennant	<i>Celithemis elisa</i>	2	3	5
Halloween pennant	<i>Celithemis eponina</i>	3 (1)	1 (1)	4 (2)
Banded pennant	<i>Celithemis fasciata</i>	4 (2)	-	4 (2)
Swamp darner	<i>Epiaeschna heros</i>	481 (9)	169 (3)	650 (12)
Eastern pondhawk	<i>Erythemis simplicicollis</i>	53 (8)	21	74 (8)
Seaside dragonlet	<i>Erythrodiplax berenice</i>	36 (13)	36 (2)	72 (15)
Slaty skimmer	<i>Libellula incesta</i>	-	1 (1)	1 (1)
Widow skimmer	<i>Libellula luctuosa</i>	3	4	7
Common whitetail	<i>Libellula lydia</i>	11 (3)	12	23 (3)
Needham's skimmer ^a	<i>Libellula needhami</i> ^a	10 (3)	16 (2)	26 (5)
Twelve-spotted skimmer	<i>Libellula pulchella</i>	69 (6)	49 (4)	118 (10)
Painted skimmer	<i>Libellula semifasciata</i>	3 (1)	67 (2)	70 (3)
Great blue skimmer	<i>Libellula vibrans</i>	6 (1)	15 (4)	21 (5)
Blue dasher	<i>Pachydiplax longipennis</i>	283 (25)	494 (7)	777 (32)
Wandering glider	<i>Pantala flavescens</i>	27 (5)	43 (4)	70 (9)
Spot-winged glider	<i>Pantala hymenaea</i>	68 (8)	52 (3)	120 (11)
Eastern amberwing	<i>Perithemis tenera</i>	38 (5)	-	38 (5)
Variegated Meadowhawk	<i>Sympetrum corruptum</i>	-	7 (2)	7 (2)
Cherry-faced meadowhawk	<i>Sympetrum internum</i>	8 (4)	4 (3)	12 (7)
Ruby meadowhawk	<i>Sympetrum rubicundulum</i>	1 (1)	-	1 (1)
Carolina saddlebags	<i>Tramea carolina</i>	22 (4)	60 (2)	82 (6)
Black saddlebags	<i>Tramea lacerata</i>	143 (14)	101 (5)	244 (19)
Totals		3,007 (271)	1,664 (82)	4,671 (353)

^a State listed in NY

^b State listed in NJ

^c Only recorded in NY

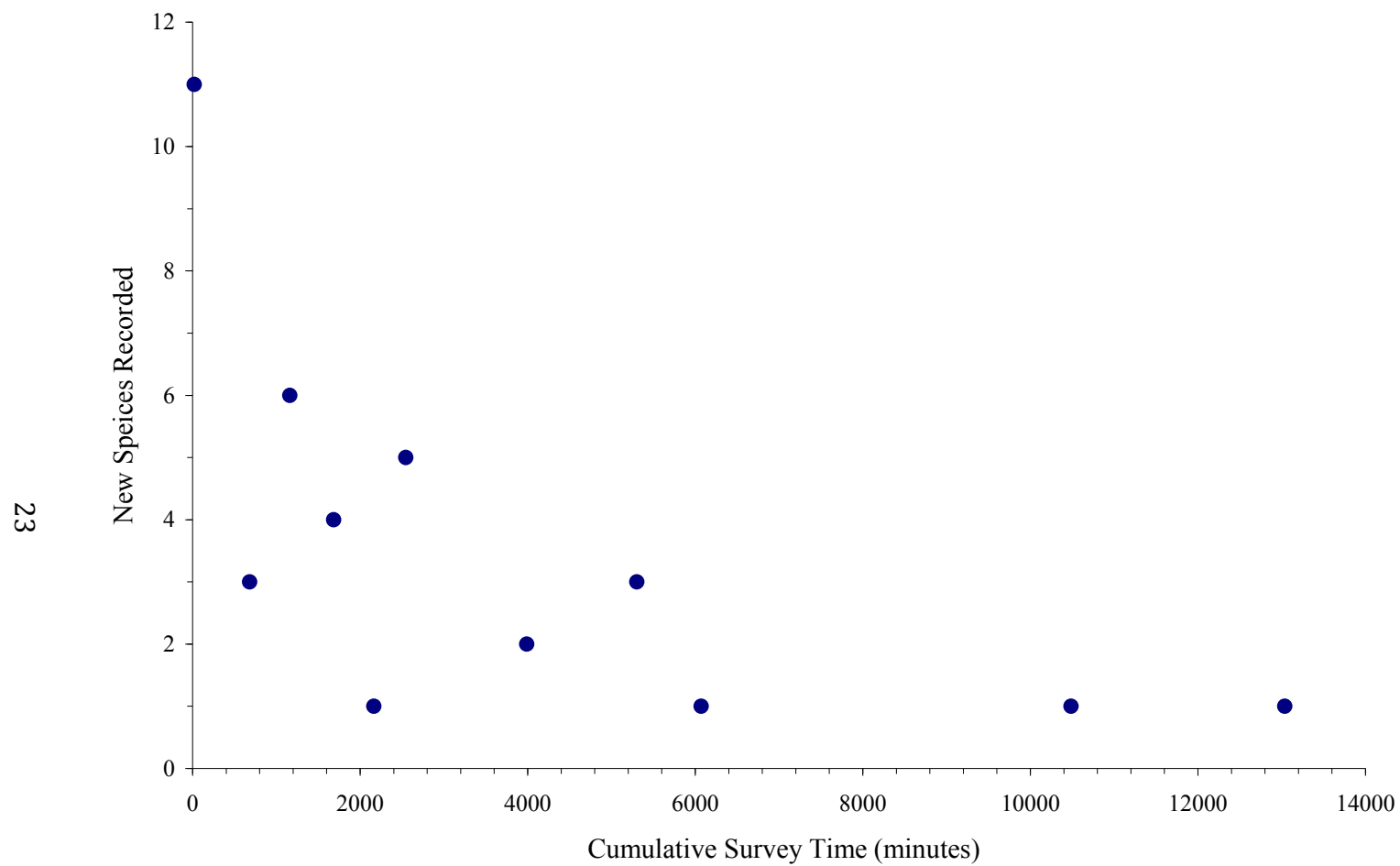


Figure 10. New species recorded by cumulative survey time ($n = 14,056$ min) at Gateway National Recreation Area, New York and New Jersey, during 2004-2005.

Table 4. Summary of odonate species recorded during 2004-2005 at Fire Island National Seashore (FIIS), Gateway National Recreation Area (GATE), and Sagamore Hill National Historic Site (SAHI). FIIS and SAHI data are from Briggs et al. (2006a and 2006b, respectively)

Location	Species Richness	Number of Sites Where		Number of		
		Species were Recorded	Rare Species were Recorded	Rare Species Recorded	Species with Voucher Specimens	Voucher Specimens Collected
FIIS	27	18	5	2	25	92
GATE	37	38	12	2	36	353
SAHI	22	7	1	1	17	45
Total	--	63	18	3	--	490

Table 5. Species richness, diversity indexes, and proportion of species recorded compared to the Potential Species List (Appendix C) at Gateway National Recreation Area, New York and New Jersey, during 2004-2005. The proportion of species recorded from Potential Species List was calculated by dividing the number of species recorded at a given site by the number of species listed in Appendix C (n = 53).

Park Unit / Site Name	Species Richness	Simpson's Index	Shannon-Wiener Index	Proportion of	
				Total species recorded	Potential Species List recorded
Jamaica Bay ^a	30	-	-	0.81	0.57
BP: Salt marsh	11	0.883	0.971	0.30	0.21
BP: Swale	17	0.267	0.319	0.46	0.32
FBF: Community Garden	10	0.824	0.844	0.27	0.19
FBF: Culvert	2	0.500	0.301	0.05	0.04
FBF: Rag Pond	13	0.602	0.650	0.35	0.25
FT: Fishlot	10	0.558	0.547	0.27	0.19
FT: House	2	0.480	0.292	0.05	0.04
FT: Pond	4	0.345	0.308	0.11	0.08
JBWR: Big John's Pond	19	0.800	0.907	0.51	0.36
JBWR: Blind Pond	7	0.735	0.689	0.19	0.13
JBWR: East Pond	12	0.476	0.513	0.32	0.23
JBWR: Fire Break	4	0.660	0.530	0.11	0.08
JBWR: Salt marsh	8	0.835	0.826	0.22	0.15
JBWR: West Pond	15	0.400	0.461	0.41	0.28
JBWR: West Pond Marsh North #2	10	0.636	0.622	0.27	0.19
JBWR: West Pond Marsh South #1	12	0.621	0.629	0.32	0.23

Table 5. Species richness, diversity indexes, and proportion of species recorded compared to the Potential Species List (Appendix C) at Gateway National Recreation Area, New York and New Jersey, during 2004-2005. The proportion of species recorded from Potential Species List was calculated by dividing the number of species recorded at a given site by the number of species listed in Appendix C ($n = 53$) (continued).

Park Unit / Site Name	Species Richness	Simpson's Index	Shannon-Wiener Index	Proportion of	
				Total species recorded	Potential Species List recorded
Staten Island ^b	29	-	-	0.76	0.55
Ballfield	6	0.715	0.623	0.16	0.11
Blue Dot Trail Drainage Opening	5	0.692	0.597	0.13	0.09
Cliff Edge	7	0.774	0.714	0.18	0.13
Education Center Pond	11	0.789	0.816	0.29	0.21
E Lot Ditch	3	0.410	0.307	0.08	0.06
Freshwater Pond	17	0.824	0.897	0.45	0.32
Peeper Road	15	0.853	0.969	0.39	0.28
Pipe Road	7	0.791	0.752	0.18	0.13
Pipe Road Drainage	1	0.000	0.000	0.03	0.02
Promenade Marsh	7	0.720	0.686	0.18	0.13
MF: Dune/Beach	15	0.840	0.898	0.39	0.28
MF: Field	2	0.375	0.244	0.05	0.04
Sandy Hook	24	-	-	0.63	0.45
Exclamation Point Pond	12	0.803	0.830	0.32	0.23
Horseshoe Marsh	4	0.640	0.507	0.11	0.08
KLot Field	3	0.667	0.477	0.08	0.06
Newest Pond	14	0.406	0.319	0.37	0.26
Nike Pond	4	0.686	0.726	0.11	0.08
North Pond	20	0.602	0.457	0.53	0.38
Plum Marsh	4	0.810	0.950	0.11	0.08
Round Pond	7	0.391	0.345	0.18	0.13
Spermaceti Cove Inner Salt Marsh	11	0.719	0.654	0.29	0.21
Spermaceti Cove Outer Salt Marsh	3	0.787	0.787	0.08	0.06
Totals	37	-	-	0.97	0.70

^a Park subunits are abbreviated as: Breezy Point (BP), Floyd Bennett Field (FB), Fort Tilden (FT), and Jamaica Bay Wildlife Refuge (JBWR)

^b Park subunits are abbreviated as: Miller's Field (MF)

Table 6. Descriptive statistics of odonate species diversity measures for Park Subunits at Gateway National Recreation Area, New York and New Jersey, during 2004-2005. Values were calculated across all sites at each Park Unit.

	Jamica Bay		Sandy Hook		Staten Island	
	Simpon's Index	Shannon-Wiener Index	Simpon's Index	Shannon-Wiener Index	Simpon's Index	Shannon-Wiener Index
Mean	0.601	0.588	0.651	0.605	0.649	0.625
Standard Error	0.046	0.055	0.047	0.068	0.074	0.086
Standard Dev.	0.184	0.221	0.150	0.215	0.257	0.297
Median	0.612	0.585	0.676	0.581	0.747	0.700

Species Inventory at the Jamaica Bay Unit

During 2004-2005 at the Jamaica Bay Unit, the greatest number of odonates were observed at Fort Tilden Fishlot ($n = 838$ individuals), JBWR Big John's Pond ($n = 368$ individuals), and JBWR West Pond ($n = 335$ individuals) (Table 7). The greatest species richness were recorded at JBWR Big John's Pond ($n = 19$ species), Breezy Point Swale ($n = 17$ species), and JBWR West Pond ($n = 15$ species) (Table 5). Sites with the greatest measures of species diversity were Breezy Point Salt Marsh, JBWR Big John's Pond, and Floyd Bennett Field Community Garden (Table 5). The most commonly observed species at the Jamaica Bay Unit were familiar bluet ($n = 691$ individuals), swamp darner ($n = 643$ individuals), and citrine forktail ($n = 564$ individuals) (Table 7).

During 2004 odonates were recorded at all sites surveyed at the Jamaica Bay Unit. All sites that were surveyed during 2004 were resurveyed during 2005 (Table 1). Two sites were surveyed during 2005 that were not surveyed during 2004, the Community Garden at Floyd Bennett Field and the House at Fort Tilden. Community Garden at Floyd Bennett was surveyed during 2005 because we observed odonates heavily foraging around puddles after a rainstorm and therefore surveyed the site. During 2004 no activity was observed while passing the Community Gardens. Similarly at the House at Fort Tilden during 2005, we observed odonates foraging in the evening and thus, conducted a survey to document the species assemblage.

All odonate species recorded at the Jamaica Bay Unit during 2004 and 2005 have previously been documented in Kings and Queens Counties, New York, and were listed in the potential species list (Appendix C). Overall, species recorded at the Jamaica Bay Unit represented 81 % of all species recorded at GATE during 2004 and 2005, and 57 % of species listed in the potential species list (Table 5). Two NY state-listed species, Needham's skimmer and Rambur's forkail, were recorded at the Jamaica Bay Unit (Table 7). Needham's skimmer was found to categorically "unusual" at JBWR Big John's Pond (Appendix H). Rambur's forkail was found to categorically "unusual" at West Pond Marsh #2; "present" at BP Salt Marsh, and JBWR Big John's Pond, East Pond, and West Pond; and "numerous" at JBWR West Pond Marsh #1 (Appendix H).

Table 7. Abundance of odonate species by site during 2004-2005 at the Jamaica Bay Unit, Gateway National Recreation Area, New York. Abundance is presented as sight records followed by voucher specimens in parenthesis. Park subunits are abbreviated as: Breezy Point (BP), Floyd Bennett Field (FB), Fort Tilden (FT), and Jamaica Bay Wildlife Refuge (JBWR).

ScientificName	BP: Salt marsh	BP: Swale	FBF: Community Garden	FBF: Culvert	FBF: Rag Pond	FT: Fishlot	FT: House	FT: Pond	JBWR: Big John's Pond	JBWR: Blind Pond	JBWR: East Pond	JBWR: Fire Break	JBWR: Salt marsh	JBWR: West Pond	JBWR: West Pond Marsh North (2)	JBWR: West Pond Marsh South (1)	Total
<i>Anax junius</i>	16	11 (2)	-	1	3	15 (1)	20	-	15 (1)	-	2	2	-	14	1	7	107 (4)
<i>Argia apicalis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1 (1)	2 (1)
<i>Celithemis elisa</i>	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
<i>Enallagma aspersum</i>	-	-	-	-	-	-	-	-	1 (1)	-	-	-	-	-	-	-	1 (1)
<i>Enallagma civile</i>	13 (1)	1 (1)	12 (1)	-	3	-	-	-	140 (1)	9	118	5	4 (4)	258 (9)	38	90	691 (17)
<i>Enallagma durum</i>	-	-	-	-	-	-	-	-	-	9 (3)	-	-	-	-	-	-	9 (3)
<i>Epiaeschna heros</i>	15	8 (1)	20	-	6	535 (6)	30 (2)	2	2 (1)	1	1	-	10	9 (1)	-	4	643 (11)
<i>Erythemis simplicicollis</i>	-	6 (2)	-	-	4 (1)	-	-	1	10 (1)	-	1	1	-	1	2	-	26 (4)
<i>Erythrodiplax berenice</i>	-	-	-	-	-	-	-	-	-	1 (1)	-	15 (5)	-	16 (1)	-	-	32 (7)
<i>Ischnura hastata</i>	13 (4)	520 (12)	-	-	1	-	-	-	25 (2)	-	-	-	-	-	3	2 (2)	564 (20)
<i>Ischnura posita</i>	-	-	-	-	12 (6)	-	-	-	28 (2)	1	-	-	-	1 (1)	-	-	42 (9)
<i>Ischnura ramburii</i> ^a	12 (4)	-	-	-	-	-	-	-	4 (1)	-	6 (2)	-	-	18 (1)	1	27 (7)	68 (15)
<i>Ischnura verticalis</i>	-	1 (1)	-	1	2	-	-	-	20 (1)	2	3 (3)	-	-	3 (2)	2	-	34 (7)
<i>Lestes disjunctus disjunctus</i>	-	1 (1)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1 (1)
<i>Lestes disjunctus australis</i>	-	3 (3)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3 (3)
<i>Lestes eurinus</i> ^{b,c}	-	-	-	-	-	-	-	-	1 (1)	-	-	-	-	-	-	-	1 (1)
<i>Lestes rectangularis</i>	-	4 (1)	-	-	15 (7)	-	-	-	11 (5)	-	1 (1)	-	-	-	-	-	31 (14)
<i>Lestes</i> sp.	-	6 (1)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6 (1)
<i>Libellula lydia</i>	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
<i>Libellula needhami</i> ^a	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
<i>Libellula pulchella</i>	6	1 (1)	2	-	1	23 (1)	-	1	9 (1)	2 (1)	-	-	-	8	-	2	55 (4)
<i>Libellula semifasciata</i>	-	-	4	-	-	34	-	-	-	-	-	-	7	1	-	3	49
<i>Libellula vibrans</i>	-	-	3 (1)	-	-	1	-	-	3 (2)	1 (1)	-	-	1	-	-	-	9 (4)
<i>Nehalennia gracilis</i>	-	3 (2)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3 (2)
<i>Pachydiplax longipennis</i>	23	34 (3)	1 (1)	-	92 (3)	139 (1)	-	16	69 (5)	5 (1)	3	-	12	6 (3)	2	13	415 (17)
<i>Pantala flavescens</i>	4	1 (1)	10 (2)	-	1	2 (1)	-	-	-	-	-	-	3	-	-	-	21 (4)
<i>Pantala hymenaea</i>	-	1 (1)	10 (1)	-	4 (4)	38 (2)	-	-	-	-	-	-	5	3	2	-	63 (8)
<i>Perithemis tenera</i>	-	-	-	-	-	-	-	-	-	-	10 (3)	-	-	-	-	-	10 (3)
<i>Sympetrum internum</i>	1 (1)	1 (1)	-	-	-	-	-	-	2 (2)	-	-	2	-	-	-	1	7 (4)
<i>Tramea carolina</i>	7	2 (2)	-	-	-	29 (1)	-	-	12 (1)	-	-	-	4	4 (1)	-	-	58 (5)
<i>Tramea lacerata</i>	13	5 (1)	4	-	6 (1)	22	-	-	14 (1)	-	10 (1)	-	8	3 (1)	1	3 (1)	89 (6)
Total	123 (10)	609 (37)	67 (6)	2	150 (22)	838 (13)	50 (2)	20	368 (29)	21 (3)	165 (14)	10	61 (9)	335 (19)	69 (1)	155 (11)	3,043 (176)

^a State listed in NY

^b State listed in NJ

^c Only recorded in NY

Species Inventory at the Staten Island Unit

During 2004-2005 at the Staten Island Unit, the greatest species richness and number of odonates were observed at Great Kills Park Freshwater Pond ($n = 17$ species, $n = 447$ individuals), Miller Field Dune/Beach ($n = 15$ species, $n = 209$ individuals), and Great Kills Park Peeper Road ($n = 15$ species, $n = 95$ individuals) (Table 5, 8). Similarly, these three sites also showed the greatest measures of species diversity (Table 5). The most commonly observed species at the Staten Island Unit were blue dasher ($n = 206$ individuals), citrine forktail ($n = 133$ individuals), and familiar bluet ($n = 128$ individuals) (Table 8). During 2004, odonates were observed at all sites surveyed. During 2005 two drainage ditches, E Lot Ditch and Pipe Road Drainage at Great Kills Park were not resurveyed because they did not contain water.

All odonate species recorded during 2004 and 2005 have previously been documented in Richmond County, New York, and were listed in the potential species list (Appendix C).

Overall, species recorded at the Staten Island Unit represented 76 % of all species recorded at GATE during 2005 and 2005, and 55 % of species listed in the potential species list (Table 5). Two NY state-listed species, Needham's skimmer and the Rambur's forktail were recorded at the Staten Island Unit (Table 8). Needham's skimmer was found to categorically "present" at Great Kills Park Peeper Road and Freshwater Pond, and at Miller Field Dunes/Beach (Appendix H). Rambur's forktail was found to categorically "unusual" and "present" at Great Kills Park Education Center and Park Peeper Road, respectively (Appendix H).

Table 8. Abundance of odonate species by site during 2004-2005 at the Staten Island Unit, Gateway National Recreation Area, New York. Abundance is presented as sight records followed by voucher specimens in parenthesis. Survey sites were located at Great Kills Park, except for Miller Field (MF) Dune/Beach and MF Field.

ScientificName	Ballfield	Blue Dot Trail Drainage Opening	Cliff Edge	Education Center Pond	E Lot Ditch	Freshwater Pond	Peeper Road	Pipe Road	Pipe Road Drainage	Promenade Marsh	MF: Dune/Beach	MF: Field	Total
<i>Anax junius</i>	15 (1)	-	7	1	-	11	11	3	-	1	21	-	70 (1)
<i>Celithemis elisa</i>	-	-	-	-	-	1	-	-	-	-	-	-	1
<i>Celithemis eponina</i>	-	-	-	-	-	-	-	-	-	-	1 (1)	-	1 (1)
<i>Celithemis fasciata</i>	-	-	-	-	-	-	-	-	-	-	4 (2)	-	4 (2)
<i>Enallagma civile</i>	-	-	7 (1)	15 (2)	4 (2)	92 (6)	-	1 (1)	-	8 (5)	1 (1)	-	128 (18)
<i>Epiaeschna heros</i>	-	3 (1)	-	-	-	-	1	-	-	-	1	-	5 (1)
<i>Erythemis simplicicollis</i>	-	-	-	-	-	2	-	-	-	-	-	-	2
<i>Ischnura hastata</i>	-	-	-	1 (1)	14 (3)	105 (6)	3 (2)	3 (2)	-	3 (2)	4 (3)	-	133 (19)
<i>Ischnura posita</i>	-	-	-	-	-	14	-	-	-	-	-	-	14
<i>Ischnura posita posita</i>	-	-	-	-	-	-	4 (1)	-	2 (2)	-	-	-	6 (3)
<i>Ischnura ramburii</i> ^a	-	-	-	1 (1)	-	3 (2)	-	-	-	-	-	-	4 (3)
<i>Ischnura verticalis</i>	-	-	-	10 (3)	-	36 (6)	14 (1)	-	-	2 (2)	1	-	63 (12)
<i>Lestes disjunctus australis</i>	-	-	-	-	-	-	-	-	-	-	1	-	1
<i>Lestes disjunctus disjunctus</i>	-	-	-	-	-	-	1 (1)	-	-	-	-	-	1 (1)
<i>Lestes rectangularis</i>	-	2 (1)	-	-	-	14 (7)	1 (1)	-	-	-	-	-	17 (9)
<i>Lestes</i> sp.	-	-	-	-	-	1	-	-	-	-	-	-	1
<i>Libellula incesta</i>	-	-	-	-	-	1 (1)	-	-	-	-	-	-	1 (1)
<i>Libellula lydia</i>	-	2	1	1	-	12	-	1 (1)	-	-	-	-	17 (1)
<i>Libellula needhami</i> ^a	-	-	-	-	-	5 (1)	5	-	-	-	5 (3)	-	15 (4)
<i>Libellula pulchella</i>	1	-	-	-	-	16 (1)	5 (1)	-	-	-	28 (2)	-	50 (4)
<i>Libellula semifasciata</i>	-	-	-	-	-	-	10 (1)	-	-	-	4 (1)	-	14 (2)
<i>Libellula vibrans</i>	-	11 (1)	-	-	-	-	1	-	-	-	-	-	12 (1)
<i>Pachydiplax longipennis</i>	-	5 (1)	6	4 (2)	-	115 (2)	28 (2)	-	-	-	48 (3)	-	206 (10)
<i>Pantala flavescens</i>	5 (1)	-	-	-	-	-	-	-	-	-	18	-	23 (1)
<i>Pantala hymenaea</i>	5 (1)	-	2	4	1	-	-	-	-	1	21	4	38 (1)
<i>Perithemis tenera</i>	-	-	-	3 (1)	-	-	-	-	-	-	-	-	3 (1)
<i>Sympetrum internum</i>	-	-	1	-	-	2 (2)	1 (1)	1	-	-	-	-	5 (3)
<i>Sympetrum rubicundulum</i>	-	-	-	-	-	-	-	1 (1)	-	-	-	-	1 (1)
<i>Tramea carolina</i>	2	-	-	1	-	9	5 (1)	-	-	1	-	-	18 (1)
<i>Tramea lacerata</i>	18 (4)	-	1	1	-	8 (1)	5 (1)	5	-	1	51 (1)	12	102 (7)
Total	46 (7)	23 (4)	25 (1)	42 (10)	19 (5)	447 (35)	95 (13)	15 (5)	2 (2)	17 (9)	209 (17)	16	956 (108)

^a State listed in NY

Species Inventory at the Sandy Hook Unit

At the Sandy Hook Unit during 2004-2005, the greatest species richness and number of odonates were observed at North Pond ($n = 20$ species, $n = 223$ individuals), Newest Pond ($n = 14$ species, $n = 183$ individuals), and Exclamation Point Pond ($n = 12$ species, $n = 96$ individuals) (Table 5, 9). The greatest measures of species diversity were measured at Plum Marsh and Exclamation Point Pond (Table 5). The most commonly observed species at the Sandy Hook Unit were blue dasher ($n = 156$ individuals), familiar bluet ($n = 140$ individuals), and black saddlebags (*Tramea lacerata*; $n = 96$ individuals) (Table 9).

Odonates were observed at all sites surveyed during 2004. During 2004, we determined that Horseshoe Marsh contained improper habitat for odonate species to breed and thus were not resurveyed during 2005 (Table 1). Plum Marsh contained breeding habitat appropriate for only one species, seaside dragonlet, which was recorded in 2004 and thus, this site was not resurveyed during 2005 (Table 1). Nike Pond was not completely surveyed during 2004 and was not resurveyed during 2005, because it was surrounded by dense stands of common reed and poison ivy and ultimately, could not be circumnavigated by foot. We note that the pond was, also, too deep to wade across. It is worth noting that we attempted to procure a boat to conduct a survey on the pond's surface, however logistical problems hindered this effort.

All odonate species recorded during 2004 and 2005 have previously been documented in Monmouth County, New Jersey, and were listed in the potential species list (Appendix C), except the variegated meadowhawk (*Sympetrum corruptum*). Overall, species recorded at the Sandy Hook Unit represented 63 % of all species recorded at GATE during 2004 and 2005, and 45 % of species listed in the potential species list (Table 5). No state-listed species were observed at the Sandy Hook Unit (Table 9). Although Needham's skimmer and the Rambur's forktail occur at the Park, these species are listed in New York and are not designated in New Jersey.

Table 9. Abundance of odonate species by site during 2004-2005 at the Sandy Hook Unit, Gateway National Recreation Area, New Jersey. Abundance is presented as sight records followed by voucher specimens in parenthesis.

ScientificName	Exclamation Point Pond	Horseshoe Marsh	KLot Field	Newest Pond	Nike Pond	North Pond	Plum Marsh	Round Pond	Spermaceti Cove Inner Salt Marsh	Spermaceti Cove Outer Salt Marsh	Total
Anax junius	4	-	2	1	-	9	1	1	3	1	22
Celithemis elisa	1	-	-	1	-	1	-	-	-	-	3
Celithemis eponina	1	-	-	1 (1)	-	1	-	-	-	-	3 (1)
Enallagma civile	23 (1)	1 (1)	-	97 (7)	7 (1)	11	-	-	1	-	140 (10)
Enallagma signatum	-	-	-	-	-	1 (1)	-	-	-	-	1 (1)
Epiaeschna heros	-	-	-	1	-	1	-	-	-	-	2
Erythemis simplicicollis	10	-	-	-	-	22 (3)	-	1	13 (1)	-	46 (4)
Erythrodiplax berenice	-	-	-	-	-	-	10 (3)	-	30 (5)	-	40 (8)
Ischnura hastata	-	1 (1)	-	-	-	1 (1)	1 (1)	7 (1)	1 (1)	3 (3)	14 (8)
Ischnura posita	13 (2)	-	-	-	1 (1)	2	-	4	-	-	20 (3)
Ischnura ramburii ^a	2 (1)	-	-	19 (2)	-	6 (2)	-	-	11 (1)	-	38 (6)
Ischnura verticalis	-	-	-	2 (1)	-	6 (1)	-	1	-	-	9 (2)
Libellula luctuosa	-	-	-	-	-	7	-	-	-	-	7
Libellula lydia	-	-	-	-	-	4 (1)	-	-	1 (1)	-	5 (2)
Libellula needhami ^a	2 (1)	-	-	-	-	8	-	-	-	-	10 (1)
Libellula pulchella	3 (1)	-	-	1	-	8 (1)	-	-	1	-	13 (2)
Libellula semifasciata	1 (1)	-	-	-	-	-	-	-	6	-	7 (1)
Pachydiplax longipennis	31 (3)	-	-	13	-	86 (1)	-	11 (1)	15	-	156 (5)
Pantala flavescens	-	3	12 (3)	10 (1)	-	-	-	-	-	1	26 (4)
Pantala hymenaea	-	-	-	18 (1)	-	1 (1)	-	-	-	-	19 (2)
Perithemis tenera	-	-	-	-	8	16 (1)	-	1	-	-	25 (1)
Sympetrum corruptum	-	-	-	7 (2)	-	-	-	-	-	-	7 (2)
Tamea carolina	-	-	-	2	-	3	-	-	1	-	6
Tamea lacerata	5 (1)	5 (1)	2	10 (1)	1	29 (2)	1 (1)	-	-	-	53 (6)
Total	96 (11)	10 (3)	16 (3)	183 (16)	17 (2)	223 (15)	13 (5)	26 (2)	83 (9)	5 (3)	672 (69)

^a State listed in NY

Migration Events

During 2004-2005, several migration events were observed at two odonate survey sites (Fort Tilden Fishlot and JBWR West Pond) within the Jamaica Bay Unit. The first migration event recorded was on 20 July 2004 at Fort Tilden Fishlot. We observed 114 migrating individuals during 1.5 hours, including swamp darner ($n = 92$), blue dasher ($n = 11$), spot winged glider ($n = 2$), 12 spotted skimmer ($n = 1$), black saddle bags ($n = 3$), wandering glider ($n = 1$) common green darner ($n = 3$), and Carolina saddlebags ($n = 1$).

The following day (21 July 2004) after surveying JBWR West Pond we observed a movement of swamp darners moving from the area of West Pond toward East Pond. During this movement we counted 166 individuals over a 20-min period.

The third migration event was observed on 17 August 2004 at Fort Tilden Fishlot. We observed a large swarm of migrating odonates moving in a southwest direction over the dunes towards the beach and swales. This swarm of migrants included swamp darner ($n = 350$), spot winged glider ($n = 14$), 12 spotted skimmer ($n = 14$), black saddle bags ($n = 12$), wandering glider ($n = 1$), common green darner ($n = 1$), and Carolina saddlebags ($n = 3$). The migration event lasted approximately 2 hours (125 min).

We also observed a migration event at JBWR during the 2005 field season. More specifically, on 20 July 2005 at the Fort Tilden Fishlot during a 30-min interval we observed a large swarm of migrant odonates, including >100 blue dasher, swamp darner ($n = 30$), twelve-spotted skimmer ($n = 2$), and painted skimmer ($n = 10$). Due to high temperatures and humidity, these individuals were not actively migrating. This swarm was, however, feeding and perching on all available surfaces, including trees, fencing and vegetation. All of the perched blue dashers were in the "obelisk position", which is thought to decrease the surface area exposed to sun and assists in cooling (Walker 1953, Carpenter 1999).

Discussion

During 2004 and 2005 ($n = 7,546$ and $6,510$ survey minutes, respectively; Appendix F) we documented 37 species of odonates at GATE. The majority (95%) of these species were first recorded during the 2004 field season and only 2 additional new species recorded during the 2005 field season (Table 3). The lack of new species recorded during 2005, suggests that substantial survey effort would have been required to document 1-additional new species (Figure 10). Based on the trend in new species detection (Figure 10) and general odonate observations in the field, odonate specialists believe that $> 90\%$ of the odonate species present at GATE survey sites were documented during this study.

Species diversity indexes (e.g., Simpson's and Shannon-Wiener Index) provide more information about community composition than simply species richness (Magurran 1988, Zar 1999); however, for the purposes of this study, using species diversity indexes as a sole measure of site's conservation value would be misguided, largely because odonate population dynamics often predict unevenness of species abundance across assemblages. Generally speaking, damselflies maintain larger territories and lower abundances compared to dragonflies. Thus, it's likely that a small pond, which supports healthy breeding populations of both damselfly and dragonfly, would have fewer damselflies than dragonflies due to the size limitations of the pond. By design species diversity indexes score sites with disproportionate species abundances lower than sites with evenness of species abundance. Given this limitation, we discuss the conservation value and potential of odonate sites using species richness and categorical abundances measures, in conjunction with species diversity indexes.

We discuss odonate survey sites with conservation value (i.e. sites that contain good breeding, foraging, or unique odonate habitat) and sites that could be potentially beneficial to odonates separately for each Park Subunit below. We then discuss potential threats to odonate habitat at GATE and conclude with recommendations for future monitoring.

Jamaica Bay Unit

Of the three Park Units, the Jamaica Bay Unit shows the greatest species richness (Table 5) and has the greatest number of sites with conservation value and conservation potential. This is, in part, because the Jamaica Bay Unit contains several areas with permanent and temporary water that provide breeding and foraging habitat for odonate species. In general, the most abundant species at the Jamaica Bay Unit are generalist species that are known for their persistence in degraded habitats (e.g., familiar bluet, blue dasher, swamp darned, and fragile forktail). Nonetheless, several sites at the Jamaica Bay Unit supported species with specific habitat requirements (e.g., seaside dragonlet), as well as state listed species (e.g., Rambur's forktail, Needham's skimmer). In addition, many sites contain critical or rare habitat, such as coastal ponds, dunes, and swales, which not only support odonate breeding, but also provide foraging areas, cover, and habitat for migrating odonates.

Given the near-total development of the landscape surrounding the Jamaica Bay Unit, areas such as Breezy Point, Fort Tilden, and JBWR offer the only available habitat for odonates during migration. During both years of this study we observed migration events at Fort Tilden Fishlot. It appears that this area funnels odonates during migration and likely provides a critical migration corridor to Breezy Point Swales. We suspect that migrating odonates utilize the dunes

and beach habitat for foraging on their way to Breezy Point Swales, where many of these odonates likely disperse among the dunes to forage and rest. The conservation value of Breezy Point Swales is discussed in greater detail below; however, we briefly note that this site offers excellent foraging habitat and cover to migrating odonates and was usually teeming with migratory individuals.

Recall that much of GATE, including Breezy Point Swales, is located within the odonate migration corridor and offers important habitat for migrating odonates (Shannon 1935). Unlike migrations of birds, odonate migrations are intergenerational movements in which an individual migrant carries out a migration in only one direction (Russell et al. 1998). For example, fall migrants often travel south to complete their life cycle and lay eggs. Unlike with most other insect species, some of the offspring from these fall-migrating odonates may in turn migrate back north the following spring to breed. We note that densities of odonates during spring migration are often much lower than during the fall and thus, spring migration events are difficult to detect (Russell et al. 1998).

Although several aspects of odonate migration are poorly understood, it is clear that migration, in general, holds biological and conservational importance for odonate populations (Freeland et al. 2003). For example migration influences genetic variation at both the local and regional population level and is believed to contribute to the long-term stability of some populations that are exposed to a range of environmental conditions, including predator species, prey, and temperature (Freeland et al. 2003). In addition, large migratory swarms of odonates can serve as prey for migrating birds, although the extent to which is not well understood (Russell et al. 1998). Overall, odonate migration appears to satisfy a biologically necessary aspect of odonate life history.

Sites with high conservation value

JBWR Big John's Pond: Big John's Pond at JBWR showed the greatest species richness and measures of species diversity of all sites at the Jamaica Bay Unit (Table 5). In addition 37% of species recorded were found to have categorical abundance rating "numerous" (Appendix H) conveying that populations are large, based on the biology of the species, and suggests that the habitat is being used for breeding or foraging. Approximately a third (31 %) of the species present were found to have a categorical abundance rating of "present" (Appendix H), conveying that these populations meet expectations based on species biology. In addition, two state-listed species, Rambur's forktail and Needham's skimmer, were recorded at Big John's Pond. Overall, this site was one of the most productive odonate sites at GATE.

One likely reason for the high level odonate productivity is that the pond appears to contain permanent water and even when water levels were low (e.g., 2005), this site contained significant odonate activity. Generally speaking, permanent water is required by most odonate species to complete their life cycle; however, some odonates are capable of reproducing in temporary waters and some odonate larva can survive in muddy habitats for several months (Walker 1953). In addition to containing permanent water, Big John's Pond contains emergent vegetation, which not provides perching habitat and cover, but also shelters and promotes a prey base for odonates as well.

Big John's Pond is managed primarily for birds and wildlife and contains a viewing blind and fencing that protects the pond and emergent vegetation from being trampled by visitors. Given the high productivity of odonates and natural resource protections presently in place at this site, it appears that Big John's Pond may offer an opportunity for the Park to provide odonate interpretation for visitors at a nominal cost.

JBWR West Pond: West Pond is another site at JBWR with permanent water and emergent vegetation. This site provides breeding habitat for familiar bluets, Rambur's forktail, a state listed species, and likely supports other breeding species as well. Compared to other sites at JBWR, West Pond showed high species richness (Table 5). In addition, >50 % of species recorded at West Pond had a categorical abundance rating of "present" or "numerous" (Appendix H), despite having only a moderate species diversity index (Table 5).

Breezy Point Swale: Breezy Point Swale is located within the odonate migration corridor described by Shannon (1935) and offers critical habitat for migrating odonates. As stated earlier, on several occasions we observed odonates funneling over the dunes at Fort Tilden Fishlot en route to Breezy Point Swales, which was usually teaming with migratory individuals. Breezy Point Swales offers excellent foraging habitat and cover for migrating odonates and in wet years provides breeding habit for damselflies that breed in temporary waters.

Other sites of potential interest

Breezy Point Salt Marsh: The survey site at Breezy Point Salt Marsh appeared to be tidally influenced and lacked of permanent water. During periods when there is standing water (e.g., 2004) this site provides breeding habitat for Rambur's forktail, a state-listed species in NY. Breezy Point Salt Marsh is also located within the odonate migration corridor described by Shannon (1935) and contains ample food sources for migrating odonate, including an abundance of mosquitoes. In dry years this site provided foraging and migration habitat, but no breeding habitat.

FBF RAG Pond: RAG Pond at Floyd Bennett Field contained permanent water and during years with moderate water quality provides habitat for odonate breeding. For example, during 2004 this pond contained emergent vegetation and provided good breeding habitat. During 2005, the surface of the pond was completely covered with pond weed (*Lemna minor*) and the pond, in general, appeared to be eutrophic and likely limited in food and oxygen for larval odonates.

JBWR East Pond: Similar to RAG Pond, East Pond at JBWR contained permanent water and provides habitat for odonate breeding pending water quality. For example, the along the southwestern shore emergent vegetation is limited, but present and provides some structure for odonate oviposition, and perching. Along the East side of the pond during 2004 we observed an unidentified aqua-colored substance on the surface of the pond. This substance appeared to inhibit odonate oviposition, and thus breeding in these areas. We note that this pond is bordered on the west by decent upland habitat for adult foraging. Also, we observed Rambur's forktail, a state-listed species; however, we did not observe breeding behavior.

Staten Island Unit

The Staten Island Unit contains generous open space amongst a heavily developed landscape. In general, the Park unit lacks permanent water and abundant habitat that can be used for breeding by odonates. However, sites such as Freshwater Pond and Peeper Road that contain permanent water provide good foraging and breeding habitat for a suite of odonate species, including two state listed species. In addition, Freshwater Pond provided the most “exciting” odonate survey site at GATE, in part, because the rush growing along the shore provides excellent odonate habitat. The dune and beach at Miller’s Field provided foraging and potential migration habitat for several odonate species.

Sites with high conservation value

Freshwater Pond: Freshwater Pond contained high measures of species diversity and the greatest species richness of sites at Staten Island (Table 5). In addition, approximately 75 % of all species recorded had a categorical abundance rating of “present” or “numerous” (Appendix H). Similar to JBWR Big John’s Pond, Freshwater Pond appears to contain permanent water and even when water levels were low (e.g., 2005) continued to support odonate foraging activity. This site contained emergent vegetation, including rush, that likely provides breeding habitat, as well as perches, cover for adults, and a good prey base. We also note that two state-listed species, Rambur’s forktail and Needham’s skimmer, were recorded with categorical abundance rating of “present” (Appendix H). There appears to be little impact from park visitors and pets at Freshwater Pond.

Peeper Road: Similar to Freshwater Pond and JBWR Big John’s Pond, Peeper Road appears to contain water and even during years with great variation in water levels (e.g., 2005) contained enough permanent water to support odonate foraging activity. Also similar to Freshwater Pond, Peeper Road showed high species richness and species diversity (Table 5) and a majority of the species recorded had a categorical abundance rating of “present” or “numerous” (Appendix H). It appears that the emergent vegetation provides perching habitat, good food sources, and cover for odonates. Although the present emergent vegetation shows little impact from park visitors and pets, we caution that the vegetative community could become impacted by encroaching eastern reed, given that this site is located in the middle of an eastern reed marsh.

Other sites of potential interest

Miller’s Field Dune/Beach: The Dunes and Beach at Miller’s Field showed high species richness and species diversity (Table 5) and similar to both sites listed above, a majority of the species recorded had a categorical abundance rating of “present” or “numerous” (Appendix H). Nearly all odonates observed use this site as foraging habitat. In addition, we believe that the Dunes and Beach at Miller’s Field offers potential odonate migration habitat given its location and abundance of good foraging habitat.

Sandy Hook Unit

Sandy Hook contains several unique coastal habitats, including sand dunes, salt and freshwater marshes, freshwater ponds, and shrub thickets that provide valuable foraging, breeding, and migratory habitats for odonate species. Of particular importance to breeding odonates were freshwater ponds with permanent water such as Newest, North, and Exclamation Point Pond.

Given that Sandy Hook is a barrier beach peninsula located along the odonate migration corridor (Shannon 1935) we assumed that we would find habitats that could support migrating odonates. Although we did not observe any migrating events at Sandy Hook, we did record several species in habitats which they are not usually associated with, suggesting that these individuals were migrants. Specifically, Newest Pond and Spermaceti Cover Inner Salt Marsh appeared to support many migrating species and offered good foraging habitat and cover for odonates during migration. Given the location of the Sandy Hook Unit, it's possible that some of the migratory odonates observed at Breezy Point migrated over the ocean and stopped-over at Sandy Hook before continuing on.

During our study, the only species recorded that was not included in the potential species list (Appendix B) was the variegated meadowhawk, which was recorded at Newest Pond. It is considered an exotic in both New York and New Jersey as it doesn't breed west of the Mississippi River (Dunkle 2000). Variegated meadowhawks have been previously documented at Sandy Hook during 1992 (NJODES 2006) and JBWR in 1999 (Zuzworski, personal communication).

Sites with high conservation value

Newest Pond: Newest Pond contains permanent water and emergent vegetation that provides excellent foraging habitat, and likely, provides breeding and migration habitat for many of the odonate species recorded. In general, Newest Pond showed high species richness and in spite of the low diversity indexes (Table 5), half of the species recorded had a categorical abundance of "present" or "numerous" (Appendix H). It's possible that the low species diversity was influenced by the large number of damselfly species, including Rambur's forktail and familiar bluet, supported by this site. In addition, given the wealth of species detected at this site that are not usually associated with this habitat (e.g., spot-winged glider, wandering glider) we believe that Newest Pond contains excellent habitat for migrating odonates.

Exclamation Point Pond and North Pond: We will discuss Exclamation Point Pond and North Pond together, given their proximity and similarity to each other. Both sites contained high species richness and, in spite of the low diversity index in the case of North Pond (Appendix H), 50 - 60% of the species recorded had categorical abundances of "present" or "numerous" (Appendix H).

Both sites contained permanent water and surprisingly little emergent vegetation; however, odonates were observed ovipositing on algae and perching on the rocky shores. It's likely that differences in species richness between these two ponds are due to differences in pond area. For example, North Pond being larger provided more area for territorial pond species (e.g., common white tail, eastern pond hawk) to breed. In general, both ponds offered good habitat for breeding and foraging odonates.

Spermaceti Cover Inner Salt Marsh: Overall, Spermaceti Cover Inner Salt Marsh provides good habitat for both breeding and migrating odonate species. More specifically, we observed all three life stages, including newly emerged and mature adults, and breeding pairs of Rambur's forktail and seaside dragonlet suggesting that the salt marsh supports viable populations of each species. We also observed several migrant species, including Carolina saddlebags, blue dasher, and common green darner, using this site to forage and rest. It's likely that the surrounding upland provides good foraging and cover for both breeding and migrating adults.

Other sites of potential interest

Nike Pond: It appears that Nike Pond has potential habitat for odonates; however, this site was not completely surveyed due to dense stands of eastern reed and abundance of poison ivy. The pond is also too deep to wade across and thus, a boat would be required for a complete survey (see Results for more details). Ultimately, we believe that Nike Pond could possibly support greater species richness and abundance of species than were recorded during this survey.

Potential Threats to Odonate Populations

In general, current management practices at most survey sites appear to have either a neutral or beneficial effect on odonate populations at GATE. For example, public access at all Park Units was well marked and Park staff appeared diligent and actively enforced Park regulations. The most serious threat to odonate populations and their habitat appears to be the abundance of common reed at many odonate survey sites, including JBWR Big John's Pond, Peeper Road at Great Kills Park, and Exclamation Point Pond and North Pond at Sandy Hook. In fact, nearly all of the permanent and temporary water used by odonates at GATE was surrounded by common reed, to some degree.

Common reed has been shown to affect site hydrology (Angerdi et al. 2001) and could potentially negatively influence water levels at these sites if not monitored. In addition, common reed out competes native plants, causing a direct change in invertebrate abundance and assemblage (Angerdi et al. 2001). Studies have also found that sites containing common reed show reduced species diversity of damselflies (Catling and Brownell 2001).

Conclusion

Overall, GATE contained several marshes and coastal ponds that are appropriate for odonate reproduction, as well as several sites that offer good foraging and migration habitat. Odonates have a 3-stage life cycle that includes an egg stage, an aquatic larval stage the commonly lasts one year, and a terrestrial adult stage. The most productive habitats for odonates are ponds, lakes, and streams with abundant aquatic vegetation (e.g., submersed, floating, and emergent) located in and surrounding them. Aquatic vegetation oxygenates water and provides protective cover, as well as food organisms for odonates (Walker 1953, Corbet 1980). Generally speaking, habitats that contained permanent water and emergent vegetation at GATE supported odonate breeding. In addition to supporting breeding odonates, several sites at GATE offered good foraging habitat and cover for migrating odonates.

Due to its location within the odonate migration corridor (Shannon 1935) and especially considering the level of development in the surrounding landscape, GATE offers critical habitat for migrating odonates. We observed migrating odonates during both years of this study in the Jamaica Bay Unit at Fort Tilden and at Breezy Point. On several occasions researchers observed odonates funneling over the dunes at Fort Tilden Fishlot en route to Breezy Point Swales. During much of the migratory period, Breezy Point Swales was teaming with migratory odonates and generally offered excellent foraging habitat and cover to migrating odonates. At the Sandy Hook Unit, Newest Pond and Spermaceti Cover Inner Salt Marsh also supported migratory odonates, offering good foraging habitat and cover during the migratory period. Given the location of the Sandy Hook Unit, it's possible that some of the migratory odonates observed at Breezy Point migrated over the ocean and stopped-over at Sandy Hook before continuing on.

During 2004 and 2005, odonates were recorded all 38 sites surveyed at GATE. In all, 37 species of odonates were recorded, including Needham's skimmer and Rambur's forkail, which are listed as imperiled in New York (NYNHP 2006). Of the three National Parks in New York and New Jersey that were surveyed for odonates in 2004 and 2005 (FIIS, SAHI, GATE), GATE showed the greatest species richness and number of sites with odonate species.

The Jamaica Bay Unit showed the greatest species richness of the three Park Units at GATE and contains several areas with critical or rare habitat, such as coastal ponds, dunes, and swales, which not only support odonate breeding, but also provide foraging areas, cover, and habitat for migrating odonates. For example, both Big John's Pond and West Pond at JBWR contained permanent water and emergent vegetation that supported considerable odonate activity, even when water levels were low. In addition, these sites provide breeding habitat for familiar bluets, and two state-listed species, Rambur's forkail and Needham's skimmer. It's likely that these sites, along with Breezy Point Salt Marsh, support other breeding species as well. As mentioned above, the dunal system and beach at Fort Tilden Fishlot and, in particular, Breezy Point Swales were usually teaming with migratory odonates and generally offered excellent foraging habitat and cover to migrating odonates.

The Staten Island Unit contains generous open space amongst a heavily developed landscape, but generally lacks permanent water and abundant habitat that can be used for breeding by odonates. However, sites that contain permanent water such as Freshwater Pond and Peeper Road provide good foraging and breeding habitat for a suite of odonate species, including two state listed

species, Rambur's forktail and Needham's skimmer. In addition, we consider Freshwater Pond the most "exciting" odonate survey site at GATE, in part, because of the vegetation along the shore provides excellent odonate habitat. The dune and beach at Miller's Field provided foraging and potential migration habitat for several odonate species.

The Sandy Hook Unit contains several unique coastal habitats, including sand dunes, salt and freshwater marshes, freshwater ponds, and shrub thickets that provide valuable foraging, breeding, and migratory habitats for odonate species. Of particular importance to breeding odonates were freshwater ponds with permanent water such as Newest, North, and Exclamation Point Pond. Given that Sandy Hook is a barrier beach peninsula located along the odonate migration corridor (Shannon 1935), it's possible that some of the migratory odonates observed at Breezy Point migrated over the ocean and stopped-over at Sandy Hook before continuing on. Although we did not observe any migration events at Sandy Hook, we did record several species in habitats which they are not usually associated with, suggesting that these individuals were migrants. Specifically, Newest Pond and Spermaceti Cover Inner Salt Marsh appeared to support many migrating species and offered good foraging habitat and cover for odonates during migration.

Recommendations for Future Monitoring

Generally speaking, managing habitat for odonate species is managing wetlands. Based on the results of this baseline inventory we have four recommendations for future monitoring.

1. Given the high levels of odonate diversity and productivity at JBWR Big John's Pond and Peeper Road and Freshwater Pond at Great Kills Park, we recommend that odonate surveys be conducted at these ponds and in the surrounding upland habitat for 1-hour, once monthly during odonate flight season, late-May to mid-September.
2. Given that migration events are likely to occur after the passage of a cold front, we suggest that from mid-July through mid-September after the passage of cold fronts Fort Tilden Fishlot be monitored for migration events.
3. In general, we suggest that common reed be monitored and, if deemed necessary, reduced at Peeper Road and Freshwater Pond at Great Kills Park.
4. Managers at the Jamaica Bay Unit may wish to consider developing an interpretive program for odonates at Big John's Pond. We believe that the high productivity of odonates and natural resource protections presently in place at this site could allow the Park to institute a successful interpretive program for a nominal cost.

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Appendix A.

Coordinates and habitat types for sites surveyed for odonates during 2004-2005 at Gateway National Recreation Area, New York and New Jersey.

Coordinates were recorded using a handheld Garmin GPS V. Habitat types were defined using National Vegetation Classification (NVC) standards (FGDC 1997) and NY Natural Heritage Program (NYNHP) classifications (Edinger et al. 2002). Park subunits are abbreviated as: Breezy Point (BP), Floyd Bennett Field (FB), Fort Tilden (FT), Jamaica Bay and Wildlife Refuge (JBWR).

Parkunit / Subunit / Site Name	NVC Habitat Type	NYNHP Habitat Type	UTMX	UTMY
Jamaica Bay Unit				
BP: Saltmarsh	Mid-Atlantic Maritime Salt Shrub; Eastern Reed Marsh	High Salt Marsh; Reedgrass/Purple Loosestrife Marsh	4488996.84	589886.63
BP: Swale	Northeastern Atlantic Brackish Interdunal Swale	Brackish Interdunal Swale; Shallow Emergent Marsh	4490002.81	590109.10
FB: Rag Pond	Water-lily Aquatic Wetland; Eastern Reed Marsh	Deep Emergent Marsh; Artificial Pond; Eutrophic Pond; Reedgrass/Purple Loosestrife Marsh	4494382.48	592834.94
FB: Community Garden		Maritime Grassland	4493570.84	593726.31
FT: Fishlot		Paved Road/Path	4490236.84	593207.40
FT: House		Mowed Lawn	4491001.01	594596.49
JBWR: Big John's Pond	Eastern Reed Marsh	Artificial Pond	4497298.89	599478.46
JBWR: Blind Pond		Artificial Pond	4497038.14	599365.33
JBWR: East Pond	Coastal Salt Pond Marsh; Eastern Reed Marsh	Estuarine Artificial Impoundment; Reedgrass/Purple Loosestrife Marsh; Brackish Intertidal Mudflat	4497291.75	599635.49
JBWR: Saltmarsh	North Atlantic High- and Low Salt Marsh; Salt Panne Pool	High- and Low Salt Marsh; Salt Panne	4496674.26	599004.35
JBWR: West Pond	Eastern Reed Marsh; Coastal Salt Pond Marsh	Reedgrass/Purple Loosestrife Marsh; Estuarine Artificial Impoundment	4496789.79	598903.23
JBWR: West Pond Marsh North #2		Shallow Emergent Marsh	4497144.45	598714.99
JBWR: West Pond Marsh South #1		Shallow Emergent Marsh	4497448.77	598987.27

Appendix A. Coordinates and habitat types for sites surveyed for odonates during 2004-2005 at Gateway National Recreation Area, New York and New Jersey. Coordinates were recorded using a handheld Garmin GPS V. Habitat types were defined using National Vegetation Classification (NVC) standards (FGDC 1997) and NY Natural Heritage Program (NYNHP) classifications (Edinger et al. 2002). Park subunits are abbreviated as: Breezy Point (BP), Floyd Bennett Field (FB), Fort Tilden (FT), Jamaica Bay and Wildlife Refuge (JBWR) (continued).

Parkunit / Subunit / Site Name	NVC Habitat Type	NYNHP Habitat Type	UTMX	UTMY
Staten Island Unit				
Ballfield		Mowed Lawn	4489210.46	573370.13
Blue Dot Trail Drainage Opening	Eastern Reed Marsh	Shallow Emergent Marsh; Ditch/Artificial Intermittent Stream; Reedgrass/Purple Loosestrife Marsh	4489531.21	573571.46
Cliff Edge	North Atlantic Coast Backdune Grassland	Maritime Dune; Successional Old Field	4488570.73	574262.44
Education Center Pond		Artificial Pond	4488640.26	573856.26
E Lot Ditch		Ditch/Artificial Intermittent Stream; Shallow Emergent Marsh	4488230.88	573916.33
Freshwater Pond	Eastern Reed Marsh	Reedgrass/Purple Loosestrife Marsh	4489003.11	574351.21
Peeper Road		Mowed Roadside/Pathway	4488944.70	574157.33
Pipe Road	Eastern Reed Marsh	Reedgrass/Purple Loosestrife Marsh; Mowed Roadside/Pathway	4489771.97	574006.47
Pipe Road Drainage	Eastern Reed Marsh	Reedgrass/Purple Loosestrife Marsh; Ditch/Artificial Intermittent Stream	4488230.88	573916.33
Promenade Marsh		Shallow Emergent Marsh	4488655.58	573231.46
Miller Field: Dune/Beach	Northern Beachgrass Dune	Maritime Dune	4490910.82	576784.23
Miller Field: Field		Mowed Lawn	4490942.324	599004.3474
Sandy Hook Unit				
Exclamation Point Pond	Eastern Reed Marsh	Reedgrass/Purple Loosestrife Marsh; Eutrophic Pond	4480798.15	584271.66
Horseshoe Marsh	North Atlantic High- and Low Salt Marsh	High- and Low Salt Marsh; Tidal Creek	4478040.80	584911.37
K-Lot Field	Successional Old Field	Successional Old Field	4480244.12	584484.78
Newest Pond		Coastal Salt Pond	4480955.10	583789.51
Nike Pond	Eastern Reed Marsh	Reedgrass/Purple Loosestrife Marsh; Artificial Pond	4476210.81	586054.19
North Pond	Eastern Reed Marsh	Eutrophic Pond; Reedgrass/Purple Loosestrife Marsh	4480637.77	584364.23
Plum Marsh	North Atlantic High- and Low Salt Marsh	High- and Low Salt Marsh	4473465.65	586485.13
Round Pond	Eastern Reed Marsh	Eutrophic Pond; Reedgrass/Purple Loosestrife Marsh	4477374.92	585838.81
Spermaceti Cove Inner Salt Marsh	Salt Panne Pool; North Atlantic High- and Low Salt Marsh	High- and Low Salt Marsh; Salt Panne	4475807.97	585899.93
Spermaceti Cove Outer Salt Marsh	North Atlantic High- and Low Salt Marsh	High- and Low Salt Marsh	4475634.66	585939.45

Appendix B.
Photographs of sites surveyed for odonates during 2004-2005 at
Gateway National Recreation Area, New York and New Jersey.

Jamaica Bay Unit: Breezy Point, Salt Marsh



Jamaica Bay Unit: Breezy Point, Swales



Jamaica Bay Unit: Floyd Bennett Field, Culvert



Appendix B. Photographs of sites surveyed for odonates during 2004-2005 at Gateway National Recreation Area, New York and New Jersey (continued).

Jamaica Bay Unit: Floyd Bennett Field, Rag Pond



Jamaica Bay Unit: Fort Tilden, Fishlot



Jamaica Bay Unit: Fort Tilden, Pond



Appendix B. Photographs of sites surveyed for odonates during 2004-2005 at Gateway National Recreation Area, New York and New Jersey (continued).

Jamaica Bay Unit: Jamaica Bay Wildlife Refuge, Big John's Pond



Jamaica Bay Unit: Jamaica Bay Wildlife Refuge, Blind Pond



Appendix B. Photographs of sites surveyed for odonates during 2004-2005 at Gateway National Recreation Area, New York and New Jersey (continued).

Jamaica Bay Unit: Jamaica Bay Wildlife Refuge, East Pond



Jamaica Bay Unit: Jamaica Bay Wildlife Refuge, Fire Break



Jamaica Bay Wildlife Refuge, Saltmarsh



Appendix B. Photographs of sites surveyed for odonates during 2004-2005 at Gateway National Recreation Area, New York and New Jersey (continued).

Jamaica Bay Unit: Jamaica Bay Wildlife Refuge, West Pond



Jamaica Bay Unit: Jamaica Bay Wildlife Refuge, West Pond Marsh North #2



Jamaica Bay Unit: Jamaica Bay Wildlife Refuge, West Pond Marsh South #1



Appendix B. Photographs of sites surveyed for odonates during 2004-2005 at Gateway National Recreation Area, New York and New Jersey (continued).

Sandy Hook Unit: Exclamation Point Pond



Sandy Hook Unit: Horseshoe Marsh



Sandy Hook Unit: K-Lot Field



Appendix B. Photographs of sites surveyed for odonates during 2004-2005 at Gateway National Recreation Area, New York and New Jersey (continued).

Sandy Hook Unit: Newest Pond



Sandy Hook Unit: Nike Pond



Sandy Hook Unit: North Pond



Appendix B. Photographs of sites surveyed for odonates during 2004-2005 at Gateway National Recreation Area, New York and New Jersey (continued).

Sandy Hook Unit: Plum Marsh



Sandy Hook Unit: Round Pond



Sandy Hook Unit: Spermaceti Cove Inner Salt Marsh



Appendix B. Photographs of sites surveyed for odonates during 2004-2005 at Gateway National Recreation Area, New York and New Jersey (continued).

Sandy Hook Unit: Spermaceti Cove Outer Salt Marsh



Staten Island Unit: Great Kills Park, Ballfield



Staten Island Unit: Great Kills Park, Blue Dot Trail Drainage Opening



Appendix B. Photographs of sites surveyed for odonates during 2004-2005 at Gateway National Recreation Area, New York and New Jersey (continued).

Staten Island Unit: Great Kills Park, Cliff Edge



Staten Island Unit: Great Kills Park, E Lot Ditch



Appendix B. Photographs of sites surveyed for odonates during 2004-2005 at Gateway National Recreation Area, New York and New Jersey (continued).

Staten Island Unit: Great Kills Park, Education Center Pond



Staten Island Unit: Great Kills Park, Freshwater Pond



Staten Island Unit: Great Kills Park, Pipe Road



Appendix B. Photographs of sites surveyed for odonates during 2004-2005 at Gateway National Recreation Area, New York and New Jersey (continued).

Staten Island Unit: Great Kills Park, Pipe Road Drainage



Staten Island Unit: Great Kills Park, Promenade Marsh



Appendix B. Photographs of sites surveyed for odonates during 2004-2005 at Gateway National Recreation Area, New York and New Jersey (continued).

Staten Island Unit: Miller Field: Dune/Beach



Staten Island Unit: Miller Field: Field



Appendix C.

Potentially occurring odonate species (i.e. Potential Species List) at Gateway National Recreation Area, New York and New Jersey.

Potential Species List was based on expert opinion, published lists of odonates in the Northeast (Donnelly 1999, Carpenter 1991, Walker 1953), observations of NPS staff, and historical collections and biological repositories (see Methods for details).

Common Name	Scientific Name
- Damselflies -	
Eastern red damsel	<i>Amphiagrion saucium</i>
Great spreadwing	<i>Archilestes grandis</i>
Aurora damsel	<i>Chromagrion conditum</i>
Azure bluet	<i>Enallagma aspersum</i>
Familiar bluet	<i>Enallagma civile</i>
Big bluet	<i>Enallagma durum</i>
Orange bluet	<i>Enallagma signatum</i>
Vesper bluet	<i>Enallagma vesperum</i>
Citrine forktail	<i>Ischnura hastata</i>
Fragile forktail	<i>Ischnura posita</i>
Rambur's forktail *	<i>Ischnura ramburii</i> *
Eastern forktail	<i>Ischnura verticalis</i>
Southern spreadwing	<i>Lestes australis</i>
Spotted spreadwing	<i>Lestes congener</i>
Common spreadwing	<i>Lestes disjunctus</i>
Amber-winged spreadwing	<i>Lestes eurinus</i>
Sweetflag spreadwing	<i>Lestes forcipatus</i>
Elegant spreadwing	<i>Lestes inaequalis</i>
Slender spreadwing	<i>Lestes rectangularis</i>
Swamp spreadwing	<i>Lestes vigilax</i>
Sphagnum sprite	<i>Nehalennia gracilis</i>
Sedge sprite	<i>Nehalennia irene</i>
- Dragonflies -	
Common green darner	<i>Anax junius</i>
Calico pennant	<i>Celithemis elisa</i>
Halloween pennant	<i>Celithemis eponina</i>
Banded pennant	<i>Celithemis fasciata</i>
Martha's pennant	<i>Celithemis martha</i>
Petite emerald	<i>Dorocordulia lepida</i>
Swamp darner	<i>Epiaeshna heros</i>

Appendix C. Potentially occurring odonate species (i.e. Potential Species List) at Gateway National Recreation Area, New York and New Jersey. Potential Species List was based on expert opinion, published lists of odonates in the Northeast (Donnelly 1999, Carpenter 1991, Walker 1953), observations of NPS staff, and historical collections and biological repositories (see Methods for details) (continued).

Common Name	Scientific Name
- Dragonflies - (continued)	
Common baskettail	<i>Epithea cynosura</i>
Mantled baskettail *	<i>Epithea semiaquea</i> *
Eastern pondhawk	<i>Erythemis simplicicollis</i>
Seaside dragonlet	<i>Erythrodiplax berenice</i>
Lancet clubtail	<i>Gomphus exilis</i>
Bar-winged skimmer	<i>Libellula axelina</i>
Spangled skimmer	<i>Libellula cyanea</i>
White corporal	<i>Libellula exusta</i>
Slaty skimmer	<i>Libellula incesta</i>
Widow skimmer	<i>Libellula luctuosa</i>
Common whitetail	<i>Libellula lydia</i>
Needham's skimmer *	<i>Libellula needhami</i> *
Twelve-spotted skimmer	<i>Libellula pulchella</i>
Painted skimmer	<i>Libellula semifasciata</i>
Great blue skimmer	<i>Libellula vibrans</i>
Blue dasher	<i>Pachydiplax longipennis</i>
Wandering glider	<i>Pantala flavescens</i>
Spot-winged glider	<i>Pantala hymenaea</i>
Eastern amberwing	<i>Perithemis tenera</i>
Cherry-faced meadowhawk	<i>Sympetrum internum</i>
Ruby meadowhawk	<i>Sympetrum rubicundulum</i>
Carolina saddlebags	<i>Tamea carolina</i>
Black saddlebags	<i>Tamea lacerate</i>

* Species listed as imperiled in New York (NYNHP 2006)

Appendix D.

Example of voucher card template used for all voucher specimens collected during the 2004 and 2005 odonate survey of Gateway National Recreation Area, New York and New Jersey.

Voucher Field #:	Date:
ParkCode:	Time:
Park Unit:	Collected by:
SiteID:	Determined by:
Town:	Species:
County:	Male/Female
State:	Age:
Location Notes:	Behavior:
	GraphicID#:

Appendix E.

Formulas used to calculate Simpson's Index of Diversity as suggested by Krebs (1989) and Shannon-Wiener Diversity Index as suggested by Zarr (1999).

Simpson's Index: $1 - D$, where $D = \sum (p_i)^2$

p_i = Proportion of individuals of species i in the sample

Shannon-Wiener Index: $H' = - \sum (p_i) (\log_{10}(p_i))$

where, p_i = Proportion of individuals of species i in the sample

Krebs (1989) notes that any base of logarithms (e.g. $\log_{10}$, $\log_2$, and $\log_e$) can be used in calculating the Shannon-Wiener Index, since they are all convertible to one another by a constant multiplier.

Appendix F.

Expected abundance of odonate species in their primary habitat at Gateway National Recreation Area, New York and New Jersey, during 2004-2005.

Expected Abundance is based on the biology and life history of a given species in its primary habitat (see Methods). Species were considered Unusual if their recorded abundance was $\leq$ the expected abundance, Present if their recorded abundance was within the expected abundance range, and Numerous if their recorded abundance was $\geq$ to the expected abundance.

Species name	Expected Abundance		
	Unusual	Present	Numerous
<i>Anax junius</i>	2	4-12	15
<i>Argia apicalis</i>	1	2-3	4
<i>Celithemis elisa</i>	1	3-6	8
<i>Celithemis eponina</i>	3	5-16	20
<i>Celithemis fasciata</i>	5	6-20	25
<i>Enallagma aspersum</i>	1	3-8	10
<i>Enallagma civile</i>	10	20-90	100
<i>Enallagma durum</i>	4	10-12	25
<i>Enallagma signatum</i>	2	4-16	20
<i>Epiaeschna heros</i>	10	15-20	30
<i>Erythemis simplicicollis</i>	2	4-12	15
<i>Erythrodiplax berenice</i>	1	10 - 12	20
<i>Ischnura hastata</i>	1	4-30	35
<i>Ischnura posita</i>	1	3 - 10	12
<i>Ischnura ramburii</i> ^a	1	3-16	20
<i>Ischnura verticalis</i>	2	4-16	20
<i>Lestes disjunctus australis</i>	2	4-6	10
<i>Lestes disjunctus disjunctus</i>	2	4-6	10
<i>Lestes disjunctus</i>	2	4-6	10
<i>Lestes eurinus</i> ^{b,c}	1	3-5	8
<i>Lestes rectangularis</i>	2	4-15	18
<i>Lestes</i> sp.	-	-	-

Appendix F. Expected abundance of odonate species in their primary habitat at Gateway National Recreation Area, New York and New Jersey, during 2004-2005. Expected Abundance is based on the biology and life history of a given species in its primary habitat (see Methods). Species were considered Unusual if their recorded abundance was $\leq$ the expected abundance, Present if their recorded abundance was within the expected abundance range, and Numerous if their recorded abundance was $\geq$ to the expected abundance (continued).

Species name	Expected Abundance		
	Unusual	Present	Numerous
<i>Libellula incesta</i>	1	5-6	10
<i>Libellula luctuosa</i>	4	5-6	12
<i>Libellula lydia</i>	4	6-8	10
<i>Libellula needhami</i> ^a	2	4-8	10
<i>Libellula pulchella</i>	2	4-10	12
<i>Libellula semifasciata</i>	3	5-8	10
<i>Libellula vibrans</i>	2	4-12	10
<i>Nehalennia gracilis</i>	8	4-12	20
<i>Pachydiplax longipennis</i>	2	4-16	20
<i>Pantala flavescens</i>	1	3-5	6
<i>Pantala hymenaea</i>	1	3	5
<i>Perithemis tenera</i>	2	4-16	20
<i>Sympetrum corruptum</i>	1	2-3	4
<i>Sympetrum internum</i>	2	4-6	8
<i>Sympetrum rubicundulum</i>	5	7-9	12
<i>Tamea carolina</i>	2	4-8	10
<i>Tamea lacerata</i>	4	6-10	12

^a State listed in NY

^b State listed in NJ

^c Only recorded in NY

Appendix G.

Investigator effort during odonate surveys conducted at Gateway National Recreation Area, New York and New Jersey, during 2004-2005.

Raw effort is the total number of survey minutes conducted by all investigators at each site. Adjusted effort was calculated by weighting the raw effort of a given researcher by their level of experience (see Methods for details). All measures of time are shown in minutes.

Park Unit / Subunit / Site Name	2004 Effort		2005 Effort		Total Effort	
	Raw	Adjusted	Raw	Adjusted	Raw	Adjusted
Jamaica Bay Unit						
BP: Saltmarsh	130	115	270	248	400	363
BP: Swale	290	258	90	80	380	338
FBF: Community Garden	-	-	160	140	160	140
FBF: Culvert	50	50	-	-	50	50
FBF: Rag Pond	310	293	575	505	885	798
FT: Fishlot	665	663	510	458	1,175	1,120
FT: House	-	-	80	80	80	80
FT: Pond	32	28	75	68	107	96
JBWR: Big John's Pond	366	337	255	225	621	562
JBWR: Blind Pond	50	45	150	135	200	180
JBWR: East Pond	330	313	275	243	605	555
JBWR: Fire Break	60	60	-	-	60	60
JBWR: Saltmarsh	60	53	180	158	240	210
JBWR: West Pond	1,040	965	480	435	1,520	1,400
JBWR: West Pond Marsh North #2	140	133	120	105	260	238
JBWR: West Pond Marsh South #1	270	248	150	131	420	379
Staten Island Unit						
Ballfield	130	125	-	-	130	125
Blue Dot Trail Drainage Opening	310	273	60	53	370	325
Cliff Edge	170	160	-	-	170	160
E Lot Ditch	45	38	-	-	45	38
Education Center Pond	100	90	20	18	120	108
Freshwater Pond	180	150	495	443	675	593
Peeper Road	60	60	480	420	540	480
Pipe Road	30	25	270	248	300	273
Pipe Road Drainage	180	150	-	-	180	150
Promenade Marsh	88	82	60	53	148	135
Miller Field: Dune/Beach	270	255	225	199	495	454
Miller Field: Field	170	155	-	-	170	155
Sandy Hook Unit						
Exclamation Point Pond	270	270	60	53	330	323
Horseshoe Marsh	105	88	-	-	105	88
K-Lot Field	75	63	-	-	75	63
Newest Pond	190	190	660	593	850	783
Nike Pond	90	90	-	-	90	90
North Pond	640	610	610	538	1,250	1,148
Plum Marsh	90	75	-	-	90	75
Round Pond	320	295	120	105	440	400
Spermaceti Cove Inner Salt Marsh	150	125	80	70	230	195
Spermaceti Cove Outer Salt Marsh	90	75	-	-	90	75
Total	7,546	6,999	6,510	5,798	14,056	12,797

Appendix H.

Categorical abundance of odonates recorded per site at Gateway National Recreation Area, New York and New Jersey, during 2004-2005.

Categorical Abundance is based on the biology and life history of a given species (see Methods and Appendix D).

Park Subunit / Site Name	ScientificName	Qunative Abundance	Categorical Abundance		
			Unusual	Present	Numerous
Breezy Point					
Saltmarsh	Anax junius	16			X
	Enallagma civile	13			X
	Epiaeschna heros	15		X	
	Ischnura hastata	13		X	
	Ischnura ramburii	12		X	
	Libellula pulchella	6		X	
	Pachydiplax longipennis	23			X
	Pantala flavescens	4		X	
	Sympetrum internum	1	X		
	Tamea carolina	7		X	
Swale	Tamea lacerata	13			X
	Anax junius	11		X	
	Enallagma civile	1	X		
	Epiaeschna heros	8	X		
	Erythemis simplicicollis	6		X	
	Ischnura hastata	520			X
	Ischnura verticalis	1	X		
	Lestes disjunctus	1	X		
	Lestes disjunctus australis	3	X		
	Lestes rectangularis	4		X	
	Lestes sp.	6	-	-	-
	Libellula pulchella	1	X		
	Nehalennia gracilis	3	X		
	Pachydiplax longipennis	34			X
	Pantala flavescens	1	X		
	Pantala hymenaea	1	X		
	Sympetrum internum	1	X		
	Tamea carolina	2	X		
	Tamea lacerata	5		X	
Floyd Bennett Field					
Community Garden	Celithemis elisa	1	X		
	Enallagma civile	12			X
	Epiaeschna heros	20		X	
	Libellula pulchella	2	X		
	Libellula semifasciata	4		X	
	Libellula vibrans	3	X		
	Pachydiplax longipennis	1	X		
	Pantala flavescens	10			X
	Pantala hymenaea	10			X
	Tamea lacerata	4	X		
FBF Culvert	Anax junius	1	X		
	Ischnura verticalis	1	X		

Appendix H. Categorical abundance of odonates recorded per site at Gateway National Recreation Area, New York and New Jersey, during 2004-2005. Categorical Abundance is based on the biology and life history of a given species (see Methods and Appendix D) (continued).

Park Subunit / Site Name	ScientificName	Quantitative Abundance	Categorical Abundance		
			Unusual	Present	Numerous
Rag Pond	Anax junius	3		X	
	Enallagma civile	3	X		
	Epiaeschna heros	6	X		
	Erythemis simplicicollis	4		X	
	Ischnura hastata	1	X		
	Ischnura posita	12		X	
	Ischnura verticalis	2	X		
	Lestes rectangularis	15		X	
	Libellula pulchella	1	X		
	Pachydiplax longipennis	92			X
	Pantala flavescens	1	X		
	Pantala hymenaea	4		X	
	Tamea lacerata	6		X	
Fort Tilden Fishlot	Anax junius	15			X
	Epiaeschna heros	535			X
	Libellula pulchella	23			X
	Libellula semifasciata	34			X
	Libellula vibrans	1	X		
	Pachydiplax longipennis	139			X
	Pantala flavescens	2	X		
	Pantala hymenaea	38			X
	Tamea carolina	29			X
	Tamea lacerata	22			X
	Anax junius	20			X
	Epiaeschna heros	30			X
	Epiaeschna heros	2	X		
FT House	Erythemis simplicicollis	1	X		
	Libellula pulchella	1	X		
	Pachydiplax longipennis	16		X	
FT Pond	Anax junius	15			X
	Enallagma aspersum	1	X		
	Enallagma civile	140			X
	Epiaeschna heros	2	X		
	Erythemis simplicicollis	10		X	
	Ischnura hastata	25		X	
	Ischnura posita	28			X
	Ischnura ramburii	4		X	
	Ischnura verticalis	20			X
	Lestes eurinus	1	X		
	Lestes rectangularis	11		X	
	Libellula lydia	1	X		
	Libellula needhami	1	X		
Jamaica Bay Wildlife Refuge Big John's Pond	Libellula pulchella	9		X	
	Libellula vibrans	3		X	
	Pachydiplax longipennis	69			X
	Sympetrum internum	2	X		
	Tamea carolina	12			X
	Tamea lacerata	14			X

Appendix H. Categorical abundance of odonates recorded per site at Gateway National Recreation Area, New York and New Jersey, during 2004-2005. Categorical Abundance is based on the biology and life history of a given species (see Methods and Appendix D) (continued).

Park Subunit / Site Name	ScientificName	Quantitative Abundance	Categorical Abundance		
			Unusual	Present	Numerous
Blind Pond	Enallagma civile	9	X		
	Epiaeschna heros	1	X		
	Ischnura posita	1	X		
	Ischnura verticalis	2	X		
	Libellula pulchella	2	X		
	Libellula vibrans	1	X		
	Pachydiplax longipennis	5		X	
East Pond	Anax junius	2	X		
	Enallagma civile	118			X
	Enallagma durum	9	X		
	Epiaeschna heros	1	X		
	Erythemis simplicicollis	1	X		
	Erythrodiplax berenice	1	X		
	Ischnura ramburii	6		X	
	Ischnura verticalis	3	X		
	Lestes rectangularis	1	X		
	Pachydiplax longipennis	3	X		
	Perithemis tenera	10		X	
	Tramea lacerata	10		X	
	Anax junius	2	X		
	Enallagma civile	5	X		
	Erythemis simplicicollis	1	X		
JBWR Fire Break	Sympetrum internum	2	X		
	Enallagma civile	4	X		
	Epiaeschna heros	10	X		
	Erythrodiplax berenice	15		X	
Saltmarsh	Libellula semifasciata	7		X	
	Libellula vibrans	1	X		
	Pachydiplax longipennis	12		X	
	Tramea carolina	4		X	
	Tramea lacerata	8		X	
	Anax junius	14			X
	Argia apicalis	1	X		
West Pond	Enallagma civile	258			X
	Epiaeschna heros	9	X		
	Erythemis simplicicollis	1	X		
	Ischnura posita posita	1	X		
	Ischnura ramburii	18		X	
	Ischnura verticalis	3	X		
	Libellula pulchella	8		X	
	Libellula semifasciata	1	X		
	Pachydiplax longipennis	6		X	
	Pantala flavescens	3		X	
	Pantala hymenaea	5			X
	Tramea carolina	4		X	
	Tramea lacerata	3	X		

Appendix H. Categorical abundance of odonates recorded per site at Gateway National Recreation Area, New York and New Jersey, during 2004-2005. Categorical Abundance is based on the biology and life history of a given species (see Methods and Appendix D) (continued).

Park Subunit / Site Name	ScientificName	Quantitative Abundance	Categorical Abundance		
			Unusual	Present	Numerous
West Pond Marsh North #2	Anax junius	1	X		
	Enallagma civile	38		X	
	Erythemis simplicicollis	2	X		
	Erythrodiplax berenice	16		X	
	Ischnura hastata	3	X		
	Ischnura ramburii	1	X		
	Ischnura verticalis	2	X		
	Pachydiplax longipennis	2	X		
	Pantala hymenaea	3		X	
	Tamea lacerata	1	X		
West Pond Marsh South #1	Anax junius	7		X	
	Argia apicalis	1	X		
	Enallagma civile	90		X	
	Epiaeschna heros	4	X		
	Ischnura hastata	2	X		
	Ischnura ramburii	27			X
	Libellula pulchella	2	X		
	Libellula semifasciata	3	X		
	Pachydiplax longipennis	13		X	
	Pantala hymenaea	2	X		
Sandy Hook Exclamation Point Pond	Sympetrum internum	1	X		
	Tamea lacerata	3	X		
	Anax junius	4		X	
	Celithemis elisa	1	X		
	Celithemis eponina	1	X		
	Enallagma civile	23		X	
	Erythemis simplicicollis	10		X	
	Ischnura posita	13		X	
	Ischnura ramburii	2	X		
	Libellula needhami	2	X		
Horseshoe Marsh	Libellula pulchella	3	X		
	Libellula semifasciata	1	X		
	Pachydiplax longipennis	31			X
	Tamea lacerata	5		X	
	Enallagma civile	1	X		
	Ischnura hastata	1	X		
	Pantala flavescens	3		X	
	Tamea lacerata	5		X	
	Anax junius	2	X		
	Pantala flavescens	12			X
K-Lot Field	Tamea lacerata	2	X		

Appendix H. Categorical abundance of odonates recorded per site at Gateway National Recreation Area, New York and New Jersey, during 2004-2005. Categorical Abundance is based on the biology and life history of a given species (see Methods and Appendix D) (continued).

Park Subunit / Site Name	ScientificName	Quantitative Abundance	Categorical Abundance		
			Unusual	Present	Numerous
Newest Pond	Anax junius	1	X		
	Celithemis elisa	1	X		
	Celithemis eponina	1	X		
	Enallagma civile	97			X
	Epiaeschna heros	1	X		
	Ischnura ramburii	19			X
	Ischnura verticalis	2	X		
	Libellula pulchella	1	X		
	Pachydiplax longipennis	13		X	
	Pantala flavescens	10			X
	Pantala hymenaea	18			X
	Sympetrum corruptum	7			X
	Tamea carolina	2	X		
	Tamea lacerata	10		X	
Nike Pond	Enallagma civile	7	X		
	Ischnura posita posita	1	X		
	Perithemis tenera	8		X	
	Tamea lacerata	1	X		
North Pond	Anax junius	9		X	
	Celithemis elisa	1	X		
	Celithemis eponina	1	X		
	Enallagma civile	11		X	
	Enallagma signatum	1	X		
	Epiaeschna heros	1	X		
	Erythemis simplicicollis	22			X
	Ischnura hastata	1	X		
	Ischnura posita	2	X		
	Ischnura ramburii	6		X	
	Ischnura verticalis	6		X	
	Libellula luctuosa	7		X	
	Libellula lydia	4	X		
	Libellula needhami	8		X	
	Libellula pulchella	8		X	
	Pachydiplax longipennis	86			X
	Pantala hymenaea	1	X		
	Perithemis tenera	16		X	
	Tamea carolina	3		X	
	Tamea lacerata	29			X
Plum Marsh	Anax junius	1	X		
	Erythrodiplax berenice	10		X	
	Ischnura hastata	1	X		
	Tamea lacerata	1	X		
Round Pond	Anax junius	1	X		
	Erythemis simplicicollis	1	X		
	Ischnura hastata	7		X	
	Ischnura posita	4		X	
	Ischnura verticalis	1	X		
	Pachydiplax longipennis	11		X	
	Perithemis tenera	1	X		

Appendix H. Categorical abundance of odonates recorded per site at Gateway National Recreation Area, New York and New Jersey, during 2004-2005. Categorical Abundance is based on the biology and life history of a given species (see Methods and Appendix D) (continued).

Park Subunit / Site Name	ScientificName	Quantitative Abundance	Categorical Abundance		
			Unusual	Present	Numerous
Spermaceti Cove Inner Salt Marsh	Anax junius	3		X	
	Enallagma civile	1	X		
	Erythemis simplicicollis	13			X
	Erythrodiplax berenice	30			X
	Ischnura hastata	1	X		
	Ischnura ramburii	11		X	
	Libellula lydia	1	X		
	Libellula pulchella	1	X		
	Libellula semifasciata	6		X	
	Pachydiplax longipennis	15		X	
	Tamea carolina	1	X		
Spermaceti Cove Outer Marsh	Anax junius	1	X		
	Ischnura hastata	3	X		
	Pantala flavescens	1	X		
Great Kills Park Ballfield	Anax junius	15			X
	Libellula pulchella	1	X		
	Pantala flavescens	5		X	
	Pantala hymenaea	5			X
	Tamea carolina	2	X		
	Tamea lacerata	18			X
Blue Dot Trail Drainage Opening	Epiaeschna heros	3	X		
	Lestes rectangularis	2	X		
	Libellula lydia	2	X		
	Libellula vibrans	11		X	X
	Pachydiplax longipennis	5		X	
Cliff Edge	Anax junius	7		X	
	Enallagma civile	7	X		
	Libellula lydia	1	X		
	Pachydiplax longipennis	6		X	
	Pantala hymenaea	2	X		
	Sympetrum internum	1	X		
	Tamea lacerata	1	X		
	Anax junius	1	X		
Education Center Pond	Enallagma civile	15			X
	Ischnura hastata	1	X		
	Ischnura ramburii	1	X		
	Ischnura verticalis	10		X	
	Libellula lydia	1	X		
	Pachydiplax longipennis	4		X	
	Pantala hymenaea	4		X	
	Perithemis tenera	3		X	
	Tamea carolina	1	X		
	Tamea lacerata	1	X		
	Anax junius	1	X		
E Lot Ditch	Enallagma civile	4	X		
	Ischnura hastata	14		X	
	Pantala hymenaea	1	X		

Appendix H. Categorical abundance of odonates recorded per site at Gateway National Recreation Area, New York and New Jersey, during 2004-2005. Categorical Abundance is based on the biology and life history of a given species (see Methods and Appendix D) (continued).

Park Subunit / Site Name	ScientificName	Quantitative Abundance	Categorical Abundance		
			Unusual	Present	Numerous
Freshwater Pond	Anax junius	11		X	
	Celithemis elisa	1	X		
	Enallagma civile	92			X
	Erythemis simplicicollis	2	X		
	Ischnura hastata	105			X
	Ischnura posita	14			X
	Ischnura ramburii	3		X	
	Ischnura verticalis	36			X
	Lestes rectangularis	14		X	
	Lestes sp.	1	-	-	-
	Libellula incesta	1	X		
	Libellula lydia	12			X
	Libellula needhami	5		X	
	Libellula pulchella	16			X
	Pachydiplax longipennis	115			X
	Sympetrum internum	2	X		
	Tamea carolina	9			X
	Tamea lacerata	8		X	
Peeper Road	Anax junius	11		X	
	Epiaeschna heros	1	X		
	Ischnura hastata	3	X		
	Ischnura posita posita	4	X		
	Ischnura verticalis	14		X	
	Lestes disjunctus disjunctus	1	X		
	Lestes rectangularis	1	X		
	Libellula needhami	5		X	
	Libellula pulchella	5		X	
	Libellula semifasciata	10			X
	Libellula vibrans	1	X		
	Pachydiplax longipennis	28			X
	Sympetrum internum	1	X		
	Tamea carolina	5		X	
	Tamea lacerata	5		X	
Pipe Road	Anax junius	3		X	
	Enallagma civile	1	X		
	Ischnura hastata	3	X		
	Libellula lydia	1	X		
	Sympetrum internum	1	X		
	Sympetrum rubicundulum	1	X		
	Tamea lacerata	5		X	
Pipe Road Drainage	Ischnura posita posita	2	X		

Appendix H. Categorical abundance of odonates recorded per site at Gateway National Recreation Area, New York and New Jersey, during 2004-2005. Categorical Abundance is based on the biology and life history of a given species (see Methods and Appendix D) (continued).

Park Subunit / Site Name	ScientificName	Quantitative Abundance	Categorical Abundance		
			Unusual	Present	Numerous
Promenade Marsh	Anax junius	1	X		
	Enallagma civile	8	X		
	Ischnura hastata	3	X		
	Ischnura verticalis	2	X		
	Pantala hymenaea	1	X		
	Tamea carolina	1	X		
	Tamea lacerata	1	X		
Miller Field					
Dune/Beach	Anax junius	21			X
	Celithemis eponina	1	X		
	Celithemis fasciata	4	X		
	Enallagma civile	1	X		
	Epiaeschna heros	1	X		
	Ischnura hastata	4		X	
	Ischnura verticalis	1	X		
	Lestes disjunctus australis	1	X		
	Libellula needhami	5		X	
	Libellula pulchella	28			X
	Libellula semifasciata	4	X		
	Pachydiplax longipennis	48			X
	Pantala flavescens	18			X
	Pantala hymenaea	21			X
	Tamea lacerata	51			X
Miller Field Field	Pantala hymenaea	4			
	Tamea lacerata	12			X

Appendix I.

Photographs of two rare odonate species found at Gateway National Recreation Area, New York and New Jersey, during 2004-2005.

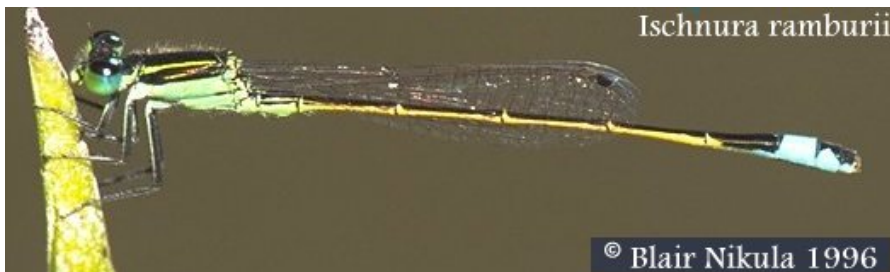
Photographs are used by permission from Blair Nikula. Needham's skimmer was found in 2004 and 2005, and is ranked by the New York Natural Heritage Program (NYNHP) as an S2S3¹ species (NYNHP 2003). Rambur's forktail was also found in during both years and is listed by the NYNHP with a ranking of S2² (NYNHP 2003). Both species have a global ranking of G5³.



Male Needham's skimmer (*Libellula needhami*)



Female Needham's skimmer (*Libellula needhami*)



Male Rambur's Forktail (*Ischnura ramburii*)



Female Rambur's Forktail (*Ischnura ramburii*)

¹S2: "Typically 6 to 20 occurrences, few remaining individuals, acres, or miles of stream, or factors demonstrably making it very vulnerable in New York State" (NYNHP 2003).

²S3: "Typically 21 to 100 occurrences, limited acreage, or miles of stream in New York State" (NYNHP 2003).

³G5: "Demonstrably secure globally, though it may be quite rare" (NYNHP 2003).

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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National Park Service
U.S. Department of the Interior



Natural Resource Program Center
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov