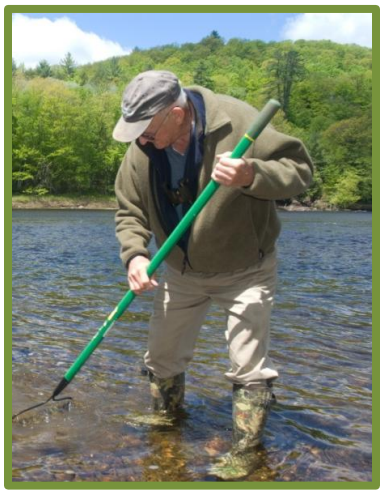
The New York Dragonfly and Damselfly Survey

2005-2009

Distribution and Status of the Odonates of New York

By
Erin L. White
Jeffrey D. Corser
Matthew D. Schlesinger



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625 Broadway, 5th Floor Albany, NY 12233-4757 (518) 402-8935 Fax (518) 402-8925 www.nynhp.org

New York Natural Heritage Program

Table 4. Sampling effort and estimated species richness for New York's Level III ecoregions.

Ecoregion	No. surveys	No. species detected	Lower bound	Upper bound	No. species estimated	Percent of expected species detected
Great Lakes	622	125	114.9	135.1	120.2	104%
High Allegheny Plateau	585	129	121.9	136.1	129.9	99%
Lower New England - Northern Piedmont	1389	151	141.5	160.5	150.7	100%
North Atlantic Coast	565	93	79.0	107.0	92.1	101%
Northern Appalachian - Acadian	843	133	129.6	136.4	135.6	98%
St. Lawrence - Champlain Valley	228	100	92.0	108.0	109.1	92%
Western Allegheny Plateau	115	54	48.5	59.5	60.6	89%

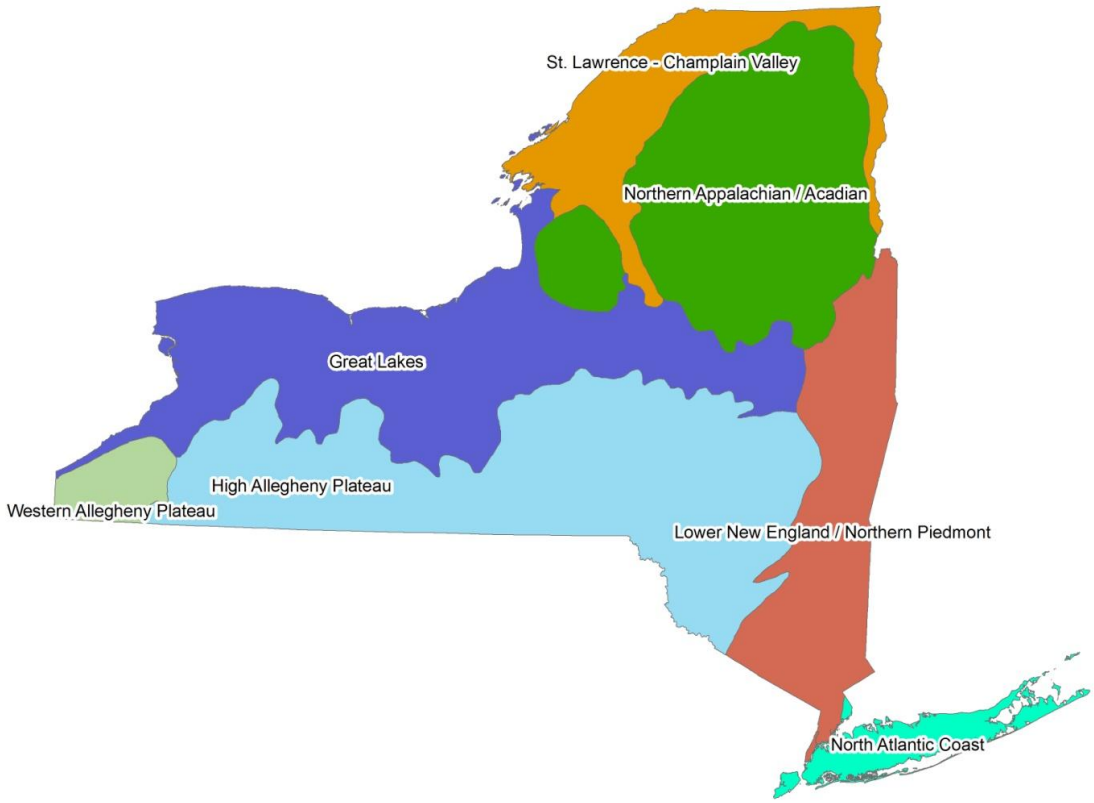

Figure 9. Ecoregions of New York.

This document contains significant contributions from

Paul G. Novak

Cover photos: Clockwise from top left: Common Green Darner (*Anax junius*), perched, Jeremy Martin 2008. Ebony Jewelwings (*Calopteryx maculata*) in the "wheel" mating position, Jeremy Martin 2006; Calico Pennant (*Celithemis elisa*), Stephen Diehl and Vici Zaremba 2008; Nick Donnelly sampling for larvae, Stephen Diehl and Vici Zaremba 2008; Exuvia (dragonfly skin), Stephen Diehl and Vici Zaremba 2008; Variable Dancer (*Argia fumipennis violacea*), Jeremy Martin 2008; Student with dragonfly at North Fork Audubon Center Dragonfly Day, Annette Oliveira 2008

Executive Summary

The New York Dragonfly and Damselfly Survey (NYDDS) began in 2005, spanned five field seasons through 2009, and relied heavily on citizen scientists to help collect data over a large geographic area. Its primary goal was to document the current distribution of all odonate species in New York State. This cooperative project between the New York State Department of Environmental Conservation (NYSDEC), Division of Fish, Wildlife and Marine Resources, and the New York Natural Heritage Program was funded through New York State Wildlife Grant T-2-1 in cooperation with the U.S. Fish and Wildlife Service Division of Wildlife and Sport Fish Restoration. Survey efforts were directed toward under-surveyed regions, areas with potential high diversity, and locations with potential for harboring Species of Greatest Conservation Need (SGCN).

NYDDS volunteers were trained at workshops held throughout the state during the summers of 2005-2007. The training was designed for beginners from all walks of life and focused on basic odonate biology, taxonomy, and identification, as well as field capture and specimen preservation techniques. Nearly 300 people were trained at these workshops, some of whom were NYSDEC or NY Natural Heritage staff. We focused most of our survey efforts on adults rather than larvae due to their relative ease of identification. Surveys were completed from April through October in or near aquatic breeding habitats such as lakes, ponds, bogs and fens, rivers and streams, marshes, swamps, and forest seeps. Wooded areas and fields near aquatic habitats were also fruitful survey sites, as adults use these areas to mature, roost, and forage. We took many steps to ensure that data received from volunteers were accurate. Participants were provided with a list that noted, for each species (and in some cases, for each sex) the level of verification necessary for record confirmation (observation, photograph or specimen). These photo and specimen vouchers were verified by odonate experts.

Our five-year sampling effort yielded many important finds. Most notable were five species added to the list of known odonates for the state, bringing the cumulative total to 194 species, one of the highest diversities of any U.S. state. Owing to the efforts of entomologists, odonatologists, and odonate enthusiasts prior to the NYDDS, New York has records extending back to the late 1800s. This existing county distribution information was compiled by odonatologist Thomas “Nick” Donnelly of the Dragonfly Society of the Americas in 1999 and again in 2004. We were unable to confirm the presence of 15 of the 189 Odonata species ever documented in New York by Donnelly, and every one of these species was rare in the state to begin with.

Participants visited over 2,170 survey sites statewide and a total of 4,383 surveys were conducted, including repeat visits. We confirmed over 18,000 individual species records based on our verification protocol. NYDDS yielded 1,111 new county records beyond these pre-existing data. Each county’s documented richness increased by 18 species on average, and we documented at least 75 species in two-thirds of New Yorks’ 62 counties. A list was compiled for each county as well as a distributional map and phenology chart for all 194 species and full species accounts are included for all 48 SGCN. We calculated draft S-ranks for rare species using NatureServe’s Element Rank Calculator and we found that of NY’s 194 odonate species, 26% are likely to be ranked as critically imperiled (S1) or imperiled (S2).

Surveys for the state historical Ringed Boghaunter (*Williamsonia lintneri*) were unsuccessful, but produced leads in the Grafton and Rome areas. We completed at least five group surveys in western NY for the Federally Endangered Hine’s Emerald (*Somatochlora*

hineana) in appropriate habitat; we did not confirm the species, and it seems unlikely to be present, with the nearest known population occurring in Michigan. Multiple surveys have often been required before the presence of Hine's Emerald was confirmed at new sites discovered in Wisconsin and other states, so future survey work may yet prove fruitful. Surveys for New York's state-threatened damselflies in Suffolk county revealed two new sites for Pine Barrens Bluet (*Enallagma recurvatum*) (previously known from nine ponds), seven new sites for Scarlet Bluet (*Enallagma pictum*) (previously known from three ponds), and The Little Bluet (*Enallagma minusculum*) is known from three locations (two in Suffolk county and one in Queens). These surveys will inform the development of a Recovery Plan for these species. Analyses of survey effort showed that the state was sampled sufficiently to document its odonate fauna. Similarly, each of the state's seven ecoregions was well sampled, while some counties could have used additional survey effort. Such counties where additional survey effort would be most productive were identified and survey effort, ecological and biogeographical explanations were forwarded as possible reasons for the apparent lower species richness in western vs. eastern New York. Since odonates are noted indicators of water quality, biodiversity, and ecological change, our findings should help inform future conservation efforts in freshwater habitats. Along with previous distribution information, this report provides baseline information on the distribution and status of odonates in New York against which to measure future change. Much like the 2000-2005 Breeding Bird Atlas followed up on the 1980-1985 Atlas, leading to some highly informative analyses of distributional shifts, we hope that in the future this survey effort will be similarly revisited to assess shifts in odonate distributions. Monitoring of this sort may be the only way to know whether we are maintaining New York's dragonfly and damselfly biodiversity in the face of continuing global change.

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Introduction

Background

Variable Dancer (*Argia fumipennis violacea*) by Wayne Jones

In recent years there has been a slow but steady growth in the popularity of the study of various insect groups, beginning with butterflies, and more recently, dragonflies. The recent interest in dragonflies began in the early 1990s, spurred in part by the publication of the first field guides to these fascinating insects.

New York State began receiving funding from a new federal funding source, the State Wildlife Grants Program, in 2003. A required element for this funding is the development of a New York State Comprehensive Wildlife Conservation Strategy (CWCS), complete with a discussion of actions needed for species designated as "Species of Greatest Conservation Need" (SGCN). Given our incomplete knowledge of the status of dragonflies and damselflies in New York State, the increasing public interest in these insects, and the need to develop the Comprehensive Wildlife Conservation Strategy, the timing was right for beginning a formal statewide survey of the dragonflies and damselflies of New York State. In the first year of funding under State Wildlife Grants, such a survey was selected.

The New York Dragonfly and Damselfly Survey (NYDDS) began in 2005 under the coordination of Paul Novak and spanned five field seasons through 2009. Erin White coordinated the project from November of 2006 through 2010. The project officially ended on March 31, 2010 with the compilation of this report. The records for the NYDDS were in part from NY Natural Heritage staff and contractors, but the majority came from trained volunteers. The results of the New York Dragonfly and Damselfly Survey have been summarized below for use by conservation biologists, planners, and odonate enthusiasts. The information gained as a result of this survey will be important in the development of Comprehensive Wildlife Conservation Strategy with respect to the conservation of these insects. Information on new locations for SGCN will help to guide conservation activities beneficial to those species and prevent harmful manipulations of their habitats.

The New York Dragonfly and Damselfly Survey was a project of the New York State Department of Environmental Conservation (NYSDEC), Division of Fish, Wildlife and Marine Resources, and the New York Natural Heritage Program (NYNHP). Funding for the NYDDS is through New York State Wildlife Grant T-2-1 in cooperation with the U.S. Fish and Wildlife Service Division of Wildlife and Sport Fish Restoration.

Project Objectives

The main project objective was to document the distribution of all odonate (dragonfly and damselfly) species occurring in New York, by building upon existing county distribution information previously compiled by world reknowned odonatologist Thomas "Nick" Donnelly (Donnelly 1992, 1999, 2004a) of the Dragonfly Society of the Americas. A second, related

objective was to direct intensive survey efforts to selected habitats, particularly the habitats that support those SGCNs.

Two additional project objectives included evaluating the relative abundance of three state Threatened damselfly species at sites on Long Island and surveying some areas with the potential to support the federally listed Hine's emerald dragonfly (*Somatochlora hineana*).

While this project had no specific education objective, we expected the New York Dragonfly and Damselfly Survey to foster public interest in the conservation of dragonflies, damselflies, and the aquatic habitats on which they depend. Finally, as all dragonflies and damselflies are aquatic in their immature stages, they can provide important information on water-quality issues that are matters of public concern.

Methodology

Survey Design

Due to the efforts of entomologists, odonatologists, and odonate enthusiasts prior to the NYDDS, New York has odonate records that extend back to the late 1800s (Needham 1928). Odonatologist Nick Donnelly compiled and published The Dragonflies and Damselflies of New York in 1992 and 1999 which summarized county, phenology, and observational information for each odonate species recorded in the state (Donnelly 1992, 1999). Donnelly verified museum records and compiled data from museums and individuals to complete these lists as well as published The Distribution of North American Odonata in 2004 as part of his dot map project, which documented county-level distributional information throughout species' ranges in North America (Donnelly 2004b,c,d, Abbott 2010). Many of the New York records were from years prior to 1990, and in many cases, much earlier. Participants were encouraged to survey close to home as well as in targeted locations, as new or interesting finds were possible anywhere in the state.

Unlike some other Atlas projects, like the New York State Breeding Bird Atlas (NYSBBA; McGowan & Corwin 2008), volunteers were not assigned sites or blocks, but allowed to choose survey sites themselves. This approach facilitated recruitment of a much smaller potential volunteer base of unknown size. (For comparison, birding is the most popular form of wildlife watching. The NYSBBA had over 1,200 volunteers [McGowan & Corwin 2008] who were skilled birders at the beginning of the project.) Many volunteers were more comfortable participating when allowed to travel short distances and choose their own survey sites. Further, odonate habitat is not distributed as uniformly across the landscape as that for other taxa. Odonates have aquatic larvae and adults of most species stay close to water; to some degree the distribution of effort expended to survey odonates must match the distribution of aquatic ecosystems. While this survey design yielded somewhat uneven coverage across the state (see Survey Effort, page 12) we attempted to fill the most egregious geographic holes with targeted surveys (described below).

There had been Atlas efforts for odonate fauna in other states in recent years to model our work after, including the the Ohio Odonata Survey, Maine Dragonfly and Damselfly Survey, New Jersey Odonata Survey (The Ohio Odonata Survey 2005, Brunelle & deMaynadier 2005, Bangma & Barlow 2010). At the onset of the NYDDS, survey designs and protocols from these and other surveys, as well as expert opinion, were consulted and built upon for implementation in New York.

Trained participants were asked to follow one of three strategies for their survey work: 1. Frequent visits to a small number of sites close to home, 2. Visits to habitats supporting particular species or species groups, and 3. Visits to a wide variety of habitats in counties with few species recorded as of 2004. We suggested that volunteers concentrate their efforts in or near aquatic habitats such as lakes, ponds, bogs and fens, rivers and streams, marshes, swamps, and forest seeps since these are the larval habitats of odonates and where many adults can be observed breeding. Wooded areas and fields near aquatic habitats were also fruitful survey sites, as adults use these areas to mature, roost, and forage. We focused most of our efforts on surveying for adults rather than larvae due to the ease of identification of the adult form compared to the larvae. We did provide training to participants in larval sampling and tank rearing of larvae to adult form (for ease and confirmation of identification) before our last field season and emphasized the collection of dragonfly exuviae during the last few years of the survey in order to gain more records for elusive riverine species. An exuvia is the skin left behind when an adult emerges from the water and metamorphoses into adult form and can be identified by experts to species level. These are generally found on shorelines, emergent vegetation, rock, or human structures like bridge abutments at aquatic habitats. While the primary goal of the project was to document the current distribution of all odonate species in New York State, secondary goals guided survey work as well. Special efforts were made to direct survey efforts to regions that were previously under-surveyed, areas with potential to hold great diversity of species, as well as the following habitats that offered the greatest potential for new locations for SGCNs (Appendix I):

- Large rivers and streams
- Small, low gradient forest streams
- Seepages and rivulets that feed into streams and gorges
- Bogs/fens, bog ponds, and small streams within bogs
- Lakes and ponds with abundant water lilies
- Lakes at higher elevations (principally Adirondacks and Catskills)
- Brackish marshes, ponds and lakes (these are principally on Long Island)
- Coastal plain ponds and lakes (these are only on Long Island)

Exuvia, by Stephen Diehl and Vici Zaremba 2008

These goals became a way to streamline our efforts during the last two years of the survey, when we held several "county busters" and group survey efforts for specific purposes as well as directed individual survey efforts for SGCN.

Survey work was completed from 2005-2009 during the months of April through October. Odonates actually spend most of their lives in the water, as larvae, from several months to years, whereas adults survive for a single warm season, usually a month to three months. The earliest odonates in New York emerge in late April or early May (and at least one migratory species, the Common Green Darner [*Anax junius*] can be seen earlier) and die by July after completing their flight season. Others will not emerge until August and can fly into October or November, even surviving early frosts. Therefore, surveyors were encouraged to visit sites multiple times throughout the season (approximately once in early to mid-June, once in mid to late July, and once in mid-August to mid-September) to provide the most comprehensive list of

odonate species that could be present at a site. In addition, certain sites were targeted for survey work to coincide with emergence or appearance of certain taxa. For instance, for targeted survey work on Snaketails (*Ophiogomphus* spp.), timing our searching for emerging adults and exuviae on rivers and streams in early June proved most productive.

Volunteers were advised to time surveys for mid-morning through late afternoon, with specific recommendations for some species like those of the genera *Aeshna* and *Somatochlora* with peaked activity in the evening during feeding swarms. Species of another genus, *Neurocordulia*, were sought with surveys timed at dusk for adult activity, while their exuviae and emerging adults were sought in early morning hours and during the day.

We also completed targeted group work, especially in the last years of the survey. In an attempt to survey under-represented areas of the state, groups of trained volunteers were organized to target specific areas of the state during a one or two-day stretch in field season. Generally, the groups would either split off into small groups and go to separate sites, or the large group would visit several locations for shorter periods throughout the day. Such locations included Ontario and Yates counties in the Finger Lakes region, Delaware and Otsego (which yielded two new county records for Otsego County and 12 new county records for Delaware County), and smaller groups headed to Wyoming, Orleans, Erie, and Lewis counties in 2008. Fulton, Herkimer, and Chenango counties were surveyed with group efforts in 2009.

The Northeastern meeting of the Dragonfly Society of the Americas was held in Malone, New York on June 26-29, 2008, led by Jan Trybula and Erin White. There were at least 40 people in attendance and 66 odonate species were found over two days of field surveys in bogs in the Adirondack Park as well as river habitats in Robert Moses State Park.

In May of 2009, a Spring Event was held near Albany to serve as a kick-off for the final field season and as an opportunity to thank volunteers for their participation in the Survey. Some preliminary results were presented and great finds were highlighted, but species and areas of the state that had been under-represented in the Survey were also discussed and participants signed up to survey the final summer to address those needs.

Volunteer Recruitment

Volunteers played an integral role in the success of the NYDDS. This statewide project relied heavily on its citizen scientists to help collect information on dragonfly and damselfly distribution over a large geographic area. Staff and funds for contractors were limited and New York State is a large area to survey; therefore, a volunteer network overseen with high standards of data quality allowed data to be collected at a scale far beyond what NY Natural Heritage and DEC alone could have accomplished. We simply could not have done it without them!

NYDDS Workshop, by Matt Schlesinger 2007

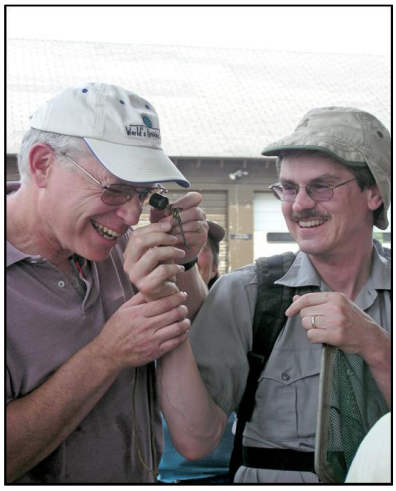
As with many citizen science projects, NYDDS did not require participants to have a scientific background or specialized experience; NYDDS Advisors provided the aforementioned training in odonate biology and survey methodology needed to get volunteers started. Depending on individual motivation and time available, each volunteer continued their scientific education and engagement with the project at

a pace that was right for them. NYDDS volunteers were trained in weekend workshops held in each region of the state during the summers of 2005-2007. The training was designed for beginners from all walks of life and focused on basic odonate biology, taxonomy, and identification, as well as capture (with a field component) and specimen preservation techniques. Nearly 300 people were trained at these workshops, some of whom were NYS DEC or NY Natural Heritage staff. Volunteers were provided with an NYDDS Handbook for Workers that covers similar material to that presented here, but in greater depth, as well as a list of all species expected to occur in New York (White 2007). The Handbook included information on selecting places to survey, when to conduct surveys, the information that needed to be collected during a survey, and how to record and report the data gathered. Experts were available in each region of New York to help volunteers select appropriate survey sites and answer their questions. While we did not train additional volunteers during the last two years of the survey, our large existing volunteer base continued to provide both important records to the database and a vital source of enthusiasm for continued study of New York's dragonflies and damselflies.

Survey Protocol

Volunteers followed standardized protocols for reporting data from the NYDDS surveys. They filled out Survey Site Visit Forms (Appendix II) with the following minimum required fields: site name, county, additional site location directions, observers, and date. Ideally, records were submitted on these paper forms or in an electronic version of the NYDDS database and contained locational, temporal, habitat, species, abundance, and behavioral information. Because the identification of selected species required careful examination under a microscope, observers were asked to collect single voucher specimens or, for other selected species, take close-up photographs.

NYDDS took many steps to ensure that data received from volunteers were accurate. Participants were provided with a list that noted, for each species (and in some cases, for each sex) the level of proof of identification necessary to verify a single observation. The acceptable levels of identification, in order of increasing identification difficulty, were Observation (OBS), Photo (PHOT—often specifying exactly what features should be photographed), and Specimen (SPEC) (Appendix I). The photo and specimen vouchers submitted with datasheets were verified by odonate experts. Nick Donnelly, Paul Novak, and Erin White reviewed adult specimens for the project. Dennis Paulson, Jan Trybula, Nick Donnelly, Paul Novak, and Erin White reviewed photos for the project, and most exuviae were identified by Virginia Brown. Paul Brunelle and Ken Tennessen also provided exuviae identification and Fred Sibley and Skip Blanchard were also experts on the project. Each fall, participants submitted data to NY Natural Heritage Program for processing into a Microsoft Access database. Following data processing and quality control, specimens were deposited in the odonate collection at the New York State Museum to provide permanent location records for each species. While specimens may have been required for species that are more difficult to identify, ethical considerations were emphasized. As insects, odonates have high reproductive rates and typically occur as large populations in the places where they are found. However,



Paul Novak holding a dragonfly for Al Hicks to examine, photographer unknown

participants were asked to keep collection to a minimum, and follow the protocol outlined in Appendix I, collecting only for species where a specimen voucher was required or identification was not possible in the field or with photos. Participants were also encouraged to follow the Collection Policy and Guidelines adopted by the Dragonfly Society of the Americas (Mauffray 2008). Specimen labels were provided to volunteers so that appropriate information could accompany specimens for data entry and museum deposition.

Other information provided to volunteers included a document highlighting regions, habitats, and species needing attention which included species that had not been recorded in the state as of 2004. In addition, the NYDDS provided letters to the volunteers that summarized the project with contact information for NY Natural Heritage staff to assist in gaining access to properties and informing others encountered on their surveys. In general, NYSDEC and staff as well as staff of The Nature Conservancy were informed of the project's survey goals, but it was left up to the individual volunteers to obtain permission to access private lands from the landowner prior to surveys. Participants were encouraged to contact NYSDEC staff prior to visits to state lands to inform them of activities that could involve collection. In addition, recommended field guides and materials were listed as well as contact information for DEC regional staff and NYDDS regional experts. Volunteers were also asked to report their hours and mileage on effort forms to demonstrate the match component requirement of the SWG funding that supported the project.

Final Results

Highlights

Our five-year odonate sampling effort in New York State yielded many excellent finds. Most notable, were five species added to the list of known odonates for the state, bringing the total to 194 species of dragonflies and damselflies known from New York (Table 1). There were 189 species of dragonflies and damselflies listed for the state prior to the NYDDS (Donnelly 2004a). The five species that had not been documented in New York before are Double-ringed Pennant (*Celithemis verna*) found by Virginia and Charles Brown in Suffolk county, Horned Clubtail (*Arigomphus cornutus*) found by Jan Trybula and Adam Simmons in St. Lawrence county, Broadtailed Shadowdragon (*Neurocordulia michaeli*) adults found by Jeff Corser in Delaware County, Four-spotted Pennant (*Brachymesia gravida*) found by Annette Oliveira in Suffolk county, and Zigzag Darner (*Aeshna sitchensis*) found by Kevin Hemeon in Warren county.

Horned Clubtail (*Arigomphus cornutus*), by Jan Trybula

NYDDS participants visited over 2,170 survey sites statewide, many of which were visited more than once. This level of effort yielded 1,111 new county records when compared to data compiled by Nick Donnelly, which is available electronically at the Odonata Central website and highlighted as the Dot Map Project (Donnelly 2004a, Abbott 2010). This total includes less than 20 hybrid records for *Sympetrum* and other taxa which were documented for the first time in specific counties. A full county list may be viewed in Appendix III, which lists

odonate species alphabetically by scientific name and shows whether species were documented pre-NYDDS, and/or during NYDDS, and highlights new county records. As described in the Methodology, photographic and specimen vouchers were used to confirm records for certain species (Appendix I). We were able to verify over 18,000 individual species records based on our protocol, either by accepting the record as confirmed by observation, or verifying the record with a photo, exuvia, or adult specimen. There were 9,114 vouchers submitted, most of which (8,665) were verified to the species level. In total, the NYDDS records were comprised of 2,041 photos, 6,115 adult specimens, and at least 760 exuviae with confirmed identifications by odonate experts. In some cases, multiple specimens, photos, or exuviae submitted for a species at a site counted as a single record. As aforementioned, larval collection was not the focus of the NYDDS, but some participants reared larvae in tanks to adult form to confirm identification. There were 35 verified larval records submitted during the project.

Table 1. All odonates known for New York State, listed alphabetically by scientific name. Species only known from pre-NYDDS data are followed by "pre." Species new to the state as a result of the NYDDS are indicated with "new."

Species	Common name	
Aeshna canadensis	Canada Darner	
Aeshna clepsydra	Mottled Darner	
Aeshna constricta	Lance-tipped Darner	
Aeshna eremita	Lake Darner	
Aeshna interrupta	Variable Darner	
Aeshna sitchensis	Zigzag Darner	new
Aeshna subarctica	Subarctic Darner	
Aeshna tuberculifera	Black-tipped Darner	
Aeshna umbrosa	Shadow Darner	
Aeshna verticalis	Green-striped Darner	
Amphiagrion saucium	Eastern Red Damsel	
Anax junius	Common Green Darner	
Anax longipes	Comet Darner	
Archilestes grandis	Great Spreadwing	
Argia apicalis	Blue-fronted Dancer	
Argia bipuctulata	Seepage Dancer	pre
Argia fumipennis violacea	Variable Dancer	
Argia moesta	Powdered Dancer	
Argia tibialis	Blue-tipped Dancer	
Argia translata	Dusky Dancer	
Arigomphus cornutus	Horned Clubtail	new
Arigomphus furcifer	Lilypad Clubtail	
Arigomphus villosipes	Unicorn Clubtail	
Basiaeschna janata	Springtime Darner	
Boyeria grafiana	Ocellated Darner	
Boyeria vinosa	Fawn Darner	
Brachymesia gravida	Four-spotted Pennant	new
Calopteryx aequabilis	River Jewelwing	
Calopteryx amata	Superb Jewelwing	

Species	Common name	
Calopteryx angustipennis	Appalachian Jewelwing	pre
Calopteryx dimidiata	Sparkling Jewelwing	pre
Calopteryx maculata	Ebony Jewelwing	
Celithemis elisa	Calico Pennant	
Celithemis eponina	Halloween Pennant	
Celithemis fasciata	Banded Pennant	
Celithemis martha	Martha's Pennant	
Celithemis verna	Double-ringed Pennant	new
Chromagrion conditum	Aurora Damsel	
Coenagrion interrogatum	Subarctic Bluet	pre
Coenagrion resolutum	Taiga Bluet	
Cordulegaster diastatops	Delta-spotted Spiketail	
Cordulegaster erronea	Tiger Spiketail	
Cordulegaster maculata	Twin-spotted Spiketail	
Cordulegaster obliqua	Arrowhead Spiketail	
Cordulia shurtleffi	American Emerald	
Didymops transversa	Stream Cruiser	
Dorocordulia lepida	Petite Emerald	
Dorocordulia libera	Racket-tailed Emerald	
Dromogomphus spinosus	Black-shouldered Spinyleg	
Enallagma antennatum	Rainbow Bluet	
Enallagma aspersum	Azure Bluet	
Enallagma basidens	Double-striped Bluet	
Enallagma boreale	Boreal Bluet	
Enallagma carunculatum	Tule Bluet	
Enallagma civile	Familiar Bluet	
Enallagma cyathigerum	Northern Bluet	
Enallagma divagans	Turquoise Bluet	
Enallagma doubledayi	Atlantic Bluet	
Enallagma durum	Big Bluet	
Enallagma ebrium	Marsh Bluet	
Enallagma exsulans	Stream Bluet	
Enallagma geminatum	Skimming Bluet	
Enallagma hageni	Hagen's Bluet	
Enallagma laterale	New England Bluet	
Enallagma minusculum	Little Bluet	
Enallagma pictum	Scarlet Bluet	
Enallagma recurvatum	Pine Barrens Bluet	
Enallagma signatum	Orange Bluet	
Enallagma traviatum	Slender Bluet	
Enallagma vernale	Northern Bluet	
Enallagma vesperum	Vesper Bluet	
Enallagma weewa	Blackwater Bluet	
Epiaeschna heros	Swamp Darner	
Epicordulia princeps	Prince Baskettail	

Species	Common name	
Epitheca canis	Beaverpond Baskettail	
Epitheca cynosura	Common Baskettail	
Epitheca semiaquea	Mantled Baskettail	
Epitheca spinigera	Spiny Baskettail	
Erythemis simplicicollis	Eastern Pondhawk	
Erythrodiplax berenice	Seaside Dragonlet	
Erythrodiplax minuscula	Little Blue Dragonlet	pre
Gomphaeschna antilope	Taper-tailed Darner	
Gomphaeschna furcillata	Harlequin Darner	
Gomphus abbreviatus	Spine-crowned Clubtail	
Gomphus adelphus	Mustached Clubtail	
Gomphus borealis	Beaverpond Clubtail	
Gomphus descriptus	Harpoon Clubtail	
Gomphus exilis	Lancet Clubtail	
Gomphus fraternus	Midland Clubtail	
Gomphus lividus	Ashy Clubtail	
Gomphus quadricolor	Rapids Clubtail	
Gomphus rogersi	Sable Clubtail	
Gomphus septima	Septima's Clubtail	
Gomphus spicatus	Dusky Clubtail	
Gomphus vastus	Cobra Clubtail	
Gomphus ventricosus	Skillet Clubtail	
Gomphus viridifrons	Green-faced Clubtail	pre
Hagenius brevistylus	Dragonhunter	
Helocordulia uhleri	Uhler's Sundragon	
Hetaerina americana	American Rubyspot	
Ischnura hastata	Citrine Forktail	
Ischnura kellicotti	Lilypad Forktail	
Ischnura posita	Fragile Forktail	
Ischnura prognata	Furtive Forktail	pre
Ischnura ramburii	Rambur's Forktail	
Ischnura verticalis	Eastern Forktail	
Ladona deplanata	Blue Corporal	
Ladona exusta	White Corporal	
Ladona julia	Chalk-fronted Skimmer	
Lanthus parvulus	Northern Pygmy Clubtail	
Lanthus vernalis	Southern Pygmy Clubtail	
Lestes australis	Southern Spreadwing	
Lestes congener	Spotted Spreadwing	
Lestes disjunctus	Common Spreadwing	
Lestes dryas	Emerald Spreadwing	
Lestes eurinus	Amber-winged Spreadwing	
Lestes forcipatus	Sweetflag Spreadwing	
Lestes inaequalis	Elegant Spreadwing	
Lestes rectangularis	Slender Spreadwing	

Species	Common name	
Lestes unguiculatus	Lyre-tipped Spreadwing	
Lestes vigilax	Swamp Spreadwing	
Leucorrhinia frigida	Frosted Whiteface	
Leucorrhinia glacialis	Crimson-ringed Whiteface	
Leucorrhinia hudsonica	Hudsonian Whiteface	
Leucorrhinia intacta	Dot-tailed Whiteface	
Leucorrhinia proxima	Red-waisted Whiteface	
Libellula auripennis	Golden-winged Skimmer	
Libellula axilena	Bar-winged Skimmer	
Libellula cyanea	Spangled Skimmer	
Libellula flavida	Yellow-sided Skimmer	
Libellula incesta	Slaty Skimmer	
Libellula luctuosa	Widow Skimmer	
Libellula needhami	Needham's Skimmer	
Libellula pulchella	Twelve-spotted Skimmer	
Libellula quadrimaculata	Four-spotted Skimmer	
Libellula semifasciata	Painted Skimmer	
Libellula vibrans	Great Blue Skimmer	
Macromia illinoiensis	Illinois River Cruiser	
Nannothemis bella	Elfin Skimmer	
Nasiaeschna pentacantha	Cyrano Darner	
Nehalennia gracilis	Sphagnum Sprite	
Nehalennia integricollis	Southern Sprite	
Nehalennia irene	Sedge Sprite	
Neurocordulia michaeli	Broadtailed Shadowdragon	new
Neurocordulia obsoleta	Umber Shadowdragon	
Neurocordulia yamaskanensis	Stygian Shadowdragon	
Ophiogomphus anomalus	Extra-striped Snaketail	
Ophiogomphus aspersus	Brook Snaketail	
Ophiogomphus carolus	Riffle Snaketail	
Ophiogomphus colubrinus	Boreal Snaketail	pre
Ophiogomphus howei	Pygmy Snaketail	
Ophiogomphus mainensis	Maine Snaketail	
Ophiogomphus rupinsulensis	Rusty Snaketail	
Pachydiplax longipennis	Blue Dasher	
Pantala flavescens	Wandering Glider	
Pantala hymenaea	Spot-winged Glider	
Perithemis tenera	Eastern Amberwing	
Plathemis lydia	Common Whitetail	
Progomphus obscurus	Common Sanddragon	
Rhionaeschna mutata	Spatterdock Darner	
Somatochlora albicinta	Ringed Emerald	pre
Somatochlora cingulata	Lake Emerald	
Somatochlora elongata	Ski-tailed Emerald	
Somatochlora forcipata	Forcipate Emerald	

Species	Common name	
Somatochlora franklini	Delicate Emerald	
Somatochlora incurvata	Incurvate Emerald	
Somatochlora kennedyi	Kennedy's Emerald	pre
Somatochlora linearis	Mocha Emerald	
Somatochlora minor	Ocellated Emerald	
Somatochlora tenebrosa	Clamp-tipped Emerald	
Somatochlora walshii	Brush-tipped Emerald	
Somatochlora williamsoni	Williamson's Emerald	
Stylogomphus albistylus	Least Clubtail	
Stylurus amnicola	Riverine Clubtail	pre
Stylurus notatus	Elusive Clubtail	pre
Stylurus plagiatus	Russet-tipped Clubtail	
Stylurus scudderi	Zebra Clubtail	
Stylurus spiniceps	Arrow Clubtail	
Sympetrum corruptum	Variegated Meadowhawk	pre
Sympetrum costiferum	Saffron-winged Meadowhawk	
Sympetrum danae	Black Meadowhawk	
Sympetrum internum	Cherry-faced Meadowhawk	
Sympetrum obtrusum	White-faced Meadowhawk	
Sympetrum rubicundulum	Ruby Meadowhawk	
Sympetrum semicinctum	Band-winged Meadowhawk	
Sympetrum vicinum	Yellow-legged Meadowhawk	
Tachopteryx thoreyi	Gray Petaltail	
Tramea abdominalis	Vermilion Saddlebags	pre
Tramea calverti	Striped Saddlebags	pre
Tramea carolina	Carolina Saddlebags	
Tramea lacerate	Black Saddlebags	
Williamsonia fletcheri	Ebony Boghaunter	
Williamsonia lintneri	Ringed Boghaunter	pre

Survey Effort

Survey Participants

Michael Blust and Nick Donnelly sampling larvae, by Stephen Diehl and Vici Zaremba 2008

Over the project's five years, 341 volunteers registered to participate in the project. This tally includes a small handful of project organizers, NY Natural Heritage and DEC staff, and contractors. Volunteers came from all over the state, with notably high participation in the Adirondacks, Capital region, Hudson Valley, and Lake Ontario and Lake Erie basins (Figure 1). Many volunteers traveled far and wide to conduct surveys, so a map of home zip codes does not represent the distribution of survey sites. Nearly half (156; 45.7%) participated in at least one field survey (Figure 2), not including volunteers whose names were not on site survey forms but who might have contributed specimens because not only registered volunteers participated in surveys. Beyond the 156 registered volunteers who participated, 277 additional named individuals participated in surveys (for a total of 433 unique surveyors at a minimum), plus hundreds more unidentified adults and children in school groups, camp groups, workshops, and college courses. Many of these groups were facilitated by Audubon NY through a grant with the Biodiversity Research Institute. Although many surveyors participated in only a single or a few surveys, many registrants and other volunteers participated in hundreds of surveys (Figure 2).

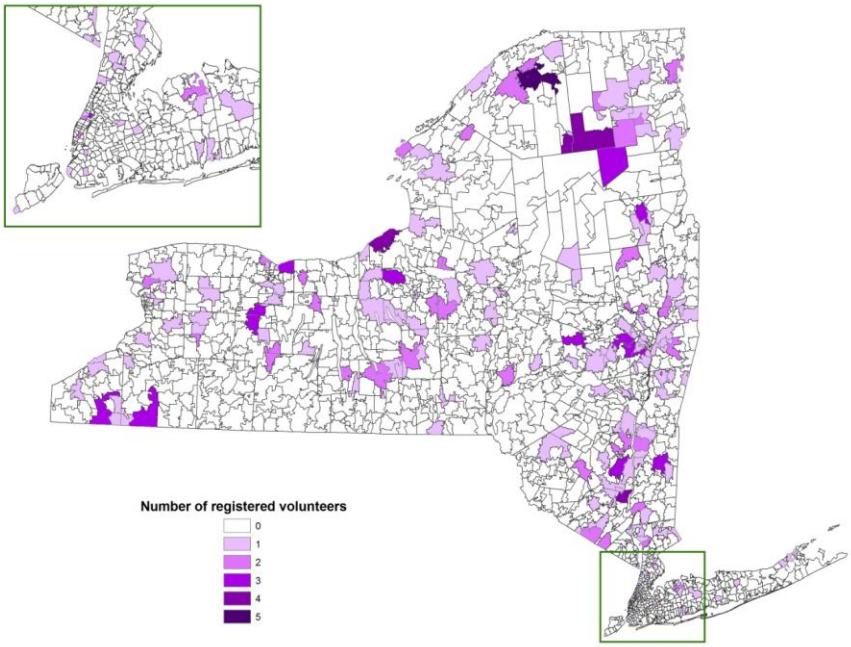


Figure 1. Number of registered NYDDS volunteers by zip code. The New York City metropolitan area is enlarged to show detail.

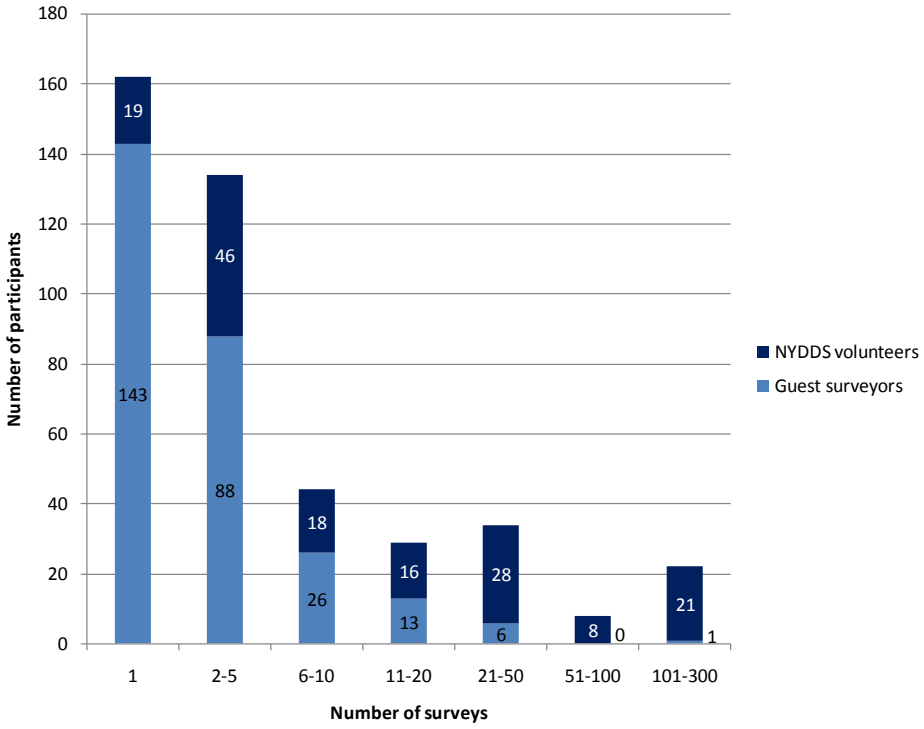


Figure 2. Number of field surveys in which NYDDS volunteers and other surveyors participated from 2005-2009.

Sites Visited and Surveys Conducted

Over 2,170 sites were visited all over New York State (Figure 3). Including repeat visits to the same site on different dates, a total of 4,383 surveys were conducted. (This latter tally does not include sites where specimens were collected but surveys were not reported.) Survey participants visited a wide variety of habitat types: rivers, streams, lakes, ponds, bogs, springs, beaches, and forests (Table 2). Sites were somewhat evenly distributed among lakes and ponds, wetlands (bogs and fens, marshes and swamps), and rivers and streams. Openings visited included trails, roads, railroad beds, fields, and forest gaps. These numbers add up to more than the total number of sites because participants were allowed to choose multiple habitat types per site. For instance, a fen might have had a creek running through it, or a pond might have graded into a marsh. Not every site was given a habitat classification, so these tallies are based on the subset of sites with habitat information (64% of sites). In addition, it should be noted that participants may have had different criteria they used to classify a habitat as bog vs. fen or marsh vs. swamp, so it does make sense for us to speak in generalities by lumping wetland types together for the purposes of discussion. Since surveys in various breeding habitats were somewhat evenly distributed across the broad habitat categories of pond/lake, wetlands, and running water, we can expect that the NYDDS survey effort was about equal across types and that surveys revealed species known to inhabit each type.

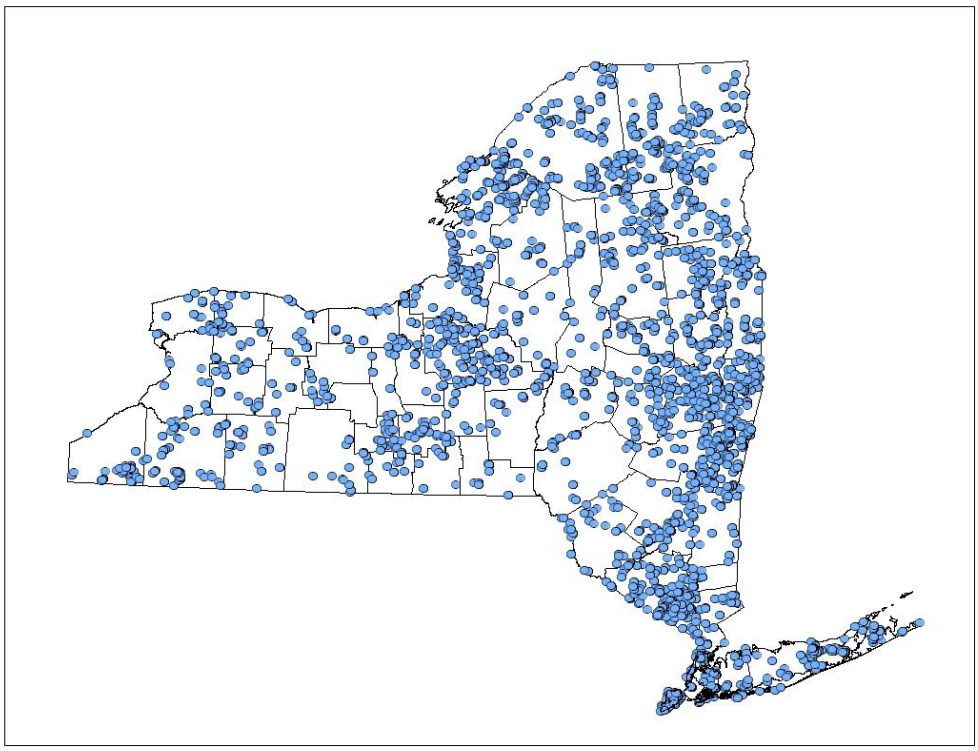


Figure 3. Locations of survey sites visited during the NYDDS.

Table 2. Number of NYDDS sites classified as each of five major habitat types.

Habitat type	Number of sites
Bog/fen	233
Marsh/swamp	665
Pond/lake	1,244
Openings	719
Running water	1,094

Survey effort was lowest in 2005, the first year of the project, but picked up to a solid, steady pace from 2006-2008, with over 1,000 surveys in each year (Figure 4). In 2009, we encouraged a more focused effort from a smaller pool of volunteers so we could specifically target particular species, locations, and habitat types with directed survey. There were still over 600 surveys conducted in 2009. As we would expect, survey effort varied by month. Across years, the large majority (82%) of surveys were conducted in June, July, and August (Figure 5), with the remainder conducted in May and September and a small handful in earlier and later months.

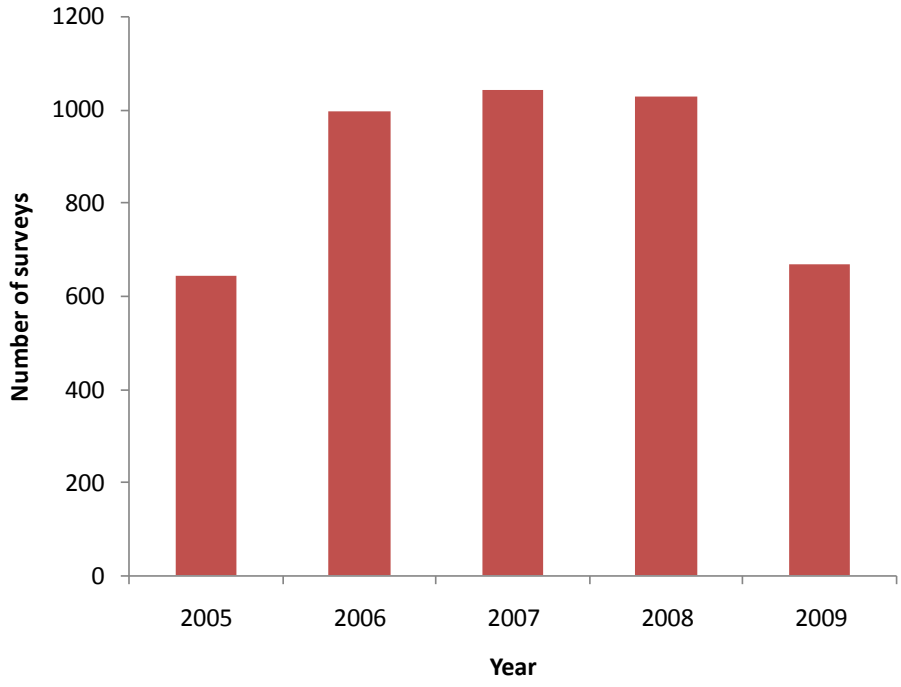


Figure 4. Number of NYDDS surveys by year.

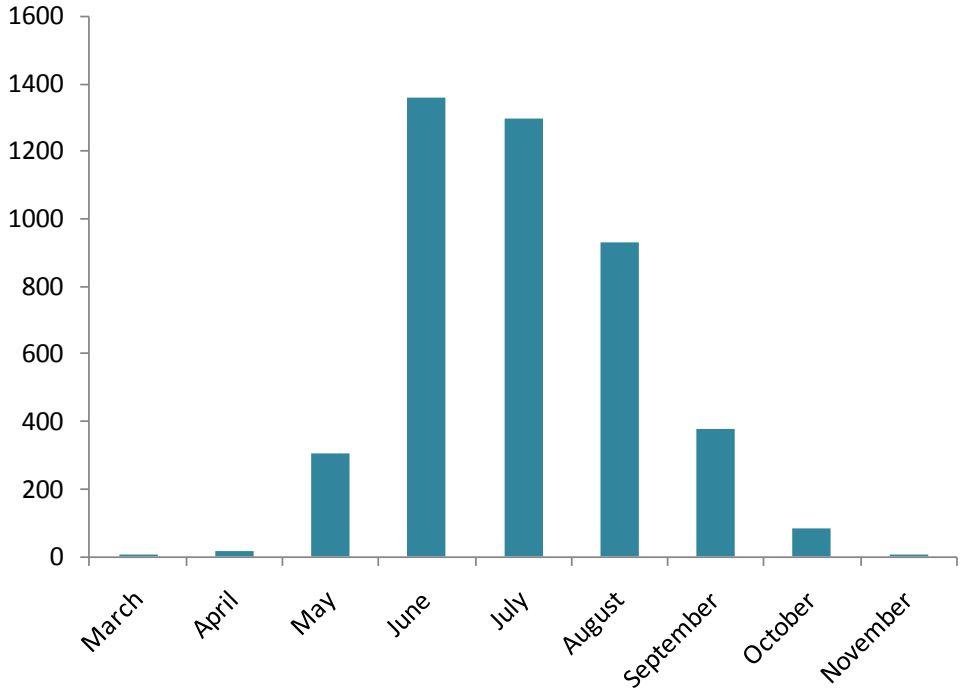


Figure 5. Number of NYDDS surveys by month, compiled across 2005-2009.

How Thoroughly was New York Surveyed?

We were interested in exploring the completeness with which this five-year effort sampled New York State for odonates. We wanted to know how well sampled the state was geographically and by ecoregion. Further, we wanted to know whether the patterns of species detection and species richness we observed were real or artifacts of sampling effort. To address this, we calculated the expected number of species for each county and ecoregion in New York and compared that to the number of species actually detected during the Survey. For this analysis, we removed all detections that were not identified to species. We retained hybrid specimens if both of the two component species were not present in a particular county, but removed them for all other analyses.

We calculated expected species richness through rarefaction (Colwell *et al.* 2004) using the program EstimateS (Colwell 2009). Briefly, the objective of this analysis was to determine the expected number of species given the rate of accumulation over the course of multiple surveys within a sampling unit (county, ecoregion, entire state). The order of surveys was randomized 50 times so that especially productive or unproductive surveys did not drive the pattern of species accumulation. Two main, related, products were generated from these analyses: 1) the total expected number of species; and 2) a curve showing how the number of species accumulated with sampling effort (number of surveys). Dividing the number of species observed (S_{obs} Mao Tau) by the number expected (MMMeans) yielded the percent of expected species detected during the Survey.

Given the rate at which surveys accumulated new species records over the five years of the project, the NYDDS detected approximately the number of species that would be expected for New York State (Table 3). In other words, the NYDDS sampled the state more than sufficiently to enumerate its odonate fauna as expected from the pattern of survey productivity. Note that it does not mean that that new species for New York might not continue to be discovered; as a case in point, when we ran this analysis in early 2009 in preparation for the final field season, we obtained a similar result: that we had sampled the state as a whole sufficiently. But then in 2009 a zigzag darner was documented for the first time in the state. Even though the NYDDS was highly successful in documenting New York's odonate species, more survey effort is bound to unearth exciting new finds.

Table 3 shows how the number of species documented in New York accumulated with increasing sampling effort. Surveys used in this analysis included repeat visits to the same site on different dates, but did not include sites where specimens were collected but surveys were not reported. We included verified (confirmed according to the protocol in Appendix I) as well as unvouchered records (see page 23 for a description of verification). At roughly 1,000 surveys, the curve really starts to "level off," which suggests that the productivity of sampling is slowing down. As noted above, however, additional species continued to be detected, but at a much slower rate.

The state level is not the only geographic region of interest; most of New York's counties were well sampled during the NYDDS. Fifty counties (80%) had at least 70% of their expected species detected during the course of the Survey. Ten counties (16%) had at least 90% of their expected species detected. Five counties (8%) in southern and central New York fell under 50% detection of their expected species; these counties would have required more effort to enumerate the majority of their species. This information is displayed graphically in Figure 7. Those with knowledge of the volunteer base can point to the darker colors as evidence of particularly active volunteers.

Table 3. Sampling effort and estimated species richness for New York State and its 62 counties. The number of species detected includes both verified and unvouchered records.

County	No. surveys	No. species detected	Lower bound	Upper bound	No. species estimated	Percent of expected species detected
Albany	183	89	82.6	95.4	92.3	96%
Allegany	23	42	34.3	49.7	68.9	61%
Bronx	62	29	24.1	33.9	32.3	90%
Broome	17	46	39.7	52.3	90.2	51%
Cattaraugus	107	65	58.9	71.1	77.3	84%
Cayuga	42	39	31.5	46.5	46.5	84%
Chautauqua	190	72	61.5	82.5	72.0	100%
Chemung	10	47	39.7	54.4	105.2	45%
Chenango	18	45	39.1	50.9	83.0	54%
Clinton	65	48	41.7	54.3	68.8	70%
Columbia	228	86	78.4	93.6	87.5	98%

County	No. surveys	No. species detected	Lower bound	Upper bound	No. species estimated	Percent of expected species detected
Cortland	28	47	38.1	55.9	66.8	70%
Delaware	24	53	46.5	59.5	84.9	62%
Dutchess	42	59	49.2	68.8	81.2	73%
Erie	19	26	18.2	33.8	44.5	58%
Essex	205	91	84.1	97.9	107.2	85%
Franklin	190	95	87.9	102.1	106.6	89%
Fulton	38	69	61.4	76.6	99.0	70%
Genesee	69	51	45.2	56.8	65.4	78%
Greene	51	51	42.6	59.4	68.0	75%
Hamilton	92	76	68.6	83.5	93.5	81%
Herkimer	32	56	48.6	63.4	80.9	69%
Jefferson	152	77	71.7	82.3	84.7	91%
Kings	23	21	16.3	25.7	28.0	75%
Lewis	44	64	57.9	70.1	89.0	72%
Livingston	10	29	21.3	36.7	67.3	43%
Madison	97	76	68.5	83.5	84.8	90%
Monroe	16	26	18.7	33.3	50.3	52%
Montgomery	25	57	47.6	66.4	84.9	67%
Nassau	52	48	41.6	54.4	57.3	84%
New York	5	13	6.7	19.3	54.7	24%
Niagara	26	39	32.4	45.6	50.9	77%
Oneida	28	40	33.1	46.9	59.6	67%
Onondaga	135	76	68.9	83.1	77.2	98%
Ontario	17	28	21.3	34.7	41.3	68%
Orange	166	87	80.6	93.4	92.7	94%
Orleans	33	42	37.2	46.8	60.8	69%
Oswego	86	65	60.9	69.1	76.5	85%
Otsego	56	64	55.9	72.1	81.9	78%
Putnam	23	42	35.5	48.5	92.4	45%
Queens	105	33	29.9	36.1	37.3	89%
Rensselaer	244	114	104.7	123.3	128.2	89%
Richmond	129	49	40.7	57.3	50.7	97%
Rockland	175	84	77.1	90.9	85.1	99%
Saratoga	103	85	76.0	94.0	101.8	83%
Schenectady	46	54	46.0	62.0	71.2	76%
Schoharie	38	57	49.0	65.0	80.3	71%
Schuyler	120	87	81.1	92.9	90.1	97%
Seneca	16	38	31.3	44.7	59.7	64%
St Lawrence	192	115	108.1	121.9	131.0	88%
Steuben	12	48	41.2	54.8	88.3	54%

County	No. surveys	No. species detected	Lower bound	Upper bound	No. species estimated	Percent of expected species detected
Suffolk	285	87	80.6	93.4	88.7	98%
Sullivan	43	64	55.6	72.4	105.8	60%
Tioga	10	33	26.5	39.5	69.0	48%
Tompkins	44	56	46.0	66.0	93.4	60%
Ulster	103	85	78.7	91.4	101.4	84%
Warren	113	93	85.8	100.2	111.4	83%
Washington	89	91	83.7	98.3	118.3	77%
Wayne	21	27	18.9	35.1	43.3	62%
Westchester	151	81	76.9	85.1	93.4	87%
Wyoming	30	41	35.0	47.0	59.0	70%
Yates	5	12	9.2	14.8	21.5	56%
New York State	**4803**	**185**	**181.3**	**188.7**	**181.5**	**102%**

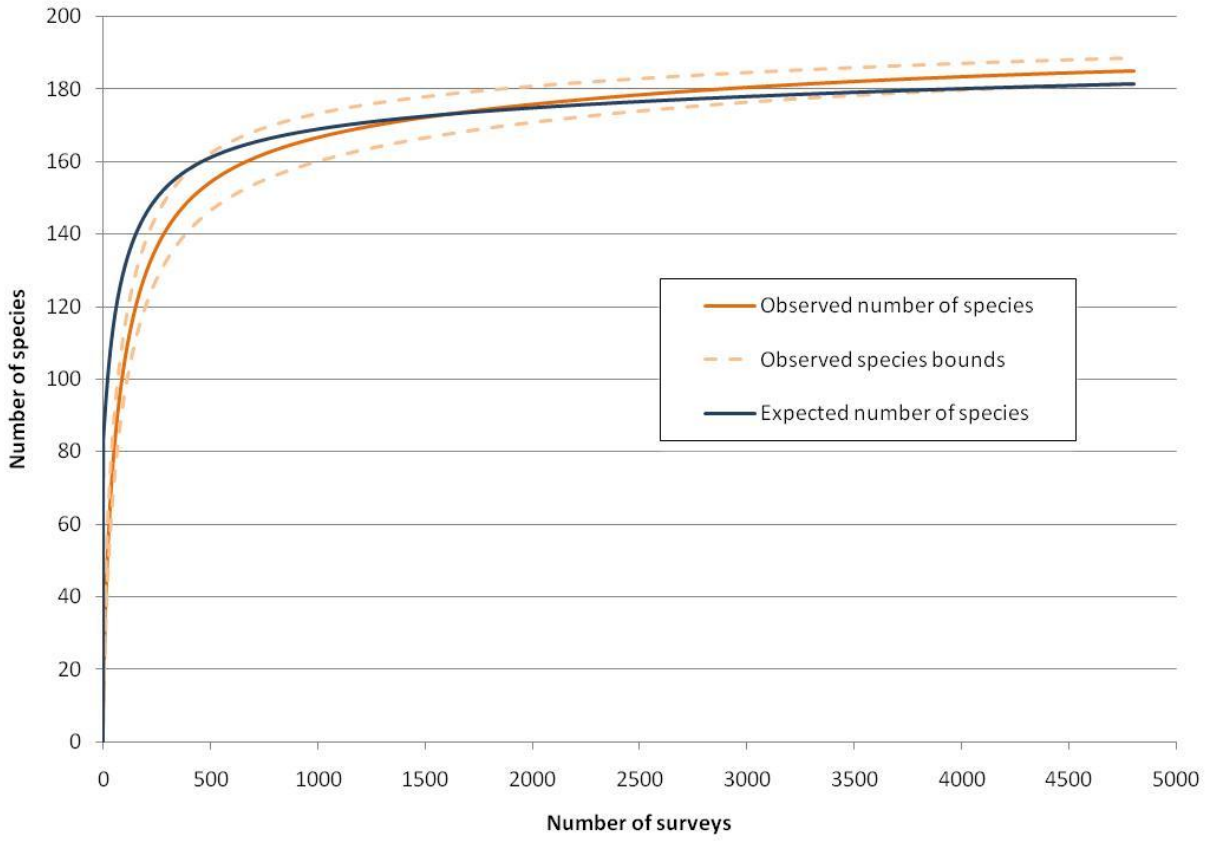


Figure 6. NYDDS species accumulation curve for New York State.

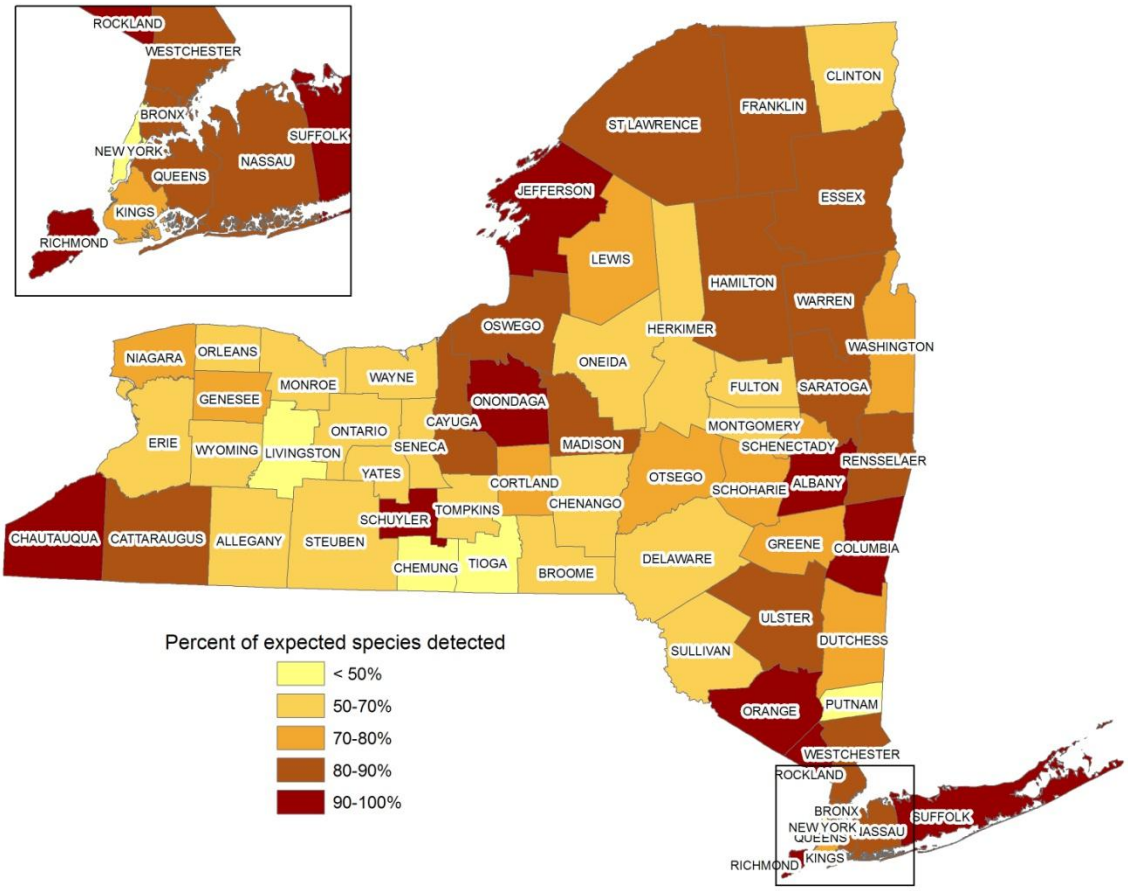


Figure 7. Percent of expected species of odonates detected by county during the five years of NYDDS. The New York City metropolitan area is enlarged to show detail.

Generally speaking, the more surveys in a county, the higher percentage of its expected species were detected (Figure 8). However, in some cases relatively few surveys were needed to detect most of a county's species; for instance, 23 surveys in Kings County were sufficient to detect 75% of its expected species, and 42 surveys in Cayuga County were sufficient to detect 84% of its expected species. By comparison, 205 surveys in Essex County detected 85% of its expected species. The main point is that sampling effort was not perfectly related to how fully a county's odonate fauna was detected. Another pattern depicted in Figure 8 is the increasing expected species richness with increasing numbers of surveys. In theory, there should not be a relationship here; however, increased effort is often put toward counties with richer odonate faunas and counties that are felt to be undersampled. In fact, this was a primary goal of the Survey's final year.

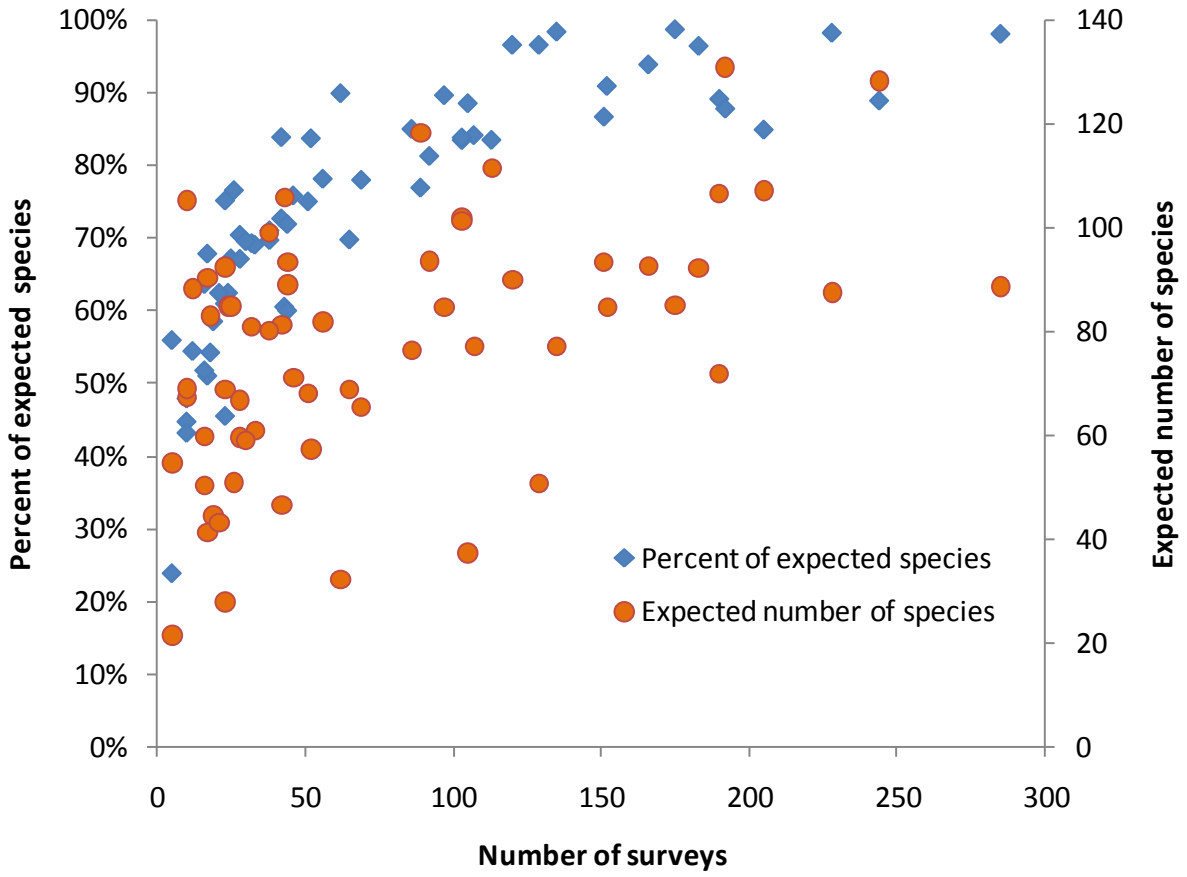


Figure 8. Percent of expected species detected in each county, and expected number of species in each county, as related to the number of NYDDS surveys conducted. Each dot represents a county.

Of greater interest ecologically (or biogeographically) is the sampling sufficiency of different ecological regions of the state, given that they might be expected to have different odonate faunas. So we conducted a similar analysis by "Level III ecoregion," which is The Nature Conservancy's adaptation of Bailey's (1997) ecoregions of the world. Ecoregions are defined as "large areas of the earth's surface that have similarities in faunal and floral composition due to large-scale, predictable patterns of solar radiation and moisture" (Groves *et al.* 2002, after (Bailey 1997). New York intersects seven Level III ecoregions (Table 4; Figure 9) with considerably varying odonate biodiversity. All ecoregions were well sampled, with five ecoregions having 98% or more of their expected species detected, and the Western Allegheny Plateau was the lowest, but still well sampled, at 89%.