



Status and Distribution of Odonates at Cape Cod National Seashore



Common Green Darner (*Anax junius*), freshly emerged adult, Blackwater Pond, Provincetown.
BLAIR NIKULA

Status and distribution of Odonates at Cape Cod National Seashore

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Abstract

Odonates are significant components of most wetland habitats and important indicators of their health. At Cape Cod National Seashore (CACO), we compiled odonate records dating back to the 1980s and, based partly on that data, identified 41 wetland sites for sampling, representing six freshwater habitats (kettle pond, inter-dune pond, dune slack, riparian marsh, vernal pool, and bog). We surveyed these sites for adult odonates during the 2016–2018 field seasons. Ten sites were surveyed all three years (total 19–20 surveys/site); all ten had at least some historical data. The remaining 31 sites were surveyed for one field season, a total of 6–8 times each.

We conducted 391 surveys, recording 53,435 individuals and 74 species (45 dragonflies and 29 damselflies); not all individuals were identified to species. Abundance and species richness varied significantly between habitats. For all individuals recorded, abundance was greatest at vernal pools and kettle ponds. Riparian sites had the lowest abundance. Species richness was highest at kettle ponds, including several species of conservation concern, two listed as Threatened by the state of Massachusetts. Riparian marshes and dune slacks had relatively low richness.

Among the 10 sites surveyed three years, we found significant annual variation in abundance and species richness. There was significant and generally greater between-site variation in abundance within a year than between years at sites. Community analysis found pond depth, habitat type, and presence of predaceous fish were significant factors explaining between-site variation in community composition. Habitats also differed significantly in community composition. Multidimensional scaling showed sites tend to cluster together by habitat type. Vernal ponds have the highest average community similarity to all other habitats (53.5%), with dune slack (52.9%), bog (52.0%) and inter-dune (51.5%) close behind. In contrast, riparian sites (46.3%) and kettle ponds (39.5%) are least similar to other habitats.

Overall, 86 species of odonates have been recorded at CACO, a rich and diverse assemblage reflecting the variety and quality of freshwater habitats present. Although these habitats are relatively well-protected, stressors include climate change, nutrient inflow from adjacent development, road runoff, and trampling of emergent vegetation. A plan for monitoring is beyond the scope of this project. Ideally, it would be best to use the insight into odonate variation obtained from these surveys to develop a monitoring program designed to meet standards of statistical confidence and power currently employed in NPS monitoring programs.

Acknowledgements

Ken Shea conducted many of the field surveys, often assisted by Janet Sisterson; without their volunteer efforts the scope of the project would have been diminished. Mark Faherty of MassAudubon served as administrator for the project and provided many valuable suggestions and insights. Ginger (Carpenter) Brown conducted the first odonate surveys within the park in the 1980's, and her annual reports provided the basis upon which all subsequent work has been built. Ken Shea provided his more recent historical records from the seashore. Several other naturalists provided records, most notably Jackie Sones and Jeremiah Trimble, who accompanied the senior author on many field trips within the park during the 1990's. Thanks are also extended to current and former CACO scientists Stephen Smith, Sophia Fox, and John Portnoy for their help and insights into the ecology of, and threats to kettle pond vegetation. Holly Plaisted created the Microsoft Access database used for data entry and storage. Ginger Brown and Pamela Hunt reviewed the manuscript and provided many suggestions and improvements. Finally, Ginger Brown was instrumental in introducing the senior author and many others to the wonders of dragonflies and damselflies.

Introduction

Odonates (dragonflies and damselflies) are a prominent wildlife group in many freshwater habitats and can be a significant component of invertebrate biomass and species diversity. They spend most of their life as aquatic insects, before transitioning to flying, terrestrial adults at the end of their life cycle, and thus play an important role in the flow of energy within and between freshwater and terrestrial ecosystems. They are sensitive to conditions in their breeding wetland and surrounding uplands, conspicuous in flight over wetlands, and relatively easy to identify, making them potentially valuable for assessing wetland condition and integrity (Bried and Samways 2015, Kutcher and Bried 2014, Oertli 2008, Samways 2008). Their conspicuousness and bold colors also foster public awareness, appreciation, and concern for their conservation (Nikula et al. 2002).

The northeastern USA is a hotspot of odonate diversity and hosts an unusually rich odonate fauna. It is also a region of historic and continuing threats to freshwater ecosystems, with an early history of European colonization and the highest human population densities on the continent (White et al. 2015). Within the Northeast, Cape Cod National Seashore (CACO) encompasses approximately 10,900 ha in the coastal sandplain region, an area that supports a number of unique plant communities and wetland types, such as pitch pine and scrub oak barrens, oak woodlands, maritime shrub land, heathlands, sandplains grasslands, and coastal plain ponds. These plant communities and wetlands are among the highest priorities for conservation in the Northeast, because of the large numbers of endangered, threatened, and special-concern plant and animal species they support (Neill 2007). CACO is the largest protected coastal landscape and area of sand-plain vegetation in New England (Eberhardt et al. 2003) and lies in coastal New England, an area recognized as one of four regions of exceptional conservation significance for odonate biodiversity in North America (Corser et al. 2014).

Cape Cod supports a unique and diverse odonate fauna, attributable to its location at the northern edge of the Atlantic Coastal Plain and the southern limit of recent glaciation, leading to a mix of southern species at their northern limit and northern species at their southern limit (Gibbs and Gibbs 1954, Carpenter 1991). Surveys in the early 1950's recorded 72 species on Cape Cod and failed to record 13 species previously recorded (Gibbs and Gibbs 1954). Multi-year surveys in the 1980's recorded 90 species and failed to find seven recorded earlier in the 20th century (Carpenter (1991). Currently, there are about 102 species reported from Cape Cod, though six of these are "historic" (>75 years; Nikula 2016). Prior to the present study about 80 species had been recorded at CACO (B. Nikula unpublished data, K. Shea unpublished data). The exact totals are uncertain due to taxonomic and/or identification issues for a couple of taxa, and uncertainty over the historical record for at least two species.

In addition to its geographic location and mild climate, another factor contributing to Cape Cod's odonate abundance and diversity is the abundance and diversity of its wetland types. Riparian habitat is quite limited on Cape Cod, but this is compensated for by an abundance of vernal pools, bogs, dune slack wetlands, red maple swamps, and coastal plain ponds that vary in size, depth, and bathymetry. Although there are over 300 coastal plain ponds on Cape Cod, this habitat type is

globally rare and threatened (Sorrie 1994). Threats to coastal plain ponds ultimately result from the boom in development and human recreation that occurred along the coast in the mid to late 20th century, and involve such proximate causes as water level drawdown for municipal water supply; alteration of and continuing impacts to pond shore and littoral zone vegetation for beach development and recreation; alteration of uplands habitats for beach, residential, commercial, and industrial development; pesticides; nutrient enrichment from fertilizers and septic systems; as well as acid and mercury deposition (Sorrie 1994). Given these threats, and the value of coastal plain ponds in supporting many regionally rare and endemic species of odonates, White et al. (2015) considered these ponds to be the most vulnerable habitat type in the Northeast.

Although Cape Cod odonates have been relatively well documented, much of the survey work conducted and resultant literature (e. g., Gibbs and Gibbs 1954, Carpenter 1991) has been on the “Upper Cape” (the basal half of the peninsula from the Cape Cod Canal east to Brewster and Harwich) not the “Outer Cape” (Chatham north to Provincetown), where CACO is located. The odonate work that has taken place at CACO has been limited in scope, generally as a small part of a larger regional survey or study (e. g., Carpenter 1989, 1990, 1991, Gibbons 2001, Gibbons et al. 2002), rather than as a comprehensive, systematic inventory of the park, such as has been done for NPS sites on Long Island, NY (Briggs et al. 2010 a, b, c). In spite of this, a large body of data on CACO odonates was compiled in several forms, including a number of observational databases made over the period 1990–2015 by qualified observers. A preliminary consolidation and review of these data produced over 3280 records representing approximately 80 species, from about 30 wetland sites, as well as several upland sites, sampled intermittently over the 25-year period, although only 13 sites were sampled five or more times during this period. Among the species recorded were several rare, state-listed species, including three Massachusetts Threatened Species: Attenuated Bluet (*Enallagma daeckii*); Pine Barrens Bluet (*Enallagma recurvatum*); and Scarlet Bluet (*Enallagma pictum*). Three additional formerly state-listed species, New England Bluet (*Enallagma laterale*), Comet Darner (*Anax longipes*), and Spatterdock Darner (*Rhionaeschna mutata*), were also present. This historical data suggests that CACO supports a particularly diverse odonate community, especially compared to other nearby coastal National Park Service sites such as Sagamore Hill NHS (22 species), Fire Island NS (27 species), and Gateway NRA (37 species) (Briggs et al. 2010 a, b, c).

Given the dependence of odonates on freshwater habitats and undisturbed adjacent woodlands (Butler and deMaynadier 2008, Carpenter 1990, Corbet 1999, Minot et al. 2020), and the ongoing degradation of some of these habitats by recreational activities and adjacent development, as well as potential impacts from acid and mercury deposition, the park’s ability to protect these habitats requires that the existing information be better organized, and that more current, systematically collected data be obtained to determine the current status of the park’s resident odonates and their habitats.

The goal of this project was to produce a systematic inventory of odonates at CACO, similar in field methods to those conducted at other parks in the Northeast Coastal and Barrier Network (Briggs et al. 2010 a, b, c), but differing in focusing on wetlands used for breeding and feeding, and by sampling each site more intensely over the course of the flight season. We incorporated both “historic”

(defined in this study as pre-2015) data and new data collected as part of this project. The existing historic data was used to identify sites and habitat types in the park known to support rare species and/or high levels of species diversity, and provides, to the extent possible, a basis for comparing present observations with prior. This report tabulates and analyzes observations by species, site, and habitat type, and lists and discusses all the species recorded at CACO in terms of occurrence, distribution, abundance, habitat affinity, degree of specialization, and conservation status. The report also identifies habitat types and sites at CACO that are most important for supporting high levels of odonate diversity and/or rare species and discusses the odonate community at CACO in a regional context, as well as current and potential threats in the seashore to odonates and their habitats. We hope the report will be an important reference for park natural resource management and planning staff in evaluating and mitigating threats to freshwater habitats and will also provide useful information for park interpreters. Associated with this report is an ACCESS database that incorporates all existing data and observations, both historical and those collected during the current surveys.

Administratively, this project was implemented through a cooperative agreement with Massachusetts Audubon Society's Wellfleet Bay Wildlife Sanctuary. Field work was conducted by the senior author, who has been studying odonates since 1990, and local odonate expert Ken Shea, who has been surveying odonates within the park for over a decade. CACO permanent staff provided in-kind services in the planning and facilitation of this project, development of an ACCESS database, and in the coordination and review of reports.

Methods

Overview

Data on adult odonates were collected via standardized sampling over a three-year period, 2016–2018, at 41 permanent or semi-permanent wetland site. These sites include 10 that have significant historic data and/or are of known importance to rare species, plus 31 chosen to provide a more representative sample of odonate habitat types. The 10 “historic” sites were surveyed in each of the three years (3YearSites), for a total of 20 surveys at each site (except 19 surveys at one site). An additional 31 sites were surveyed for one field season (1YearSites), either 2016, 2017, or 2018 (Table 1). Wetland sites surveyed extend the length of the park (Figures 1, 2, 3, 4). Descriptions of each of the 41 wetlands surveyed, including aerial images, photos of the transect area, transect coordinates, and survey results can be found in a supplemental document (Nikula and Cook 2024).

The multi-year data at the 10 3YearSites provide some basis for assessing annual variation in odonate abundance and occurrence, while the 31 additional sites provide a more extensive sampling of wetlands capable of supporting odonate populations. For each sample site, surveys were conducted eight times during the adult flight season (mid-June through mid-September) in 2016 and six times each in 2017 and 2018. At each site, time constrained transect surveys (40-minute long) were conducted along the wetland edge where emergent vegetation is most prevalent and where most adult odonates occur; given differences in topography and vegetation, this resulted in unequal transect lengths surveyed across sites.



Figure 1. Odonate study area in Cape Cod, MA, with survey site locations noted (see Fig. 2 - Fig. 4 for site names and more specific locations). Red = vernal pool; pink = riparian marsh; green = bog; blue = kettle pond; yellow: inter-dune pond; white = dune slack. Cape Cod National Seashore boundary outlined in green. Created using Google maps. Scale bar lower right corner is 3 miles.

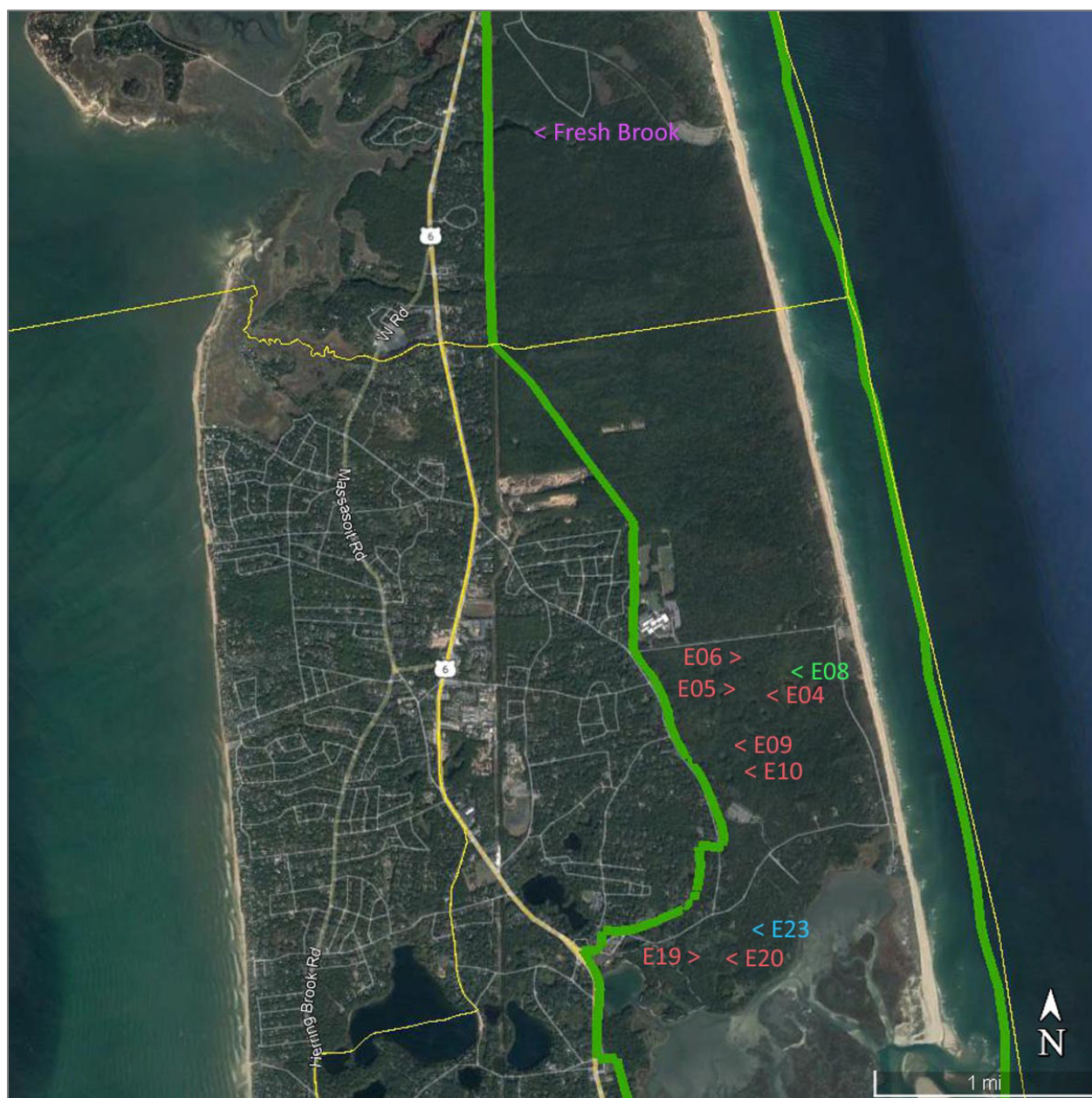


Figure 2. Odonate survey sites in Eastham and South Wellfleet, Massachusetts. Red = vernal pool; pink = riparian marsh; green = bog; blue = kettle pond. Cape Cod National Seashore boundary outlined in green. Created using Google maps. Scale bar lower right corner is 1 mile.



Figure 3. Odonate survey sites in Wellfleet and South Truro, Massachusetts. Red = vernal pool; pink = riparian marsh; green = bog; blue = kettle pond. Cape Cod National Seashore boundary outlined in green. Created using Google maps. Scale bar lower right corner is 2 miles.



Figure 4. Odonate survey sites in Provincetown and North Truro, Massachusetts. Pink = riparian marsh; green = bog; yellow: inter-dune pond; white = dune slack. Cape Cod National Seashore boundary outlined in green. Created using Google maps. Scale bar lower right corner is 2 miles.

Table 1. Odonate survey sites (n=41); towns; year(s) surveyed (2016–2018); hydrology; habitat; predaceous fish presence; depth category (shallow, <2.1m, deep, >4.9m).

Site	Town	Year(s)	Hydrology	Habitat	Predaceous Fish	Depth Category
Blackwater Pond *	Provincetown	all 3	permanent	inter-dune	no	shallow
Blackwater Pond 3	Provincetown	2017	permanent	inter-dune	yes	shallow
Clapps Pond	Provincetown	2017	permanent	inter-dune	yes	shallow
Clapps Pond Bog	Provincetown	2017	permanent	bog	yes	shallow
Clapps Round Pond 3	Provincetown	2017	permanent	inter-dune	yes	shallow
Duck Pond	Wellfleet	2016	permanent	kettle	yes	deep
Dyer Pond	Wellfleet	2016	permanent	kettle	yes	deep
E04	Eastham	2017	semi-permanent	vernal	no	shallow
E05	Eastham	2017	semi-permanent	vernal	no	shallow
E06	Eastham	2017	semi-permanent	vernal	no	shallow
E08	Eastham	2016	semi-permanent	bog	no	shallow
E09 *	Eastham	all 3	semi-permanent	vernal	no	shallow
E10 *	Eastham	all 3	semi-permanent	vernal	no	shallow
E19	Eastham	2017	semi-permanent	vernal	no	shallow
E20	Eastham	2017	semi-permanent	vernal	no	shallow
E23	Eastham	2017	permanent	kettle	no	shallow
Fresh Brook	Wellfleet	2018	permanent	riparian	yes	shallow
Great Pond Truro *	Truro	all 3	permanent	kettle	yes	deep
Great Pond Wellfleet *	Wellfleet	all 3	permanent	kettle	yes	deep
Herring Pond *	Wellfleet	all 3	permanent	kettle	yes	shallow
Herring River East	Wellfleet	2018	permanent	riparian	yes	shallow
Herring River West	Wellfleet	2018	permanent	riparian	yes	shallow
Higgins Pond	Wellfleet	2018	permanent	kettle	yes	deep

* 3YearSites

Table 1 (continued). Odonate survey sites (n=41); towns; year(s) surveyed (2016–2018); hydrology; habitat; predaceous fish presence; depth category (shallow, <2.1m, deep, >4.9m).

Site	Town	Year(s)	Hydrology	Habitat	Predaceous Fish	Depth Category
Horseleech Pond *	Wellfleet	all 3	permanent	kettle	yes	deep
Little Bennett Pond	Provincetown	2017	permanent	inter-dune	no	shallow
Little Spectacle Pond	Wellfleet	2018	permanent	kettle	no	shallow
P05	Provincetown	2017	semi-permanent	dune slack	no	shallow
P14	Provincetown	2018	permanent	bog	no	shallow
P25	Provincetown	2017	permanent	inter-dune	no	shallow
Pasture Pond 4	Provincetown	2017	permanent	inter-dune	yes	shallow
Round Pond East	Truro	2018	permanent	kettle	yes	deep
Round Pond West	Truro	2017	permanent	kettle	yes	deep
Salt Meadow Big Pool	Truro	2018	permanent	riparian	no	shallow
Snow Pond *	Truro	all 3	permanent	kettle	yes	deep
Spectacle Pond	Wellfleet	2018	permanent	kettle	yes	deep
T01 *	Truro	all 3	semi-permanent	bog	no	shallow
T20	Truro	2018	semi-permanent	bog	no	shallow
T27	Truro	2018	permanent	kettle	no	shallow
T28	Truro	2018	permanent	bog	no	shallow
Turtle Pond *	Wellfleet	all 3	permanent	kettle	yes	shallow
W07	Wellfleet	2018	semi-permanent	vernal	no	shallow

* 3YearSites

Sample Sites and Habitats

Given the dependence of odonates on freshwater wetlands for reproduction, and the sensitivity of those wetlands to human pressures and impacts, surveys were focused on wetlands. Cape Cod National Seashore has several hundred freshwater wetlands that range in size and duration from very small ($<30 \text{ m}^2$), ephemeral dune slack wetlands to permanent coastal plain ponds up to 44 hectares (NPS unpublished data, Portnoy et al. 2001). Because the nymphal stage of nearly all Cape Cod odonates spends at least one overwintering period in the natal wetland (Corbet 1999), we sampled permanent and semi-permanent wetlands. This latter wetland type is also used by the few species that can complete the nymph stage in a single season (Corbet 1999), so the full range of odonate species known from Cape Cod are potentially available to be sampled.

The number of sites one can sample depends on a number of factors, particularly the duration of a sampling event (survey), the number of times a site is sampled (number of surveys), time interval between sampling events, and the length of the sampling season. Based on these factors, and prior experience with odonate surveys at CACO, we determined a feasible number of sites to sample. These included 10 “historic” sites, plus an additional 31 sites, chosen in a stratified random process based on habitat type and hydrological category, with travel time to a site being used on a few occasions to eliminate a selected site for the next, more readily accessible site of the same habitat type.

The seashore’s roughly 97 permanent and semi-permanent freshwater wetlands include the following wetland types: shallow and deep kettle ponds, permanent and semi-permanent inter-dune ponds, bogs, riparian marshes, and semi-permanent “vernal” ponds (NPS, unpublished data). The distinctions between these categories, however, are not always clear. For example, many wetlands classified as vernal pools are quite boggy, with extensive sphagnum mats. The distinction between deep and shallow kettle ponds is based upon maximum depth of the pond—and likely has little significance to odonates, which are more impacted by the extent (and perhaps species composition) of emergent and floating vegetation. For purposes of this study, the 41 surveyed wetlands were divided into six categories: kettle pond, inter-dune pond, dune slack, vernal pool, bog, and riparian marsh. Because we attempted to sample habitat types in proportion to their occurrence, the number of sites sampled per habitat type is not equal.

Kettle ponds, remnants of the last glacial advance and retreat 10,000-15,000 years ago, vary considerably in size, depth, and slope, as well as the extent and diversity of emergent and floating vegetation. In general they are acidic ($\text{pH} < 6.0$) and range in trophic condition from oligotrophic to eutrophic (Portnoy et al. 2001). Size varies from 0.5 to 44.0 hectares and depth from 2-18 meters (Portnoy et al. 2001). The 15 ponds surveyed in this study ranged in size from 0.5-17.8 hectares and 2-18 meters in depth. All but two have no inlet or outlet; Herring Pond and Higgins Pond empty into the Herring River, the latter by way of a manmade channel connecting it to Herring Pond. Water quality has been monitored at many of the ponds by NPS personnel for several decades. A number of rare and/or state-listed plants have been recorded at CACO ponds (LeBlond 1989). Those ponds with a shallow slope tend to have the most extensive and diverse emergent flora, and typically support the greatest diversity of odonates. One of the key indicator plants in coastal plain ponds is military rush

(*Juncus militaris*)(Sorrie 1994), which seems to be an indicator species for several coastal plain specialist odonates; it is present at eight of the 15 kettle ponds surveyed. Further information on CACO kettle ponds can be found in Portnoy et al. (2001), Roman et al. (2000), Smith (2012, 2018), Sobczak et al. (2003), and Sorrie (1994)

Inter-dune ponds are located entirely in Provincetown, beyond the terminus of the glacial moraine at High Head. They form in the deeper depressions in the dunes where the rising sea level over the past few thousand years has pushed the water table to the surface. Although typically very shallow, they rarely dry completely. Most are heavily vegetated with emergent and floating vegetation. Although superficially similar to kettle ponds, they are shallower and roughly half the age. Aquatic and emergent vegetation, at least structurally, appears very similar to that at kettle ponds. For example, military rush occurs at three of the seven ponds surveyed. Additional information can be found in Smith (2020), Smith et al. (2008b), and Winkler (1990, 1992).

Vernal pools are temporary wetlands subject to complete drying in all or some years. They are quite variable in size, the largest equivalent to small ponds in area, though they are shallower, rarely more than a few feet deep even in the wettest years. The distinction between ponds and vernal pools is based primarily upon hydrology, vernal pools drying completely in some or most years, ponds rarely, if ever. The vernal pools we sampled were semi-permanent and typically only dried out during drought years. Because they periodically dry completely, vernal pools lack populations of predaceous fish, which can negatively impact the populations of many odonate species. Vernal pools are typically densely vegetated and consequently have a dense layer of detritus, an important component of the food web (Colburn 2005). Dominant vegetation in vernal pools can change in response to variation in water table depth in wet versus dry years (Roman and Barrett 2004) and some of the vernal pools within CACO have become completely overgrown with water willow (*Decodon verticillatus*) and lack open water even in the wettest of years.

Bogs are characterized by a dense mat of sphagnum, in many cases a floating mat, making them rather treacherous habitats to navigate. Those within CACO are small and the perimeters of most are overgrown with a dense layer of shrubs, in particular leatherleaf (*Chamaedaphne calyculata*) and/or water willow. The larger sites often have an open, deep pool in the center, which contains water even in the driest years.

Dune slacks form in the shallower dune depressions and most dry completely in most years. They are boggy, vegetated thickly with a mat of cranberry (*Vaccinium macrocarpon*) rather than sphagnum, and frequently host one or more species of orchids. Thus, they have characteristics of both vernal pools and bogs. Over time they become overgrown with shrubs and eventually in many cases with pitch pine (*Pinus rigida*). Although their hydrology is similar to vernal pools, they typically are less wooded and more open. They are also younger, in some cases only a few decades old (Smith et al. 2005, 2008a, Winkler 1992).

Sites characterized as riparian marsh cover a rather broad spectrum of habitats within CACO, from the clearly lotic Herring River in Wellfleet (two sites surveyed), to the rather stagnant, pond-like Fresh Brook, and the cattail-dominated Salt Meadow Big Pool in Truro. Sections of Herring River,

including the survey sites, are bordered by broad swaths of marshy, seepage areas, with a diverse array of vegetation—and treacherous footing! This was the only truly lotic wetland surveyed. The entire water surface at Fresh Brook is covered with a dense growth of water lily (*Nymphaea odorata*) and water shield (*Brasenia schreberi*), and water movement is imperceptible. Salt Meadow Big Pool lacks emergent or floating vegetation, but is broadly bordered by cattail (*Typha sp.*) marsh; water flow here is also imperceptible to the eye.

Target Life Stage

Odonate surveys take one of three forms, or some combination of the three: adult surveys, surveys for the aquatic nymphs, or surveys of exuviae (the exoskeleton left behind, usually on emergent vegetation, when a nymph emerges from the water and transforms to a flying adult). All three types of surveys have their advantages and disadvantages (Bried and Hinchliffe 2019, Bried et al. 2012, Giugliano et al. 2012, Raebel et al. 2010).

Adult odonates, especially dragonflies (Anisoptera), are highly mobile organisms, even migratory in a few species, and the presence of adults is not confirmation of breeding at a site. Even when breeding activity occurs at a site, the habitat may not be suitable for survival of the immature stage (*i.e.*, the site may be a population sink). Additionally, in most species the adults have a relatively short flight season, lasting only a few weeks. In some species the flight period occurs early in the season (primarily June in the Northeast), while in others it occurs mid-season (July through mid-August) or late in the season (early August into October). Adults are active only under sunny or mostly sunny weather conditions. Thus, surveys must be conducted several times during the season to capture the different flight periods and only on days when the weather is favorable. In a few species, primarily the largest dragonflies (*e. g.*, darners and cruisers) the adults occur at very low density and/or spend very little time at the breeding sites and are easily missed. Freshly emerged adults (teneral) provide proof of successful breeding but are often difficult to identify (especially damselflies), are very fragile and easily damaged if handled, and leave the breeding sites soon (1-3 hours) after emerging, usually early in the morning.

Nymphal surveys provide good evidence of breeding at a site and do not have the seasonal or weather constraints of adult surveys. However, in many groups, especially among damselflies, nymphs are very difficult to identify and may require considerable examination time in the lab. They also can be difficult to sample well. Most nymphs live on the bottom of wetlands, often among dense vegetation, and collecting them can result in considerable disturbance to the habitat; this is especially a concern at bogs and fens, where the nymphs often burrow into the peat or reside at the base of sphagnum. In large, deep ponds they may reside at considerable depths and be very difficult to reach.

The presence of exuviae at a wetland provides the best evidence of successful breeding at that site. Exuviae, however, present the same identification issues as nymphs. Additionally, exuviae are brittle and easily destroyed by rain or wind; thus, exuvial surveys must be conducted very frequently, multiple times a week during peak odonate activity (Aliberti Lubertazzi and Ginsberg 2009). In some of the larger species, emergence may occur several meters back from the wetland, or 2-3 meters up on tree trunks, making them very difficult to find.

The adult stage is the most conspicuous and readily identifiable life stage and more sensitive to land use practices adjacent to wetlands than the difficult to identify aquatic stages (Kutcher and Bried 2014). While the presence of adults does not confirm breeding at a site, it is at least evidence that the species is utilizing the site and that the site is likely of some value to the species. And while a single adult or two, present on one or two occasions, may be of minimal significance, the presence of numbers of individuals on multiple occasions can reasonably be used to infer residency. Several recent studies have determined that adult surveys can be used to accurately infer species residency, based on a number of reliable indicators that are highly correlated with the presence of exuviae (Bried et al. 2015, Patten et al. 2015, 2019, Pearce-Higgins and Chandler 2020).

Finally, the vast majority of historical data available for CACO is of adults, the one exception being some of the data from Colburn (2005). Thus, after carefully considering the various pros and cons, we concluded that adult surveys would be the most feasible and provide the most useful results for this project.

Sampling Frequency and Duration

Surveys were conducted from early June through mid-September, which corresponds to the peak flight period of most odonate species on Cape Cod. For any given species, however, the flight period can range from just 4-5 weeks long to as long as 5 months as in the Common Green Darner (Nikula et al. 2003). Additionally, some species occur at very low density and/or are very elusive in their habits (e. g., the adults spend very little time at wetlands). Thus, multiple surveys within a species' flight period may be needed to detect its presence (Bried et al. 2007). A few species have very late flight seasons, extending into early November in a couple of cases (e. g., Spotted Spreadwing, Autumn Meadowhawk), and therefore were not well-sampled in these surveys.

In 2016, the field season was divided into 8 periods of approximately 14 days each, with one survey conducted at a site during each period. During that first season, 13 sites were surveyed eight times each (except Horseleech Pond, which was surveyed seven times). After examining the results, we concluded that reducing the number of surveys to six/season would still provide an adequate representation of the odonate fauna at each site, and that the additional time would permit a larger number of sites to be surveyed. Consequently, 25 sites were surveyed six times each in 2017, and 23 sites were surveyed six times each in 2018.

Each survey was 40 minutes/in duration (the distance varying depending upon the number of odonates encountered), which in a study by Bried et al. (2007, 2012) gave a 97.7% correlation with data collected for 60 minutes. For a study of three species of bluet damselflies (genus *Enallagma*) on Cape Cod, three surveys at a site during the flight period in June reportedly achieved near 100% detectability, and detection occurred with 30 minutes of sampling (Gibbons 2001, Gibbons et al. 2002). We therefore believe that this length and frequency of sampling is very likely to detect most species present in a given year. On the other hand, given the considerable day-to-day variation in numbers (e. g., Carpenter 1990) it is likely insufficient to draw conclusions about population levels at better than a very coarse scale.

Survey Protocol

Adult odonate activity is impacted by time of day, temperature, cloud cover, and high winds. Consequently, surveys were conducted between 1000 and 1600 hours on sunny to mostly sunny days when air temperature was at least 18°C (65°F) and wind speeds were below 40kph (25mph). Surveys used the “checklist counting technique” as described by Royer et al. (1998) and used for odonate surveys at other parks in the Northeast Coastal and Barrier Network (Briggs et al. 2010 a, b, c). This technique requires that investigators move through a site actively looking for, identifying, and counting odonates as encountered. We focused the 40-minute-long surveys on the section of pond where emergent and floating leaved vegetation was most developed (Butler and deMaynadier 2008) or most accessible. Depending upon the site, sampling involved walking parallel to shore, traversing the emergent zone, or following the aquatic vegetation-open water interface (Gibbons et al. 2002, Bried et al. 2015). At the smaller sites, such as most vernal pools, the survey consisted of a complete loop around the perimeter of the wetland.

For each survey we recorded: site name; observer; date; start time; end time; air temperature; wind speed (using Beaufort Code); wind direction; sky code (based upon % of cloud cover); and water level. A sample data sheet is provided in Appendix 1.

For each species detected we recorded the total number of adults, and to the extent possible the number of males, number of females, and the number of immature male/females (where it was not possible to distinguish between the two, immature males often resembling females). Additionally, for each species we recorded evidence of breeding, including number of tandem pairs; number of ovipositing females; number of ovipositing pairs; and number of teneral (i.e., recently emerged individuals that have not yet matured and achieved adult coloration and/or patterns) when they were identified. Individuals that could not be identified to species were recorded at the genus or family level.

Most dragonflies and many damselflies are readily identifiable in the field visually with the aid of close-focusing binoculars. Some of the more difficult species, especially damselflies, require in-hand identification. In such cases individuals were netted, identified in the hand, and released. For the more significant species (e. g., state-listed) photos were taken for documentation. Various references were used to confirm identifications (Westfall and May 1996, Needham et al. 2014, Nikula et al. 2003, Lam 2004, Paulson 2011). Taxonomy follows Paulson (2018). Records of state-listed species were submitted to the Massachusetts Natural Heritage and Endangered Species Program.

Data Presentation and Analysis

Analysis was performed on different subsets of the data collected in this project to answer different questions related to variation in abundance and community metrics due to time, habitat type, and site factors. Although most data presented and analyzed was based on observations where individuals were identified to species, some used data that also included individuals only identified to sub-order, family, or genus. In addition, different subsets of survey sites and/or year of sampling were analyzed. The 10 sites that were sampled for three years (10 sites x 3 annual samples), referred to as 3YearSites, were used to provide insight into annual variation and compare community metrics from a single year with those based on pooling the three years together. For insight into differences due to

habitat type and other site factors, we used a second group (AllSites1YearEach), which consisted of the 31 sites sampled for one year (1YearSites) plus one randomly selected year from each of the 10 3YrSites. The AllSites1YearEach group thus consists of a single year's data, collected in either 2016, 2017, or 2018, for each of the 41 sites surveyed and is a broader and more representative sample of the Seashore's Odonate habitat types. Because this group contains only a single year's data for each pond, collected in one of three years, and sampling of sites in each of the habitat types was not evenly distributed among these years (Table 2), this data was not used to analyze annual effects.

Table 2. Number of sites/habitat surveyed by year in the AllSites1YearEach group at Cape Cod National Seashore.

Year	Habitat						Total
	Bog	Dune Slack	Inter-dune Pond	Kettle Pond	Riparian Marsh	Vernal Pool	
2016	1	0	0	2	0	1	4
2017	1	1	7	4	0	5	18
2018	4	0	0	9	4	2	19
Total	6	1	7	15	4	8	41

One last group, AllSitesAllYears, consisting of all the 61 annual samples conducted in this project, provides insight into the full range of values and species recorded in annual samples. For analyses, the term “survey” refers to one of the 6-8 data collection events that occurred in a given year at a site and the term “annual sample” refers to the pooled data from all surveys for the entire year at a given site, i.e., total number of individuals of each species recorded in a given year at a site.

Variation in Abundance

Annual variation in abundance was analyzed with repeated measures Analysis of Variance (ANOVA). For each of the 3YearSites, the total number of individuals recorded each year for different taxonomic groups was standardized as individuals/survey (annual sample for a site in a given year divided by the number of surveys it was based on). The taxonomic groups analyzed were All Families (all individuals identified at least to family level combined), which was further subdivided into sub-orders Zygoptera (damselflies) and Anisoptera (dragonflies), and into the four families that represented 99% of all the individuals recorded. When data for a given group did not meet assumptions of normality, it was log transformed ($\text{LN}(X+1)$).

Variation in abundance by habitat type was based on data from AllSites1YearEach, using the mean number of individuals identified to species/survey for each of the 41 sites annual samples, grouped by habitat type. Because these data did not meet assumptions of normality and/or homogeneity of variance, the non-parametric Kruskal-Wallis ANOVA was used.

Community Analysis

We used PRIMER 7 (Clarke et al. 2014) and PERMANOVA+ (Anderson et al. 2008) to compare measures of odonate community diversity and similarity/dissimilarity at the sample site and habitat type level, and to evaluate the role that temporal and environmental factors potentially play in

accounting for the variability recorded. Data used in this analysis was limited to individuals identified to species.

Species diversity was evaluated using the Shannon diversity index ($H' \log_e$) and the Simpson index D , based on numbers of individuals of each species recorded at a given sample site over the course of a sampling season (year). For the ten sites sampled each year in 2016, 2017, and 2018, diversity was calculated for each site annually, and as a three-year pooled sample. Calculation of diversity for each habitat type was based on a single annual sample from each of the 41 sites sampled, specifically each of the 31 sites sampled only one year, plus a single, randomly selected year for each of the 10 3YearSites. For each habitat type, species diversity metrics were calculated using the means of each individual site within a given habitat type.

Odonate community similarity/dissimilarity was examined in a number of ways using species count data for each species at a site in a given sampling season that were standardized as individuals/survey. These data were then subjected to a fourth root transformation to balance contributions of abundant versus rare species (Clarke et al. 2014) and used for subsequent analyses. Multi-dimensional scaling (MDS) based on the Bray-Curtis Similarity Matrix was used to ordinate the relationship of species composition among sample sites in two-dimensional space. Permutational multivariate analysis of variance (PERMANOVA) was used to analyze variation in community structure between sample sites due to year and environmental factors such as habitat type, hydroperiod (permanent or semi-permanent), presence of predaceous fish (yes or no), and depth category (shallow or deep). Sites categorized as “shallow” have maximum depth <2.1 m whereas “deep” sites are >4.9 m. Presence of predaceous fish was based on Mather et al. (2003), data collected by Tupper and Cook (2008) and Cook (unpublished data).

PERMANOVA+ is semi-parametric, based on values of a resemblance measure, such as Bray-Curtis Similarity. It generates test statistics and significance testing analogous to analysis of variance (ANOVA), and partitions the variation observed into estimated components of variation (%ECV), a measure of the relative importance of each model factor in explaining overall variation, as well as residual variation not explained by model factors (Anderson et al. 2008). Additional analysis of the similarity/dissimilarity of sites and habitat types due to these factors was conducted using the Similarity Percentage (SIMPER) routine in PRIMER 7. This calculates the percentage similarity among sites within a given factor group and the dissimilarity between factor groups.

Results and Discussion

Results By Species and Sites

A total of 391 surveys was conducted at 41 sites (AllSitesAllYears), resulting in 3,998 records, in which one or more individuals of a taxon were recorded during a survey. A total of 53,435 individual odonates were identified. However, not every individual was identifiable to species. Recently emerged (“teneral”) damselflies were especially problematic and often identified only to genus, or in a few cases family or sub-order. Overall, 5,605 (10.5%) of individuals recorded could not be identified to species. Of these, 4,698 (83.8%) were damselflies. In the following analyses, individuals not identified to species are either included or excluded depending upon the taxonomic level under consideration.

From the 47,830 individuals identified to species during surveys, 74 species were recorded, 45 dragonflies (61%) and 29 damselflies (39%) (Table 3). Although damselflies comprised only 39% of the species recorded in surveys, they comprised 60% of individuals recorded to species. Three species, Taiga Bluet, Harlequin Darner, and Band-winged Meadowhawk, were new records for the Seashore while 10 species known historically were not recorded during surveys. However, three of these 10 were observed incidental to conducting formal surveys, and two new species were recorded after formal surveys, in 2019, bringing the overall CACO species total to 86 species (see Appendix 2 for details).

The most frequently recorded species were Eastern Forktail (76% of surveys), Slaty Skimmer (68%), Common Green Darner (59%), and Blue Dasher (59%), and the most numerous were Eastern Forktail (5,147 individuals), Blue Dasher (4,740 individuals), Atlantic Blue (4,726 individuals), and Sweetflag Spreadwing (4,159 individuals) (Table 3). The seven most common species comprised 59% of the total individuals, while seven species were recorded just once (Figure 5).

Table 3. Results by species in the AllSitesAllYears group at Cape Cod National Seashore. This excludes 5605 individuals not identified to species.

Common Name	Scientific Name	# of Sites	# of Surveys	% of Surveys	# of Individuals	High Count
Spotted Spreadwing	<i>Lestes congener</i>	8	10	3	16	3
Northern Spreadwing	<i>Lestes disjunctus</i>	4	6	2	203	120
Amber-winged Spreadwing	<i>Lestes eurinus</i>	18	58	15	692	50
Sweetflag Spreadwing	<i>Lestes forcipatus</i>	27	112	29	4159	800
Elegant Spreadwing	<i>Lestes inaequalis</i>	11	22	6	62	9
Slender Spreadwing	<i>Lestes rectangularis</i>	33	80	20	248	16
Swamp Spreadwing	<i>Lestes vigilax</i>	17	105	27	1262	110
Ebony Jewelwing	<i>Calopteryx maculata</i>	2	14	4	32	6
Eastern Red Damsel	<i>Amphiagrion saucium</i>	2	3	1	19	10
Variable Dancer	<i>Argia fumipennis</i>	15	141	36	1587	126
Taiga Bluet	<i>Coenagrion resolutum</i>	1	1	<1	2	2
Northern Bluet	<i>Enallagma boreale</i>	9	16	4	627	250
Azure Bluet	<i>Enallagma aspersum</i>	14	45	12	1079	200
Familiar Bluet	<i>Enallagma civile</i>	6	25	6	547	100
Attenuated Bluet ¹	<i>Enallagma daeckii</i>	10	35	9	391	50
Atlantic Bluet	<i>Enallagma doubledayi</i>	10	67	17	4726	1056
Skimming Bluet	<i>Enallagma geminatum</i>	15	105	27	3032	512
New England Bluet ²	<i>Enallagma laterale</i>	8	10	3	98	40
Little Bluet	<i>Enallagma minusculum</i>	7	24	6	732	162
Pine Barrens Bluet ¹	<i>Enallagma recurvatum</i>	9	18	5	308	70
Orange Bluet	<i>Enallagma signatum</i>	4	17	4	158	64
Slender Bluet	<i>Enallagma traviatum</i>	7	14	4	67	20

¹ Massachusetts Threatened (MA Wildlife 2015)

² former Special Concern (MA Wildlife 2015)

³ Species of Greatest Conservation Need (MA Wildlife 2015)

Table 3 (continued). Results by species in the AllSitesAllYears group at Cape Cod National Seashore. This excludes 5605 individuals not identified to species.

Common Name	Scientific Name	# of Sites	# of Surveys	% of Surveys	# of Individuals	High Count
Vesper Bluet	<i>Enallagma vesperum</i>	3	5	1	8	3
Citrine Forktail	<i>Ischnura hastata</i>	9	14	4	33	5
Lilypad Forktail	<i>Ischnura kellicotti</i>	5	20	5	396	96
Fragile Forktail	<i>Ischnura posita</i>	36	171	44	721	30
Rambur's Forktail	<i>Ischnura ramburii</i>	1	1	<1	1	1
Eastern Forktail	<i>Ischnura verticalis</i>	39	297	76	5147	410
Sphagnum Sprite	<i>Nehalennia gracilis</i>	11	47	12	2362	275
Canada Darner	<i>Aeshna canadensis</i>	1	1	<1	2	2
Mottled Darner	<i>Aeshna clepsydra</i>	15	33	8	92	8
Spatterdock Darner ³	<i>Rhionaeschna mutata</i>	3	3	1	6	3
Black-tipped Darner	<i>Aeshna tuberculifera</i>	9	21	5	58	20
Green-striped Darner	<i>Aeshna verticalis</i>	2	3	1	3	1
Common Green Darner	<i>Anax junius</i>	39	229	59	518	15
Comet Darner ³	<i>Anax longipes</i>	9	16	4	18	2
Harlequin Darner	<i>Gomphaeschna furcillata</i>	3	4	1	8	3
Lancet Clubtail	<i>Gomphus exilis</i>	11	21	5	30	3
Common Sanddragon	<i>Progomphus obscurus</i>	8	29	7	80	17
Swift River Cruiser	<i>Macromia illinoensis</i>	1	1	<1	3	3
Petite Emerald	<i>Dorocordulia lepida</i>	3	6	2	8	2
Common Baskettail	<i>Epithea cynosura</i>	15	17	4	44	10
Prince Baskettail	<i>Epithea princeps</i>	4	17	4	24	2
Calico Pennant	<i>Celithemis elisa</i>	19	132	34	1288	111

¹ Massachusetts Threatened (MA Wildlife 2015)

² former Special Concern (MA Wildlife 2015)

³ Species of Greatest Conservation Need (MA Wildlife 2015)

Table 3 (continued). Results by species in the AllSitesAllYears group at Cape Cod National Seashore. This excludes 5605 individuals not identified to species.

Common Name	Scientific Name	# of Sites	# of Surveys	% of Surveys	# of Individuals	High Count
Halloween Pennant	<i>Celithemis eponina</i>	10	22	6	89	24
Banded Pennant	<i>Celithemis fasciata</i>	9	22	6	50	9
Martha's Pennant	<i>Celithemis martha</i>	11	67	17	580	64
Eastern Pondhawk	<i>Erythemis simplicicollis</i>	40	218	56	1859	150
Seaside Dragonlet	<i>Erythrodiplax berenice</i>	1	1	<1	1	1
Blue Corporal	<i>Ladona deplanata</i>	9	16	4	28	8
White Corporal	<i>Ladona exusta</i>	15	38	10	157	15
Frosted Whiteface	<i>Leucorrhinia intacta</i>	2	2	1	2	1
Dot-tailed Whiteface	<i>Leucorrhinia frigida</i>	22	51	13	468	151
Golden-winged Skimmer	<i>Libellula auripennis</i>	1	1	<1	1	1
Bar-winged Skimmer	<i>Libellula axilena</i>	7	9	2	12	3
Spangled Skimmer	<i>Libellula cyanea</i>	17	51	13	118	7
Slaty Skimmer	<i>Libellula incesta</i>	39	265	68	3161	114
Needham's Skimmer	<i>Libellula needhami</i>	4	10	3	12	2
Twelve-spotted Skimmer	<i>Libellula pulchella</i>	7	10	3	15	3
Four-spotted Skimmer	<i>Libellula quadrimaculata</i>	1	1	<1	4	4
Painted Skimmer	<i>Libellula semifasciata</i>	27	84	21	357	20
Great Blue Skimmer	<i>Libellula vibrans</i>	1	2	1	3	2
Elfin Skimmer	<i>Nannothemis bella</i>	1	2	1	6	5
Blue Dasher	<i>Pachydiplax longipennis</i>	41	229	59	4740	254
Wandering Glider	<i>Pantala flavescens</i>	2	3	1	3	1
Spot-winged Glider	<i>Pantala hyemaea</i>	4	4	1	28	25

¹ Massachusetts Threatened (MA Wildlife 2015)

² former Special Concern (MA Wildlife 2015)

³ Species of Greatest Conservation Need (MA Wildlife 2015)

Table 3 (continued). Results by species in the AllSitesAllYears group at Cape Cod National Seashore. This excludes 5605 individuals not identified to species.

Common Name	Scientific Name	# of Sites	# of Surveys	% of Surveys	# of Individuals	High Count
Eastern Amberwing	<i>Perithemis tenera</i>	9	47	12	605	60
Common Whitetail	<i>Plathemis lydia</i>	2	3	1	4	2
Saffron-winged Meadowhawk	<i>Sympetrum costiferum</i>	2	6	2	39	12
Ruby Meadowhawk	<i>Sympetrum rubicundulum</i>	39	150	38	3476	240
Band-winged Meadowhawk	<i>Sympetrum semicinctum</i>	3	6	2	36	16
Autumn Meadowhawk	<i>Sympetrum vicinum</i>	35	94	24	798	75
Carolina Saddlebags	<i>Tamea carolina</i>	22	111	28	275	15
Black Saddlebags	<i>Tamea lacerata</i>	4	5	1	6	2
Totals	–	41	391	–	47830	–

¹ Massachusetts Threatened (MA Wildlife 2015)

² former Special Concern (MA Wildlife 2015)

³ Species of Greatest Conservation Need (MA Wildlife 2015)

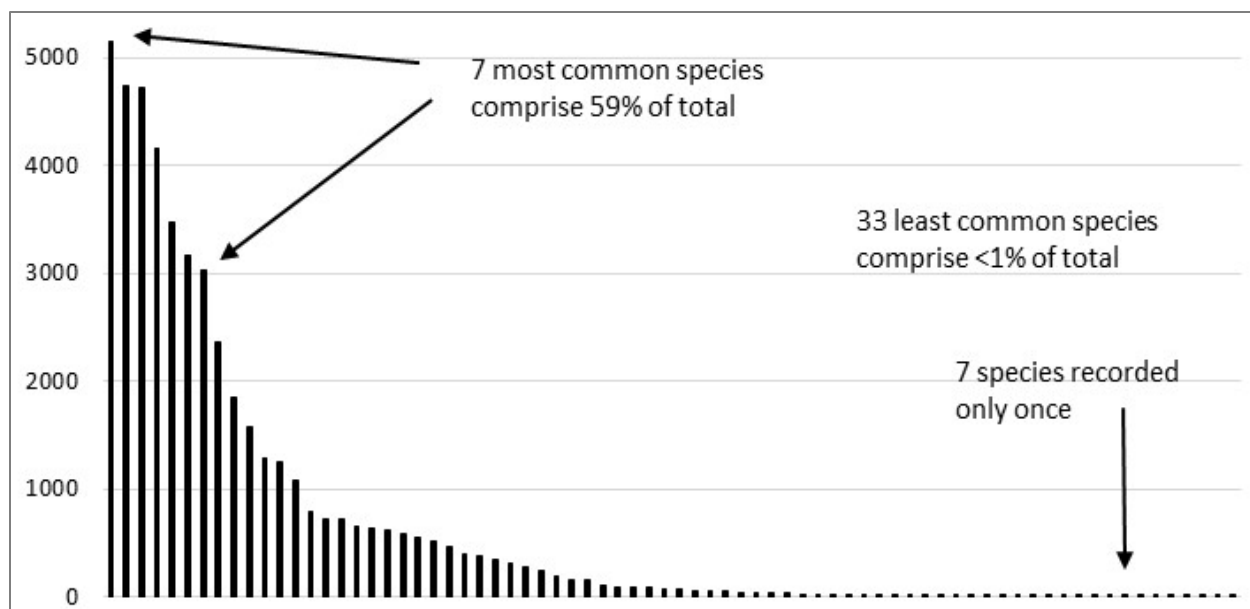


Figure 5. Abundance distribution of species, based upon number of individuals (74 species total) at Cape Cod National Seashore.

Based on data from AllSitesAllYears, the number of species recorded per site ranged from 11 to 41. The highest species richness was at Great Pond Wellfleet (41 species), Great Pond Truro (37 species), and Turtle Pond, Wellfleet (36 species) (Table 4). Adjusted for effort, Herring Pond, Wellfleet averaged 14.5 species/survey, followed by Turtle Pond (12.9 species/survey) and Snow Pond, Truro (11 species/survey). The vernal pool E20, the smallest site surveyed, had the lowest richness with 4.8 species/survey. The average for all 41 sites was 8.8 species/survey. Eleven sites averaged 10 or more species/survey, seven kettle ponds, two inter-dune ponds, one bog, and one vernal pool. Abundance (Individuals/Survey) averaged 137 and ranged from 21 at Salt Meadow to 330 at Herring Pond (Table 4).

Table 4. Results by site in the AllSitesAllYears group at Cape Cod National Seashore. Number of individuals includes those not identified to species.

Site	# of Surveys	# of Species	Species/Survey	# of Individuals	Individuals/Survey
Blackwater Pond *	20	32	10.4	2367	118
Blackwater Pond 3	6	21	10.2	518	86
Clapps Pond	6	14	6.5	312	52
Clapps Pond Bog	6	12	7.2	227	38

*3YearSites

Table 4 (continued). Results by site in the AllSitesAllYears group at Cape Cod National Seashore. Number of individuals includes those not identified to species.

Site	# of Surveys	# of Species	Species/ Survey	# of Individuals	Individuals/ Survey
Clapps Round Pond 3	6	17	7.2	340	57
Duck Pond	8	16	5.4	726	91
Dyer Pond	8	24	8.8	359	45
E04	6	15	5.5	485	81
E05	6	15	5.5	352	59
E06	6	16	6	406	68
E08	8	22	6.8	819	102
E09*	20	25	10.3	6444	322
E10*	20	26	8.1	4118	206
E19	6	13	7.2	309	52
E20	6	12	4.8	218	36
E23	6	17	8	1380	230
Fresh Brook	6	17	6.3	200	33
Great Pond Truro *	20	37	5.5	1591	80
Great Pond Wellfleet *	20	41	10.6	2607	130
Herring Pond *	20	34	14.5	6597	330
Herring River East	6	17	6.2	230	38
Herring River West	6	16	5.2	185	31
Higgins Pond	6	22	10.2	810	135
Horseleech Pond *	19	33	10.1	4254	224
Little Bennett Pond	6	16	8.5	616	103
Little Spectacle Pond	6	20	9.2	700	117
P05	6	14	7.3	767	128
P14	6	13	7.8	518	86
P25	6	13	7.5	657	110
Pasture Pond 4	6	18	8.2	334	56
Round Pond East	6	23	10.3	1726	288
Round Pond West	6	23	8.8	304	51
Salt Meadow Big Pool	6	11	5.2	125	21
Snow Pond *	20	33	11	2316	116
Spectacle Pond	6	24	10.3	438	73
T01 *	20	27	7.2	2933	147
T20	6	20	10.5	527	88
T27	6	23	9.2	1371	229
T28	6	21	8.2	621	104

*3YearSites

Table 4 (continued). Results by site in the AllSitesAllYears group at Cape Cod National Seashore. Number of individuals includes those not identified to species.

Site	# of Surveys	# of Species	Species/ Survey	# of Individuals	Individuals/ Survey
Turtle Pond	20	36	12.9	2821	141
W07	6	21	8.7	807	135
Totals	391	74	8.8	53435	137

*3YearSites

Results by Suborder and Family – AllSitesAllyears

At the suborder level, Damselflies (Zygoptera) comprised 42% of all species ever recorded at CACO and 62% of individuals recorded in these surveys, whereas Dragonflies (Anisoptera) accounted for 58% of species and 38% of individuals (Table 5). Two families, Pond Damsels and Skimmers, accounted for 86% of the individuals recorded in current surveys and 68.6 % of all species known from CACO. These two families are the most speciose in MA, accounting for 46% of the state total (Table 5).

Table 5. Abundance and species richness by sub-order and family at Cape Cod National Seashore (CACO), Massachusetts (MA). # CACO species includes 74 recorded in surveys, plus 12 additional species representing either historic or recent incidental records; # of individuals does not include historical/incidental data or 798 individuals not identified to at least the family level. Based on AllSitesAllYears data identified to at least Family.

Families	Records From This and Historical CACO Surveys		Records From This Survey Only		All Species Records Across MA	
	# CACO Species	% CACO Species	# of Individuals	% of Individuals	# of MA Species	% of MA Species
Spreadwings (Lestidae)	8	9.3	8141	16	9	5.5
Broad-winged Damsels (Calopterygidae)	1	1.2	32	<1	5	3.0
Pond Damsels (Coenagrionidae)	27	31.4	24454	46	35	21.2
All Damselfly (Zygoptera)	36	42	32627	62	49	29.7
Darners (Aeshnidae)	10	11.6	844	<2	20	12.1
Clubtails (Gomphidae)	3	3.5	110	<1	27	16.4
Cruisers (Macromiidae)	2	2.3	3	<1	2	1.2
Emeralds (Corduliidae)	3	3.5	78	<1	23	13.9
Skimmers (Libellulidae)	32	37.2	18975	36	41	24.8
All Dragonfly (Anisoptera)	50	58.0	20010	38	113	70.3 *
Total	86	100	52637	100	165	100 *

* MA species include 3 species of spiketail family, absent from Cape Cod and not included as a row in this table.

Measures of Species Diversity – AllSites1YearEach

Based on a single annual sample for each site (AllSites1YearEach), the Shannon Diversity Index at a site ranged from highs of 2.791 at Turtle Pond and 2.665 at Snow Pond to lows of 0.987 at Horseleeche Pond and 1.117 at Round Pond East. Simpson's Diversity Index ranged from a high of 0.919, recorded at both Turtle Pond and Snow Pond, to lows of 0.354 at Horseleeche Pond and 0.426 at Round Pond East (Table 6).

Table 6. Measures of species richness, diversity (Shannon H', Simpson's D), abundance, and sampling effort for the 41 sites sampled for a single year at Cape Cod National Seashore. Based on AllSites1YearEach data identified to species.

Sample Site	Year	# of Surveys	# of Species	# of Individuals	# of Species/ Survey	# of Individuals/ Survey	Shannon Diversity Index H'	Simpson's Diversity Index D
Blackwater Pond	2017	6	18	629	10.7	105	2.233	0.851
Blackwater Pond 3	2017	6	21	445	10.2	74	2.352	0.875
Clapps Pond	2017	6	14	301	6.5	50	1.906	0.806
Clapps Bog	2017	6	12	216	7.2	50	2.153	0.869
Clapps Round Pond 3	2017	6	17	324	7.2	54	1.888	0.755
Duck Pond	2016	8	16	607	5.4	76	1.354	0.589
Dyer Pond	2016	8	24	359	8.8	45	2.521	0.881
E04	2017	6	15	443	5.5	74	1.373	0.645
E05	2017	6	15	312	5.5	51	1.941	0.818
E06	2017	6	16	367	6.0	61	1.470	0.629
E08	2016	8	22	720	6.8	90	2.008	0.809
E09	2016	8	19	2003	9.3	250	2.037	0.814
E10	2018	6	21	1016	9.3	169	1.732	0.718
E19	2017	6	13	245	7.2	41	1.967	0.821
E20	2017	6	12	195	4.8	33	1.945	0.831
E23	2017	6	17	1229	8.0	205	1.154	0.477
Fresh Brook	2018	6	17	175	6.3	29	2.137	0.847
Great Pond Truro	2017	6	23	417	9.0	70	2.399	0.888
Great Pond Wellfleet	2018	6	29	1182	11.0	197	2.097	0.823
Herring Pond	2017	6	24	1772	15.3	295	2.328	0.861
Herring River East	2018	6	17	120	6.2	20	2.514	0.910
Herring River West	2018	6	16	142	5.2	24	2.047	0.812
Higgins Pond	2018	6	22	549	10.2	92	2.212	0.843

Table 6 (continued). Measures of species richness, diversity (Shannon H', Simpson's D), abundance, and sampling effort for the 41 sites sampled for a single year at Cape Cod National Seashore. Based on AllSites1YearEach data identified to species.

Sample Site	Year	# of Surveys	# of Species	# of Individuals	# of Species/ Survey	# of Individuals/ Survey	Shannon Diversity Index H'	Simpson's Diversity Index D
Horseleech Pond	2018	6	26	2311	10.7	385	0.987	0.354
Little Bennett Pond	2017	6	16	586	8.5	98	2.162	0.860
Little Spectacle Pond	2018	6	20	498	9.2	83	2.214	0.865
P05	2017	6	14	723	7.3	121	1.794	0.783
P14	2018	6	13	446	7.8	74	1.682	0.700
P25	2017	6	13	621	7.5	104	1.581	0.680
Pasture Pond 4	2017	6	18	319	8.2	53	2.285	0.871
Round Pond East	2018	6	23	1682	10.3	280	1.117	0.426
Round Pond West	2017	6	23	285	8.8	48	2.259	0.845
Salt Meadow Big Pool	2018	6	11	107	5.2	18	2.214	0.882
Snow Pond	2018	6	27	929	12.7	155	2.665	0.919
Spectacle Pond	2018	6	24	313	10.3	52	2.511	0.893
T01	2018	6	21	1373	8.5	229	1.373	0.598
T20	2018	6	20	441	10.5	74	2.449	0.889
T27	2018	6	23	974	9.2	162	1.665	0.682
T28	2018	6	21	561	8.2	94	1.557	0.608
Turtle Pond	2018	6	27	640	13.7	107	2.791	0.919
W07	2018	6	21	566	8.7	94	1.978	0.780
Mean	–	6.2	19	662	8.4	107	1.977	0.774

There were varying degrees of correlation between the different diversity measures. Based on the 41 annual samples from AllSites1YearEach, there was highly significant ($p < 0.0001$) positive correlation between the Shannon and Simpson Index. These two measures had a low to moderate, but significant negative correlation with abundance (Individuals/Survey). The number of species (S) had negligible non-significant correlation with the two diversity indices, and a highly significant positive correlation with abundance (Table 7). In addition, based on the 37 sites in Table 6 that were sampled in 2017 or 2018 (six surveys in annual sample), there was a highly significant correlation between a site's total species recorded in a year and the mean species/survey ($r(72)=0.81$, $p<0.001$).

Table 7. Correlation among measures of species diversity and abundance at Cape Cod National Seashore. Based on AllSites1YearEach. Values of Spearman's rho or Pearson's correlation and p.

Measures of Diversity and Abundance	Simpson's Diversity Index	Shannon Diversity Index	# of Individuals / Survey
Shannon Diversity Index	rho=+0.97, $p<0.0001$ *	–	–
# of Individuals / Survey	rho=-0.40, $p=0.01$ *	rho=-0.33, $p=0.036$ *	–
Number Species	rho=0.19, $p=0.24$	corr=0.23, $p=0.141$	rho=0.49, $p<0.0011$ *

* Values of $p<0.05$ were considered significant.

Geographic Distribution of Species – AllSitesAllYears

Although political boundaries have no biological significance, the four towns on the outer Cape within which the surveyed sites lie are oriented on a generally north-south axis and suggest a possible approach for examining geographic distribution of odonates on outer Cape Cod. However, the surveyed habitat types are not evenly distributed across the towns (Table 8). Kettle ponds in CACO are predominantly located in Wellfleet and southern Truro, vernal pools in Eastham, and inter-dune ponds and dune slacks exclusively in Provincetown. Thus, species distributions at CACO are likely determined by the distribution of habitats. Nonetheless, some rather puzzling distribution patterns are apparent.

Table 8. Habitats sampled by town within Cape Cod National Seashore boundaries.

Habitat	Town				# of Sites
	Eastham	Wellfleet	Truro	Province-town	
Bog	1	0	3	2	6
Dune Slack	0	0	0	1	1
Inter-dune Pond	0	0	0	7	7
Kettle Pond	1	9	5	0	15
Riparian Marsh	0	3	1	0	4
Vernal Pool	7	1	0	0	8

Species richness (total number of species and mean species/site) and total number of individuals recorded was greatest in Wellfleet and Truro, whereas abundance (individuals/survey) was greatest in Truro and Eastham (Table 9). Provincetown had the lowest abundance and was tied with Eastham for lowest species richness, 39 species (Table 9).

Many species are absent in Provincetown, particularly those considered coastal plain specialists, which almost exclusively inhabit kettle ponds—a habitat absent in Provincetown. Most notable in this group are Attenuated Bluet, Atlantic Bluet, Little Bluet, Pine Barrens Bluet, Martha's Pennant, and Blue Corporal. These species reach their northern limit at CACO in the kettle ponds of south Truro, in particular Great and Snow ponds. Even some generalist species are missing in Provincetown, such as Familiar Bluet, Skimming Bluet, and Orange Bluet, while others such as Variable Dancer, Calico Pennant, and Autumn Meadowhawk were recorded only rarely on the Provincetown surveys. On the other hand, three species reach their greatest abundance in Provincetown: Amber-winged Spreadwing, Northern Bluet, and White Corporal. The two damselflies generally occur in fish-less wetlands, while the corporal is typically most common where its congener, the Blue Corporal is scarce to absent.

Table 9. Species by town, total individuals, and individuals/survey for each Odonate species at Cape Cod National Seashore. Based on AllSitesAllYears data.

Species	Eastham		Wellfleet		Truro		Provincetown	
	Total Individuals	Individuals/ Survey	Total Individuals	Individuals/ Survey	Total Individuals	Individuals/ Survey	Total Individuals	Individuals/ Survey
Spotted Spreadwing	10	0.1	3	<0.1	0	0.0	3	<0.1
Northern Spreadwing	1	<0.1	0	0.0	200	1.5	2	<0.1
Amber-winged Spreadwing	235	3.2	64	0.7	33	0.2	360	4.3
Sweetflag Spreadwing	2584	34.9	295	3.1	307	2.2	973	11.6
Elegant Spreadwing	0	0.0	39	0.4	2	<0.1	21	0.3
Slender Spreadwing	90	1.2	41	0.4	54	0.4	63	0.8
Swamp Spreadwing	5	<0.1	815	8.5	273	2.0	169	2.0
Ebony Jewelwing	0	0.0	32	0.3	0	0.0	0	0.0
Eastern Red Damselfly	0	0.0	19	0.2	0	0.0	0	0.0
Variable Dancer	0	0.0	939	9.8	646	4.7	2	0.0
Taiga Bluet	0	0.0	2	<0.1	0	0.0	0	0.0
Northern Bluet	85	1.1	5	0.1	15	0.1	522	6.2
Azure Bluet	380	5.1	8	0.1	567	4.1	124	1.5
Familiar Bluet	0	0.0	547	5.7	0	0.0	0	0.0
Attenuated Bluet	0	0.0	205	2.1	186	1.4	0	0.0
Atlantic Bluet	0	0.0	474	4.9	4252	31.0	0	0.0
Skimming Bluet	13	0.2	2672	27.8	347	2.5	0	0.0
New England Bluet	3	<0.1	30	0.3	2	<0.1	63	0.8
Little Bluet	0	0.0	519	5.4	213	1.6	0	0.0
Pine Barrens Bluet	0	0.0	37	0.4	271	2.0	0	0.0
Orange Bluet	0	0.0	154	1.6	4	<0.1	0	0.0
Slender Bluet	0	0.0	18	0.2	45	0.3	4	0.0
Vesper Bluet	0	0.0	3	<0.1	5	<0.1	0	0.0

Table 9 (continued). Species by town, total individuals, and individuals/survey for each Odonate species at Cape Cod National Seashore. Based on AllSitesAllYears data.

Species	Eastham		Wellfleet		Truro		Provincetown	
	Total Individuals	Individuals/ Survey	Total Individuals	Individuals/ Survey	Total Individuals	Individuals/ Survey	Total Individuals	Individuals/ Survey
Citrine Forktail	14	0.2	1	<0.1	0	0.0	18	0.2
Lilypad Forktail	0	0.0	378	3.9	10	0.1	8	0.1
Fragile Forktail	161	2.2	355	3.7	120	0.9	85	1.0
Rambur's Forktail	0	0.0	1	<0.1	0	0.0	0	0.0
Eastern Forktail	1538	20.8	2125	22.1	779	5.7	705	8.4
Sphagnum Sprite	643	8.7	0	0.0	1467	10.7	252	3.0
Canada Darner	2	0.0	0	0.0	0	0.0	0	0.0
Mottled Darner	0	0.0	44	0.5	44	0.3	4	0.0
Spatterdock Darner	0	0.0	3	<0.1	3	<0.1	0	0.0
Black-tipped Darner	43	0.6	3	<0.1	12	0.1	0	0.0
Green-striped Darner	2	<0.1	0	0.0	1	<0.1	0	0.0
Common Green Darner	137	1.9	158	1.6	111	0.8	112	1.3
Comet Darner	0	0.0	6	0.1	6	<0.1	6	<0.1
Harlequin Darner	3	0.0	0	0.0	5	<0.1	0	0.0
Lancet Clubtail	0	0.0	16	0.2	14	0.1	0	0.0
Common Sanddragon	0	0.0	67	0.7	13	0.1	0	0.0
Swift River Cruiser	0	0.0	3	<0.1	0	0.0	0	0.0
Petite Emerald	0	0.0	0	0.0	8	0.1	0	0.0
Common Baskettail	1	<0.1	11	0.1	31	0.2	1	<0.1
Prince Baskettail	0	0.0	20	0.2	4	<0.1	0	0.0
Calico Pennant	7	0.1	532	5.5	746	5.4	3	<0.1
Halloween Pennant	6	<0.1	61	0.6	22	0.2	0	0.0
Banded Pennant	0	0.0	39	0.4	11	0.1	0	0.0

Table 9 (continued). Species by town, total individuals, and individuals/survey for each Odonate species at Cape Cod National Seashore. Based on AllSitesAllYears data.

Species	Eastham		Wellfleet		Truro		Provincetown	
	Total Individuals	Individuals/ Survey	Total Individuals	Individuals/ Survey	Total Individuals	Individuals/ Survey	Total Individuals	Individuals/ Survey
Martha's Pennant	0	0.0	207	2.2	373	2.7	0	0.0
Eastern Pondhawk	1086	14.7	227	2.4	201	1.5	345	4.1
Seaside Dragonlet	1	<0.1	0	0.0	0	0.0	0	0.0
Blue Corporal	0	0.0	19	0.2	9	0.1	0	0.0
White Corporal	0	0.0	17	0.2	70	0.5	70	0.8
Frosted Whiteface	2	<0.1	0	0.0	0	0.0	0	0.0
Dot-tailed Whiteface	380	5.1	28	0.3	30	0.2	30	0.4
Golden-winged Skimmer	0	0.0	0	0.0	1	<0.1	0	0.0
Bar-winged Skimmer	8	0.1	0	0.0	1	<0.1	3	0.0
Spangled Skimmer	19	0.3	40	0.4	40	0.3	19	0.2
Slaty Skimmer	331	4.5	1241	12.9	1045	7.6	544	6.5
Needham's Skimmer	0	0.0	1	<0.1	11	0.1	0	0.0
Twelve-spotted Skimmer	9	0.1	1	<0.1	1	<0.1	4	<0.1
Four-spotted Skimmer	0	0.0	0	0.0	4	<0.1	2	0.0
Painted Skimmer	132	1.8	44	0.5	107	0.8	74	0.9
Great Blue Skimmer	3	0.0	0	0.0	0	0.0	0	0.0
Elfin Skimmer	0	0.0	0	0.0	0	0.0	6	<0.1
Blue Dasher	2645	35.7	835	8.7	354	2.6	906	10.8
Wandering Glider	1	<0.1	0	0.0	2	<0.1	0	0.0
Spot-winged Glider	1	<0.1	1	<0.1	25	0.2	1	<0.1
Eastern Amberwing	0	0.0	570	5.9	35	0.3	0	0.0
Common Whitetail	0	0.0	2	<0.1	0	0.0	2	<0.1
Saffron-winged Meadowhawk	0	0.0	14	0.1	25	0.2	0	0.0

Table 9 (continued). Species by town, total individuals, and individuals/survey for each Odonate species at Cape Cod National Seashore. Based on AllSitesAllYears data.

Species	Eastham		Wellfleet		Truro		Provincetown	
	Total Individuals	Individuals/ Survey	Total Individuals	Individuals/ Survey	Total Individuals	Individuals/ Survey	Total Individuals	Individuals/ Survey
Ruby Meadowhawk	1639	22.1	119	1.2	1183	8.6	535	6.4
Band-winged Meadowhawk	0	0.0	35	0.4	1	<0.1	0	0.0
Autumn Meadowhawk	96	1.3	281	2.9	410	3.0	11	0.1
Carolina Saddlebags	48	0.6	135	1.4	37	0.3	55	0.7
Black Saddlebags	2	<0.1	1	<0.1	1	<0.1	2	<0.1
TOTALS	12366	147	14562	106	14795	154	6109	83
# of Sites	9	–	13	–	9	–	10	–
# of Surveys	84	–	137	–	96	–	74	–
Mean Surveys / Site	9.3	–	10.5	–	10.7	–	7.4	–
Mean Species / Site	18.0	–	24.7	–	24.2	–	17.0	–
Number of Species	39	–	60	–	60	–	39	–

Results by Habitat

Abundance and Species Richness Overall – AllSitesAllYears

Not all habitats are equally represented within the seashore, and because we sampled habitats in proportion to their occurrence, they are not equally represented in these surveys (Table 10). Consequently, when comparing abundance results across habitats we have standardized the data as individuals/survey. Comparing species richness across habitats presents issues that are more difficult to resolve, due in part to the variation in flight seasons (e. g., species accumulation curves can be affected by variation in the timing of surveys within a given season) and also due to differences in sampling effort by habitat. As a simple, though imperfect, means of standardization we have calculated the average number of species/survey. As noted above, in annual samples based on equal sampling effort/site, average number of species/survey at sites is highly correlated with total number of species recorded. However, the strength of that correlation decreases as sampling effort becomes unequal. Thus, species accumulation (total number of species recorded by site or habitat) can be affected by sampling effort, which can be expressed as number of sites sampled per habitat, number of surveys per habitat, or number of surveys/site/habitat type. This latter is an attempt to standardize the sampling effort at sites of different habitat types. However, despite attempts at standardization, some of these results, particularly cumulative number of species (by habitat type or sites within habitat type) and total number of individuals are significantly correlated with sampling effort. This is particularly true in the AllSitesAllYears data (Table 10), where sampling intensity (Surveys/Site) varied by habitat and was greatest in kettle ponds and vernal pools. For these data, surveys/site by habitat had a significant positive correlation with total species ($r(10)=0.95$, $p=0.003$), mean species/site ($r(10)=0.91$, $p=0.011$) and total number of individual ($r(10)=0.95$, $p=0.004$) by habitat. In contrast, abundance by habitat (individuals/survey) is not significantly correlated with any measure of sampling effort, number of sites/habitat ($r(10)=0.48$, $p=0.33$), number of surveys by habitat ($r(10)=0.55$, $p=0.26$), or surveys/site by habitat ($r(10)=0.69$, $p=0.13$).

Abundance was greatest at vernal pools (173 individuals/survey) and kettle ponds (158/survey), whereas kettle ponds averaged more species/survey than vernal pools (10.6 vs. 7.8). Riparian marsh had the lowest number of individuals/survey (31) and species/survey (5.7) (Table 10). Total species recorded by habitat ranged from 60 in kettle pond to 14 in dune slack, which was represented by only one site.

Table 10. Sampling effort, species richness and abundance by habitat at Cape Cod National Seashore. Based on AllSitesAllYears data, all individuals, including those only identified to order/family.

Habitat	Sites	Surveys	Surveys/ Site	Total # Species	Species/ Site	Species/ Survey	Individuals	Individuals/ Survey	% Individuals
Bog	6	52	8.67	37	18	7.6	5645	109	11
Dune Slack	1	6	6.00	14	14	7.3	767	128	1
Inter-dune Pond	7	56	8.00	36	20	8.9	5144	92	10
Kettle Pond	15	177	11.80	60	27	10.6	28000	158	52
Riparian Marsh	4	24	6.00	26	15	5.7	740	31	1
Vernal Pool	8	76	9.50	39	18	7.8	13139	173	25
Total	41	391	9.54	74	21	8.8	53435	137	100%

Habitat Species Diversity and Abundance – AllSites1YearEach

Species diversity by habitat type was compared using single season values of all individuals identified to species from all sites within each habitat type. Mean diversity indices were highest at riparian sites and inter-dune ponds and lowest at dune slacks. Mean annual species richness was greatest at kettle ponds (23.3) and lowest at the one dune slack sampled (14). Kruskal-Wallis ranked ANOVA found significant differences between habitats in number of species, species/survey, and abundance (individuals/survey), but differences in Shannon and Simpson diversity indices were not significant (Table 11).

Pairwise tests showed significant differences in abundance between riparian sites and all other habitat types except dune slack, which was represented by one just site (Table 12). For all other between habitat pairs, differences in abundance were not significant. Pairwise tests also found significant differences in species richness between kettle pond sites and all other habitat types except dune slack, which was represented by one just site (Table 13). For all other between habitat pairs, differences in species richness were not significant. However, some of the between-habitat differences in species richness recorded here are probably due to differences in sampling effort. Total number of species recorded in a habitat was highly correlated with number of sites ($r(10)=0.99$, $p<0.001$), as was mean number of species at sites in a given habitat ($r(10)=0.94$, $p=0.005$). In contrast, for the AllSites1YearEach data, there were no significant correlations between any measure of sampling effort and mean number of species/survey by habitat, mean number of individuals/site by habitat, or mean individuals/survey.

Table 11. Mean site community metrics by habitat type at Cape Cod National Seashore. Values are means of sampling season data of individual sites. Based on AllSites1YearEach data, identified to species.

Habitat	#Sites	Surveys/ Site	# Individuals	Individuals/ Survey	# Species	Species/ Survey	Shannon Diversity Index H'	Simpson's Diversity Index D
Bog	6	6.3	626	102	18.2 (12-22)	8.2	1.870	0.746
Dune Slack	1	6.0	723	121	14 (14)	7.3	1.794	0.783
Inter-dune Pond	7	6.0	461	77	16.7 (13-22)	8.4	2.058	0.814
Kettle Pond	15	6.3	916	150	23.3 (16-29)	10.2	2.018	0.751
Riparian Marsh	4	6.0	136	23	15.3 (11-17)	5.7	2.228	0.863
Vernal Pool	8	6.3	643	97	16.5 (12-21)	7.0	1.805	0.757
All	41	6.2	662	107	19.0 (11-29)	8.5	1.977	0.774
Kruskal-Wallis ANOVA p	–	–	–	0.018 *	0.001 *	0.004 *	0.3481	0.446

* Values of $p < 0.05$ were considered significant

Table 12. Mean abundance (Individuals/Survey) of sites grouped by habitat type, and results of Mann-Whitney pairwise tests at Cape Cod National Seashore. Based on AllSites1YearEach data, identified to species.

Habitat	Individuals/ Survey	Bog	Dune Slack	Inter-dune Pond	Kettle Pond	Riparian Marsh
Bog	102	–	–	–	–	–
Dune Slack	121	0.449	–	–	–	–
Inter-dune Pond	77	0.886	0.190	–	–	–
Kettle Pond	150	0.459	1.000	0.180	–	–
Riparian Marsh	23	0.014 *	0.289	0.011 *	0.003 *	–
Vernal Pool	97	0.604	0.561	0.817	0.165	0.008 *

* Values of $p < 0.05$ were considered significant.

Table 13. Mean site species richness by habitat type and results of Mann-Whitney pairwise tests at Cape Cod National Seashore. Based on AllSites1YearEach data. Habitat total species is pooled data from all sites in a habitat type.

Habitat	#Sites	#Surveys	Habitat Total Species	Mean Site Species	Bog	Dune Slack	Inter-dune Pond	Kettle Pond	Riparian Marsh
Bog	6	38	32	18.2 (12-22)	—	—	—	—	—
Dune Slack	1	6	14	14.0 (14)	0.801	—	—	—	—
Inter-dune Pond	7	42	30	16.7 (13-22)	0.471	0.508	—	—	—
Kettle Pond	15	94	58	23.3 (16-29)	0.011 *	0.125	0.002 *	—	—
Riparian Marsh	4	24	26	15.3 (11-17)	0.238	0.717	0.443	0.009 *	—
Vernal Pool	8	50	36	16.5 (12-21)	0.471	0.558	0.861	0.001 *	0.864

* Values of $p < 0.05$ were considered significant.

Distribution of Sub-order/Family by Habitat – AllSitesAllYears

Although both suborders (dragonflies and damselflies) were represented in every habitat, there were some differences in their relative distributions. Damselflies comprised 60% of individuals recorded in surveys overall but were overrepresented in kettle ponds (70% of individuals) and underrepresented in riparian marshes (37%) and vernal pools (45%). Conversely, dragonflies were relatively underrepresented in kettle ponds (30% of individuals) (Table 14).

Table 14. Suborders by habitat (# and % of species and individuals) at Cape Cod National Seashore. Based on AllSitesAllYears data, identified to species.

Habitat	Dragonflies (Anisoptera)		Damselflies (Zygoptera)	
	# and % of Species	# and % of Individuals	# and % of Species	# and % of Individuals
Bog	28 (76)	2496 (48)	9 (24)	2677 (52)
Dune Slack	7 (50)	315 (44)	7 (50)	408 (56)
Inter-dune Pond	19 (53)	2127 (45)	17 (47)	2595 (55)
Kettle Pond	35 (58)	7803 (30)	25 (42)	17882 (70)
Riparian Marsh	18 (69)	342 (63)	8 (31)	202 (37)
Vernal Pool	23 (59)	6032 (55)	16 (41)	4951 (45)
Totals	45 (61)	19115 (40)	29 (39)	28715 (60)

For specific families, distribution by habitat varied, with five of eight families recorded in all or nearly all habitats and the other three limited to one or two. However, even widespread families tended to be most abundant/frequent in only some habitats (Tables 15, 16, 17, 18, 19).

Pond damsels (Coenagrionidae) occurred in every habitat (Table 15, 16), although with a substantial majority (70% of individuals) at kettle ponds (Table 17). Skimmers (Libellulidae) were widespread and found in every habitat (Table 15, 16), but most abundant at kettle ponds (40% of individuals) and vernal pools (32%). (Table 17). They were the most frequently encountered family in every habitat type (Table 18), though to some degree this reflects their conspicuousness (relatively large size, often bright coloration, and tendency to perch in the open). These two most speciose families, Pond Damsels and Skimmers were both most frequently encountered at kettle ponds (Table 19). Spreadwings (Lestidae) were also widespread, but most numerous at kettle ponds, vernal pools, and inter-dune ponds and much less abundant and frequent in other habitats (Table 17, 19). Darners (Aeshnidae) were found in every habitat except the one dune slack, but almost half (49%) were at kettle ponds. (Table 15, Table 17).

Table 15. Distribution of families by habitat (# of species recorded in each habitat) at Cape Cod National Seashore.

Family	Habitat					
	Bog	Dune Slack	Inter-dune Pond	Kettle Pond	Riparian Marsh	Vernal Pool
Spreadwings (Lestidae)	5	3	7	6	2	5
Broad-winged Damselfs (Calopterygidae)	0	0	0	1	1	0
Pond Damselfs (Coenagrionidae)	4	4	10	18	5	11
Damselfs (Aeshnidae)	5	1	3	6	1	4
Clubtails (Gomphidae)	1	0	0	2	0	0
Cruisers (Macromiidae)	0	0	0	1	0	0
Emeralds (Corduliidae)	2	0	1	2	1	1
Skimmers (Libellulidae)	20	6	15	24	16	18
Totals	37	14	36	60	26	39

Table 16. Relative abundance of families within habitats (% of individuals recorded within each habitat, by family); includes all individuals identified to at least family level at Cape Cod National Seashore. Columns sum to 100.

Family	Habitat						All Habitats
	Bog	Dune Slack	Inter-dune Pond	Kettle Pond	Riparian Marsh	Vernal Pool	
Spreadwings (Lestidae)	9	25	29	9	5	20	14
Broad-winged Damselfs (Calopterygidae)	0	0	0	0	1	0	<1
Pond Damselfs (Coenagrionidae)	43	31	26	60	30	25	46
Damselfs (Aeshnidae)	1	0	2	1	5	2	1
Clubtails (Gomphidae)	0	0	0	<1	0	0	<1
Cruisers (Macromiidae)	0	0	0	<1	0	0	<1
Emeralds (Corduliidae)	1	0	0	<1	1	0	<1
Skimmers (Libellulidae)	47	43	43	28	57	53	38

Table 17. Relative abundance within a family across habitats (% of individuals of a family by habitat): includes all individuals identified to at least family level at Cape Cod National Seashore. Rows sum to 100.

Family	Habitat					
	Bog	Dune Slack	Inter-dune Pond	Kettle Pond	Riparian Marsh	Vernal Pool
Spreadwings (Lestidae)	7	3	20	36	<1	34
Broad-winged Damselflies (Calopterygidae)	0	0	0	75	25	0
Pond Damselflies (Coenagrionidae)	10	1	6	70	1	12
Darners (Aeshnidae)	7	<1	17	49	4	24
Clubtails (Gomphidae)	1	0	0	99	0	0
Cruisers (Macromiidae)	0	0	0	100	0	0
Emeralds (Corduliidae)	37	0	1	54	7	1
Skimmers (Libellulidae)	13	2	11	40	2	32
All Families	11	2	10	54	1	23

Table 18. Frequency of families within habitats at Cape Cod National Seashore. % of surveys in a given habitat within which each family was recorded. Columns sum to 100.

Family	Habitat						All Habitats
	Bog	Dune Slack	Inter-dune Pond	Kettle Pond	Riparian Marsh	Vernal Pool	
Spreadwings (Lestidae)	12	18	18	8	8	15	11
Broad-winged Damselflies (Calopterygidae)	0	0	0	1	1	0	<1
Pond Damselflies (Coenagrionidae)	23	30	21	37	26	23	30
Darners (Aeshnidae)	8	5	12	8	7	11	9
Clubtails (Gomphidae)	<1	0	0	3	0	0	1
Cruisers (Macromiidae)	0	0	0	<1	0	0	<1
Emeralds (Corduliidae)	3	0	<1	1	1	<1	1
Skimmers (Libellulidae)	55	48	49	43	58	51	47

Table 19. Frequency within a family across habitat types at Cape Cod National Seashore. % of surveys in which each family was recorded across habitats. Rows sum to 100.

Family	Habitat					
	Bog	Dune Slack	Inter-dune Pond	Kettle Pond	Riparian Marsh	Vernal Pool
Spreadwings (Lestidae)	12	2	23	38	3	23
Broad-winged Damselfs (Calopterygidae)	0	0	0	86	14	0
Pond Damselfs (Coenagrionidae)	9	1	10	64	3	13
Darners (Aeshnidae)	10	1	18	47	3	21
Clubtails (Gomphidae)	2	0	0	98	0	0
Cruisers (Macromiidae)	0	0	0	100	0	0
Emeralds (Corduliidae)	25	0	3	68	3	3
Skimmers (Libellulidae)	13	1	15	48	5	18
All Families	11	1	14	53	4	17

The two species of clubtails (Gomphidae) were all at kettle ponds with the one exception of a wandering individual at a bog. (Table 15, 17). The three species of emeralds (Corduliidae) were split primarily between two habitats, with two species, Common Baskettail and Prince Baskettail, almost all at kettle ponds, while the third, Petite Emerald, is exclusively a bog inhabitant. Table 17. Broad-winged Damsels (Calopterygidae), represented by just one species, the Ebony Jewelwing, are lotic species, the few records coming only from Herring River and Herring Pond at the river outlet. (Table 15, Table 17). The one cruiser (Macromiidae) species was recorded just once, though the species is elusive and likely a regular breeder at the largest kettle ponds. (Table 15, 17).

Distribution of Species by Habitat – AllSitesAllYears

Three species were recorded in every habitat type: Slender Spreadwing, Fragile Forktail, and Common Green Darner, while nine additional species were recorded in all but one habitat type (Table 20).

Table 20. Relative abundance of species by habitat (% of individuals/survey) at Cape Cod National Seashore. Based on AllSitesAllYears data.

Species	Habitat					
	Bog	Dune Slack	Inter-dune Pond	Kettle Pond	Riparian Marsh	Vernal Pool
Spotted Spreadwing	0	0	8	0	0	92
Northern Spreadwing	1	0	1	98	0	0
Amber-winged Spreadwing	5	3	35	3	0	55
Sweetflag Spreadwing	5	20	10	9	0	57
Elegant Spreadwing	0	0	41	54	1	4
Slender Spreadwing	14	27	9	8	2	41
Swamp Spreadwing	1	0	17	82	0	0
Ebony Jewelwing	0	0	0	86	14	0
Eastern Red Damsel	0	0	0	0	100	0
Variable Dancer	0	0	0	100	0	0
Taiga Bluet	0	0	0	0	0	100
Northern Bluet	0	16	58	1	0	24
Azure Bluet	5	0	9	27	0	60
Familiar Bluet	0	0	0	100	0	0
Attenuated Bluet	0	0	0	99	0	1
Atlantic Bluet	0	0	0	100	0	0
Skimming Bluet	0	0	0	98	1	1
New England Bluet	0	0	67	25	0	8
Little Bluet	0	0	0	100	0	0
Pine Barrens Bluet	0	0	0	100	0	0
Orange Bluet	0	0	0	100	0	0
Slender Bluet	0	0	8	92	0	0
Vesper Bluet	0	0	0	100	0	0

Table 20 (continued). Relative abundance of species by habitat (% of individuals/survey) at Cape Cod National Seashore. Based on AllSitesAllYears data.

Species	Habitat					
	Bog	Dune Slack	Inter-dune Pond	Kettle Pond	Riparian Marsh	Vernal Pool
Citrine Forktail	0	76	5	3	0	16
Lilypad Forktail	0	0	3	93	4	0
Fragile Forktail	7	4	8	25	2	55
Rambur's Forktail	0	0	0	100	0	0
Eastern Forktail	3	23	6	25	0	44
Sphagnum Sprite	65	0	0	0	0	35
Canada Darner	0	0	0	100	0	0
Mottled Darner	2	0	6	93	0	0
Spatterdock Darner	0	0	0	24	0	76
Black-tipped Darner	16	0	0	2	0	82
Green-striped Darner	100	0	0	0	0	0
Common Green Darner	4	3	17	28	1	46
Comet Darner	0	0	41	59	0	0
Harlequin Darner	43	0	0	0	0	57
Lancet Clubtail	5	0	0	95	0	0
Common Sanddragon	0	0	0	100	0	0
Swift River Cruiser	0	0	0	100	0	0
Petite Emerald	100	0	0	0	0	0
Common Baskettail	55	0	3	32	4	6
Prince Baskettail	0	0	0	100	0	0
Calico Pennant	2	0	0	97	0	1
Halloween Pennant	18	0	0	78	1	3
Banded Pennant	0	0	0	100	0	0

Table 20 (continued). Relative abundance of species by habitat (% of individuals/survey) at Cape Cod National Seashore. Based on AllSitesAllYears data.

Species	Habitat					
	Bog	Dune Slack	Inter-dune Pond	Kettle Pond	Riparian Marsh	Vernal Pool
Martha's Pennant	1	0	0	99	0	0
Eastern Pondhawk	9	9	8	8	0	66
Seaside Dragonlet	0	0	0	100	0	0
Blue Corporal	0	0	0	97	3	0
White Corporal	2	0	51	47	0	0
Frosted Whiteface	0	0	0	0	0	100
Dot-tailed Whiteface	4	0	3	3	0	90
Golden-winged Skimmer	0	0	0	100	0	0
Bar-winged Skimmer	9	49	0	0	0	43
Spangled Skimmer	33	0	12	20	1	33
Slaty Skimmer	5	2	17	54	0	23
Needham's Skimmer	46	0	0	23	31	0
Twelve-spotted Skimmer	0	0	16	9	0	75
Four-spotted Skimmer	100	0	0	0	0	0
Painted Skimmer	23	32	1	4	0	40
Great Blue Skimmer	0	0	0	0	0	100
Elfin Skimmer	100	0	0	0	0	0
Blue Dasher	4	4	9	8	0	74
Wandering Glider	50	0	0	0	0	50
Spot-winged Glider	0	0	10	5	67	19
Eastern Amberwing	0	0	0	99	1	0
Common Whitetail	0	0	57	43	0	0
Saffron-winged Meadowhawk	0	0	0	100	0	0

Table 20 (continued). Relative abundance of species by habitat (% of individuals/survey) at Cape Cod National Seashore. Based on AllSitesAllYears data.

Species	Habitat					
	Bog	Dune Slack	Inter-dune Pond	Kettle Pond	Riparian Marsh	Vernal Pool
Ruby Meadowhawk	21	28	4	2	0	44
Band-winged Meadowhawk	9	0	0	0	91	0
Autumn Meadowhawk	10	0	1	61	0	28
Carolina Saddlebags	2	0	20	50	0	28
Black Saddlebags	13	0	27	7	0	53
Totals	9	11	8	31	<1	41

Bogs

Six bogs were surveyed a total of 52 times, yielding 37 species (mean=18/site) and an average of 109 individuals/survey (Table 10). Twenty-eight of the species (76%) were dragonflies, a considerably higher percentage than any other habitat, though dragonflies comprised only 48% of the individuals recorded (Table 14). Skimmers (Libellulidae, 47%), pond damsels (Coenagrionadae, 43%), and spreadwings (Lestidae, 9%) comprised almost the entire odonate fauna at the surveyed bogs (Table 16).

The most characteristic species at bogs is the appropriately-named Sphagnum Sprite, a tiny, bright green damselfly that is an obligate inhabitant of sphagnum mats and can be abundant—though very inconspicuous—at sites, including vernal pools, where sphagnum is also present. Other species found either exclusively or most frequently at bogs are Black-tipped Darner, Green-striped Darner, Harlequin Darner, Petite Emerald, Common Baskettail, Four-spotted Skimmer, and Elfin Skimmer. Several more generalist species, such as Sweetflag Spreadwing, Azure Bluet, Fragile Forktail, Eastern Pondhawk, Spangled Skimmer, Slaty Skimmer, Painted Skimmer, and Blue Dasher are often present at bog pools.

Dune Slacks

Only one dune slack was included in the surveys, P05 in Provincetown, one of the largest slacks in CACO. In fact, Smith et al. (2008, 2020) characterized this site as an inter-dune pond, though it is densely vegetated with cranberry, and its hydrology seems more typical of a dune slack.

In large part because of their temporary nature, the odonate fauna of dune slacks is less diverse than at the more permanent inter-dune ponds. Fourteen species were recorded at P05 (Table 10); given its relatively large size the odonate diversity here likely is greater than at the smaller, more typical slacks. Dominant species here were Sweetflag Spreadwing, Eastern Forktail, and Ruby Meadowhawk. This site had standing water throughout the season it was surveyed (2017), which may have resulted in higher than normal numbers of odonates. The species richness was divided evenly between dragonflies and damselflies, while 56% of the individuals were damselflies (Table 14). Skimmers (43%), pond damsels (31%), and spreadwings (25%) comprised the bulk of individuals here (Table 16).

Inter-dune Ponds

Seven sites categorized as inter-dune ponds were surveyed: 56 surveys yielded 36 species and 92 individuals/survey (Table 10). Dragonflies comprised 53% of the species and 45% of the individuals (Table 14). The most common families by frequency recorded were skimmers (49% of individuals), pond damsels (21%), and spreadwings (18%) (Table 18). Characteristic species include Amber-winged Spreadwing, Northern Bluet, New England Bluet, and White Corporal (Table 20). Despite their similarity to kettle ponds, at least superficially, inter-dune ponds host a very different odonate fauna: lower species richness (mean=20 species/site, seven fewer than kettle ponds), fewer species/survey, and with fewer individuals (92/survey versus 158/survey; Table 10). The coastal plain specialists, so typical of kettle ponds, are absent or very rare in these dunal ponds. On the other hand, many of the most common species at inter-dune ponds are rare to absent at kettle ponds. The odonate fauna, in fact, is more similar to that of vernal pools than to kettle ponds. Based on

AllSites1YearEach, similarity between inter-dune ponds and vernal pools is 54.7% and for kettle ponds it is 45.1%.

Kettle Ponds

Fifteen kettle ponds were surveyed a total of 177 times, with an average of 158 individuals/survey and an overall total of 60 species (mean=27/site) of odonates recorded (Table 10). Damselflies comprised 70% of the total individuals, a much higher percentage than in any other habitat, but just 42% of the total species (Table 14). Within this habitat, pond damselflies (family Coenagrionidae) comprised 60% of the total individuals, with pond skimmers (Libellulidae) comprising 28% of the total individuals (Table 16). Seventy percent of all the pond damselflies (family Coenagrionidae) recorded on these surveys were at kettle ponds, as were 36% of all spreadwings (Lestidae), 49% of darners (Aeshnidae), 40% of pond skimmers (Libellulidae) and virtually all (99%) of the few clubtails (Gomphidae) (Table 18). Only vernal pools host a comparable abundance and diversity of odonates.

Species that reach their greatest abundance at kettle ponds include Swamp Spreadwing, Variable Dancer, Familiar Bluet, Atlantic Bluet, Skimming Bluet, Little Bluet, Lilypad Forktail, Eastern Forktail, Mottled Darner, Common Green Darner, Lancet Clubtail, Common Sanddragon, Calico Pennant, Martha's Pennant, Blue Corporal, Slaty Skimmer, Eastern Amberwing, Autumn Meadowhawk, and Carolina Saddlebags. Evidence of the importance of kettle ponds to the local odonate fauna is that 16 species were recorded only at these sites (though three of these were represented by only one or two records and were likely wandering vagrants). For an additional 11 species >90% of the total individuals were at kettle ponds (Table 20).

A number of species considered coastal plain specialists, most at or near the northern edge of their range in southeastern Massachusetts, including several of conservation concern, are found exclusively at kettle ponds. Foremost among these are two state-listed species, Attenuated Bluet and Pine Barrens Bluet, both of which are common inhabitants at several, though not all, of the kettle ponds. A third state-listed species, the Scarlet Bluet, although not recorded on these surveys, is known historically from two kettle ponds.

Riparian Marsh

These four sites had some of the lowest species richness recorded on the surveys (mean=15 species/site), as well as very few individuals (31/survey; Table 10)). Salt Meadow Big Pool had the lowest species richness (11 species) of any site, as well as the fewest individuals (21/survey; Table 4); at least two of the species recorded here, Common Green Darner and Spot-winged Glider, were likely migrants, not residents. However, it was the only site where Needham's Skimmer occurred regularly; this species is most often found in brackish habitats.

The 17 species recorded at Fresh Brook were characteristic of lentic habitats. Most of the 17 species recorded at the two sites on Herring River were also generalist lentic species, but two species occurring here were not recorded elsewhere: Eastern Red Damsel and Band-winged Meadowhawk. Both of these are associated with seepage areas and some of the damselflies frequented the outer edges of the river floodplain, as much as 150 meters from the river itself.

Vernal Pools

Eight vernal pools were surveyed 76 times, yielding 39 species (mean=18/site) and 173 individuals/survey (Table 10); only kettle ponds averaged nearly as many individuals, though species richness was lower at vernal pools. Fifty-nine percent of the species and 55% of the individuals recorded at vernal pools were dragonflies (Table 14). The most numerous families were skimmers (53% of individuals), pond damsels (25%), and spreadwings (20%) (Table 16). Characteristic species include Sweetflag Spreadwing, Eastern Forktail, Fragile Forktail, Common Green Darner, Eastern Pondhawk, Dot-tailed Whiteface, Painted Skimmer, Blue Dasher, and Ruby Meadowhawk.

Some of the wetlands classified as vernal pools within CACO have extensive sphagnum mats, floating mats in some cases, and thus are similar in many aspects to bogs. Indeed, two such sites (T01 and E08) previously classified as vernal pools were re-classified as bogs for this study. Similarity between vernal pools and bogs was 60.7%, second only to 64.6% between vernal pools and dune slacks. Some of the smaller pools (e. g., E05 Main Pool, E06, and E20) have become almost completely overgrown with dense, nearly impenetrable water willow (*Decodon verticillatus*), small pools in the center in each being the only open area remaining; consequently, these sites had fewer species and individuals than the less shrubby, more open sites (e. g., E09, E10; Table 4).

Community Analysis and Environmental Factors – ID to Species

3YearSites

Single factor PERMANOVA models of data pooled across years for each 3YearSite found the effects of all environmental factors under consideration to be significant. However, the Estimated Components of Variation values (%ECV) indicate that habitat type and presence/absence of predaceous fish had highest value in explaining variability in community composition among sites (Table 21).

Table 21. Comparison of single factor PERMANOVA models for 3YearSites data, years pooled, showing estimated components of variation (%ECV) for each factor and residual at Cape Cod National Seashore.

Factor	p	%ECV	Residual %ECV
Habitat	0.0004*	60	40
Predaceous Fish	0.0033*	59	41
Hydroperiod	0.0079*	54	47
Depth Category	0.0092*	47	53

* Values of $p < 0.05$ were considered significant

Analysis of 3YearSites by years found that in a two-factor model, Site x Year, both factors were significant, but differences among sites played a larger role than years in explaining variation (Table 22). However, three factor models in which sites are nested in environmental factors explained more of the variation (i.e., had smaller residual %ECV). The small differences in Residual % ECV among the four nested models suggest they all have value in explaining variability. Collectively, these models indicate that although there was significant within-site annual variation, it only accounted for

roughly 9% of total variation, whereas environmental factors were the most important factor in the top 3, followed by between site variation within environmental factor groups. Of the environmental factors, the two with highest %ECV are Predaceous Fish and Habitat (Table 22).

Table 22. Results of PERMANOVA for 10 sites sampled for three consecutive years at Cape Cod National Seashore. Factor %ECV (% estimated components of variation) represents the relative importance of each factor in explaining overall variation.

Model	Residual %ECV	Factor	p	Factor %ECV
Year x Site	29.1	Year	0.0168 *	12.4
	29.1	Site	0.0001 *	58.5
Year x Site (Predaceous Fish)	20.7	Year	0.0158 *	8.9
	20.7	Predaceous Fish	0.0044 *	42.6
	20.7	Site (Predaceous Fish)	0.0001 *	27.8
Year x Site (Hydroperiod)	20.7	Year	0.0167 *	8.8
	20.7	Hydroperiod	0.0090 *	38.1
	20.7	Site (Hydroperiod)	0.0001 *	32.4
Year x Site (Habitat)	21.5	Year	0.0146 *	9.2
	21.5	Habitat	0.0009 *	42.3
	21.5	Site(Habitat)	0.0001 *	26.9
Year x Site (Depth Category)	21.6	Year	0.0156 *	9.2
	21.6	Depth Category	0.0101 *	33.1
	21.6	Site (Depth Category)	0.0001 *	36.1

* Values of $p < 0.05$ were considered significant

Multidimensional Scaling (MDS), based on a Bray-Curtis Similarity Matrix, depicts how similar/dissimilar sites are to each other. When labelled by factor levels, the degree to which sites with the same factor level cluster together provides a visual representation of how important that factor is in explaining variation in community composition. Plots of each site by year sample show, for most sites, that all three years are clustered close together and that between-year differences at a site are less than between-site differences (Figure 6). This is consistent with the relatively low value of %ECV for year effect. In addition, the clustering of kettle ponds with predaceous fish on the left and all other habitat type sites without predaceous fish on the right is consistent with the high values of %ECV for factors habitat type and presence/absence of fish.

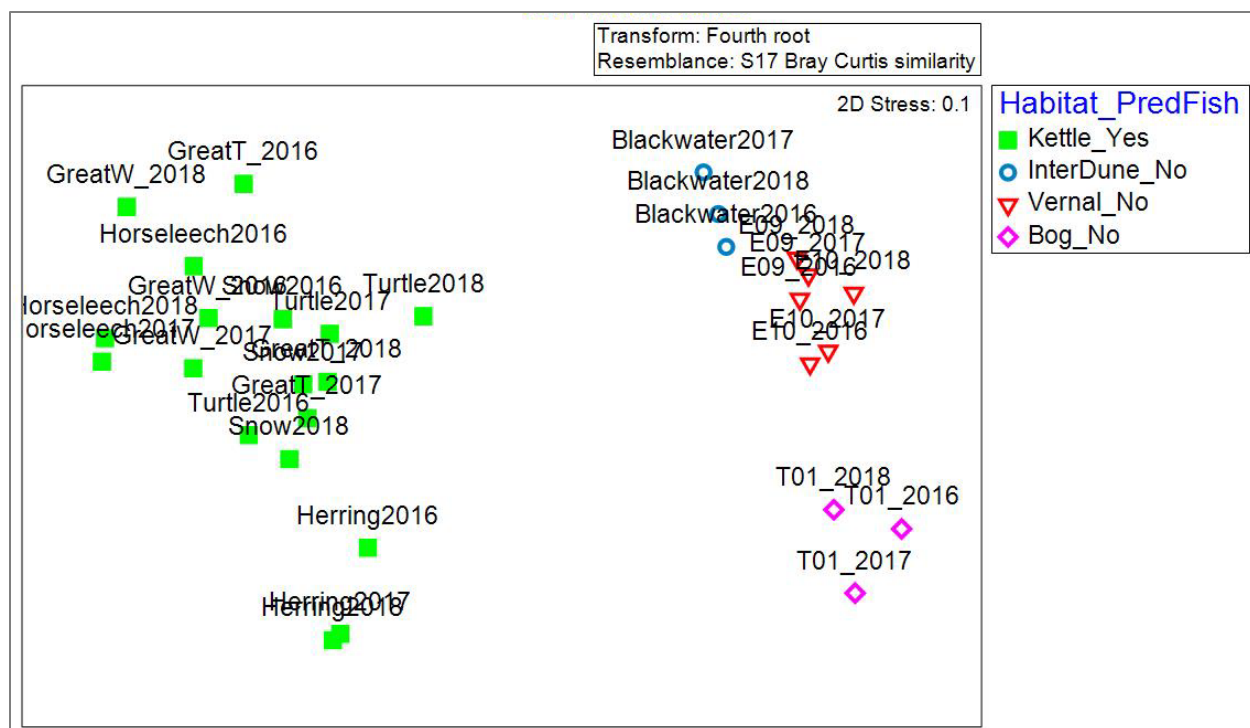


Figure 6. Multidimensional Scaling (MDS) plot of 3YearSites group data by year, showing sites and their factor levels for habitat type and presence of predaceous fish at Cape Cod National Seashore.

AllSites1YearEach

Single factor PERMANOVA of AllSites1YearEach, which consists of a single annual sample from each of the 41 sites surveyed, found that the effects of all environmental factors under consideration were significant. However, two factor crossed models explain more of the variation (i.e., had smaller residual %ECV). All of the two factor models showed significant effects for at least one factor, but the model Depth Category x Habitat was relatively better in explaining variation in community composition than the other models (Table 23).

The MDS plot of these 41 sites (Figure 7) shows sites clustered to varying degrees by habitat type, particularly kettle ponds on the left, riparian sites to lower right center, inter-dune ponds upper center and vernal pools and bogs further to the right. All the deep sites are kettle ponds, clustered on the left side. These patterns of clustering are consistent with the high values of %ECV for habitat type and depth category. Plots labelled with levels of other two-factor pairs would show similar, but slightly more dispersed clustering by factor levels.

Table 23. Results of PERMANOVA for AllSites1YearOnly group data at Cape Cod National Seashore.

Model	Residual %ECV	Factor	p	Factor %ECV
Depth Category	51.0%	Depth Category	0.0001 *	49
Habitat	54.0%	Habitat	0.0000 *	46

*Values of $p < 0.05$ were considered significant.

Table 23 (continued). Results of PERMANOVA for AllSites1YearOnly group data at Cape Cod National Seashore.

Model	Residual %ECV	Factor	p	Factor %ECV
Predaceous Fish	59.0%	Predaceous Fish	0.0001 *	41
Hydroperiod	64.0%	Hydroperiod	0.0001 *	36
Depth Category x Habitat	41.6%	Depth Category	0.0013 *	30
	41.6%	Habitat	0.0001 *	28
Hydroperiod x Depth Category	43.7%	Hydroperiod	0.0071 *	18
	43.7%	Depth Category	0.0001 *	38
Depth Category x Predaceous Fish	44.3%	Predaceous Fish	0.0030 *	35
	44.3%	Depth Category	0.0001 *	21
Habitat x Predaceous Fish	44.4%	Habitat	0.0001 *	33
	44.4%	Predaceous Fish	0.0024 *	23
Hydroperiod x Predaceous Fish	57.3%	Predaceous Fish	0.0007 *	33
	57.3%	Hydroperiod	0.2161	10

*Values of $p < 0.05$ were considered significant.

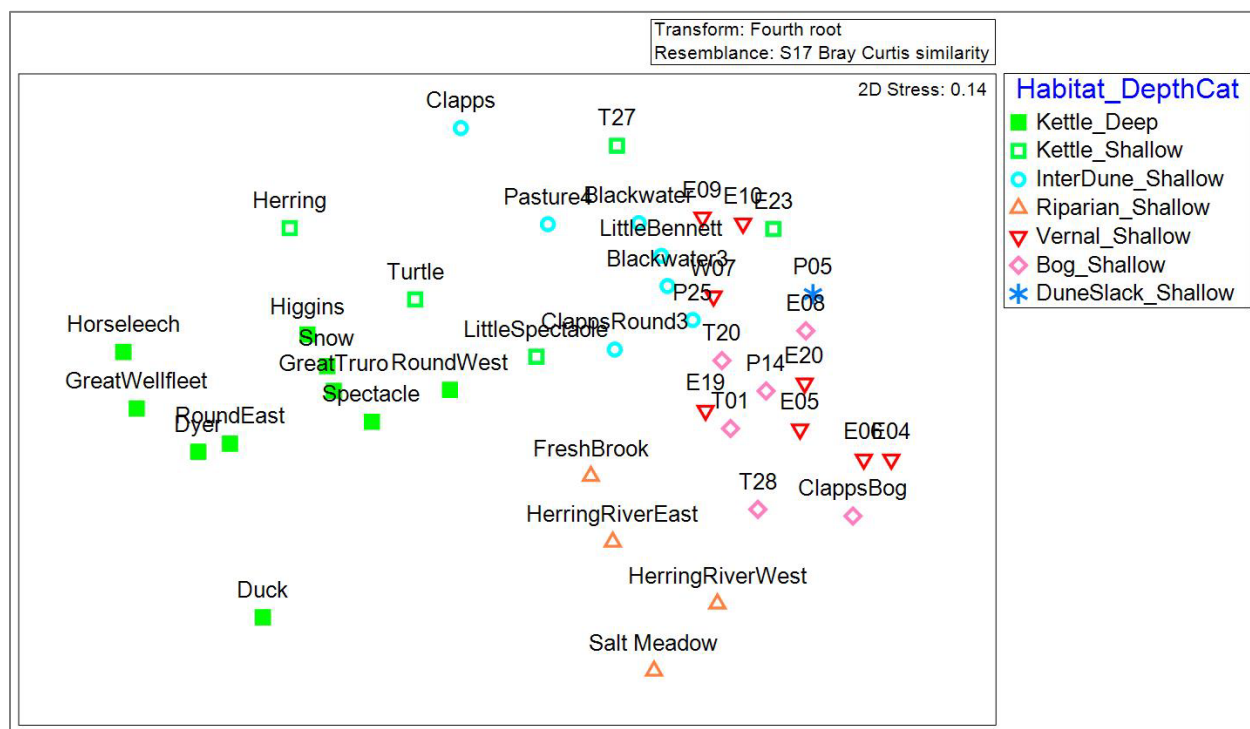


Figure 7. Multidimensional Scaling (MDS) plot of AllSites1YearOnly group data, showing sites and their factor levels for habitat type and depth category at Cape Cod National Seashore.

Community Similarity by Habitats and Towns

Percent Similarity (SIMPER) provides a measure of community similarity within and between factor levels. For factor Habitat, within-habitat similarity ranged from 66.5 to 52.6 (mean 61) and between-habitat similarity ranged from 64.6 to 36.3 (mean 49). The greatest similarity was between vernal pond-dune slack and vernal pond-bog, and the lowest was between kettle ponds and all other habitats (pair ranks 11-15, Table 24). Based on means of between habitat similarities for each habitat type, vernal pools have the highest degree of similarity to all other habitats (53.5%), with dune slack (52.9%), bog (52.0%) and inter-dune (51.5%) close behind. In contrast, riparian community sites (46.3%) and kettle ponds (39.5%) are least similar to other habitats. Consistent with this, kettle ponds had significantly greater mean species richness than all other habitats (Table 11, 13).

Table 24. Percent similarity within and between (pairs ranked 1 to 15) habitat types at Cape Cod National Seashore. Based on single factor SIMPER of AllSites1YearEach data, identified to species.

Habitat (# sampled)	Inter-dune Pond	Vernal Pool	Kettle Pond	Bog	Dune Slack	Riparian Marsh
Inter-dune Pond (7)	66.5 *	—	—	—	—	—
Vernal Pool (8)	54.7 (5)	61.1 *	—	—	—	—
Kettle Pond (15)	45.1 (11)	37.7 (14)	52.6 *	—	—	—
Bog (6)	52.0 (6)	60.7 (2)	38.9(13)	65.9 *	—	—
Dune Slack (1)	58.8 (4)	64.6 (1)	36.3 (15)	59.0 (3)	NA	—
Riparian Marsh (4)	47.2 (9)	49.8 (7)	39.7 (12)	49.3 (8)	45.6 (10)	58.0 *

* Percent similarity within

By towns, site community similarity was greatest between Provincetown and Eastham (56.5%), followed by Provincetown and Truro (47.9%), Truro and Wellfleet (47.4%), Truro and Eastham (46.8%), Provincetown and Wellfleet (43.0%), and Wellfleet and Eastham (40.1%). This reflects the geographic distribution of habitat types by town at CACO (Table 8) and their degree of similarity (Table 24).

Limitations to PERMANOVA and SIMPER

There were some limitations to these analyses. For some, the designs are unbalanced, with limited numbers of sites within some factor groups. In instances where a factor group contained only one or no sites, it was not possible to calculate within-group similarity or variability. In addition, with two-factor analysis, some cross factor calculations and interaction terms were not possible due to empty cells. For example, in a two factor Habitat Type x Hydroperiod analysis, because all the vernal pools sampled are semi-permanent and all the kettle ponds sampled are permanent, it is not possible to calculate similarity between permanent vernal pools and kettle ponds, nor between semi-permanent kettle ponds and vernal pools, because such pairings do not exist. There is also a high degree of collinearity between the categorical environmental factors, such as depth category and hydroperiod, which play a key role in defining habitat types and determining if a site is capable of supporting predaceous fish. Values of Cramer's V, a measure of the strength of association between two categorical factors found strong and significant associations between all environmental factors.

Annual Variation Results – 3YearSites

Annual Variation in Abundance by Order/Family

The 10 three-year sites provide some sense of annual variation. Each was surveyed eight times in 2016 (except for one missed survey at Horseleech Pond) and six times each in 2017 and 2018.

Based on the four families that dominated abundance and species, the average number of individuals (all families combined) per survey increased over the three years, from 136 individuals/survey in 2016 to 240/survey in 2018, an increase of 76%. This change was almost entirely attributable to changes in damselfly (Zygoptera) populations, which increased from 68 individuals/survey in 2016 to 164/survey in 2018, an increase of 144%. In contrast, dragonfly (all Anisoptera) numbers were relatively unchanged. These differences in the extent of annual variation by taxonomic groups are seen in the higher coefficients of variation (CV) among the damselflies (Zygoptera) (Table 25).

Table 25. Mean number of individuals / survey at 3YearSites, by year and select taxonomic groups at Cape Cod National Seashore. Based upon all survey records identified at least to family.

Family (sub-order)	Mean Individuals / Survey			Group Mean	Coefficient of Variation %
	2016	2017	2018		
Coenagrionidae (Zygoptera)	54.3	64.9	148.7	89	47
Lestidae (Zygoptera)	13.3	42.8	14.9	24	57
All Zygoptera (damselflies)	68	108	164	113	35
Libellulidae (Anisoptera)	64.7	70.4	69.8	68	4
Aeshnidae (Anisoptera)	3.3	2.5	2.8	3	12
All Anisoptera (dragonflies)	68	73	76	73	5
All Families	136	181	240	186	23

Repeated measures ANOVA found significant differences in abundance between sites and years in the four taxonomic groups that included any damselflies (Zygoptera), as well as in the Anisopteran family Aeshnidae (darners). In contrast, there were no annual differences in the Anisopteran family Libellulidae (common skimmers) nor for all Anisoptera combined (Table 26). Based on results of Tukey between-year tests, these differences appear to be primarily due to the greater numbers of pond damsels (Coenagrionidae) recorded in 2018 (Table 25). The taxonomic groups that varied significantly by years were those with high coefficients of variation.

Table 26. Results (values of p) of repeated measures ANOVA for effects of sites and year, by select taxonomic groups, based on standardized abundance of all individuals identified to at least family level at 3YearSites at Cape Cod National Seashore.

Family (sub-order)	ANOVA p values		Tukey HSD Q test p values		
	Sites	Years	2016–2017	2016–2018	2017–2018
Coenagrionidae (Zygoptera)	0.00100 *	0.001 *	0.9998	0.003 *	0.004 *
Lestidae (Zygoptera)	0.00200 *	0.046 *	0.0520	0.903	0.118
All Zygoptera (damselflies)	0.00700 *	0.005 *	0.1290	0.004 *	0.220
Libellulidae (Anisoptera)	0.00004 *	0.427	0.9830	0.550	0.449
Aeshnidae (Anisoptera)	0.00001 *	0.042 *	0.0360 *	0.193	0.649
All Anisoptera (dragonflies)	0.00004 *	0.256	0.9780	0.375	0.281
All Families	0.00100 *	0.009 *	0.3050	0.007 *	0.145

* Values of $p < 0.05$ were considered significant

Annual Variation in Site Abundance, Species Richness, and Diversity

Analysis of the 3YearSites, using all individuals identified to family (All Families), shows patterns of variation in abundance at the site level similar to that observed within families. Although mean numbers of individuals for all sites combined increased annually from 2016 to 2018, some sites recorded their maxima in 2017 (E09, E10, Turtle Pond). Moreover, similar to taxonomic groups, there was considerable variation across years in site coefficient of variation, ranging from a high of 51% at Horseleech Pond to a low of 8% at Blackwater Pond (Table 27). There was significant variation in abundance due to both sites and years, with significant differences between 2016 and 2018 (Table 28). The lower values of p for sites (0.001) compared to years (0.009), as well as higher coefficients of variation between sites within a year than between years within a site (Table 27), indicate that abundance between sites was generally more variable than between years.

Mean number of species recorded was greatest in 2018 (25.3) and sites with the highest mean number of species were Herring, Turtle, Great Wellfleet, and Great Truro. Number of species at sites were more stable than abundance, as seen in the lower coefficients of variation for species (Table 29). However, as with abundance, between-site variation in a year tended to be greater than between-years at a site (Site CV). Differences in number of species were significant between sites ($p=0.003$) and across years ($p=0.005$), and post-hoc tests found significant between-year differences between 2016–2017 and 2017–2018 (Table 28). The total number of species recorded at a site over three years was significantly greater than the site mean (Kruskal-Wallis $H(11)=9.61$, $p=0.002$).

Species diversity varied over the years, with the annual mean of all 10 sites decreasing slightly each year. However, at the individual site level, only three sites conformed to this pattern, an equal number showed the opposite, and the remaining four did neither. The sites with the highest mean diversity were Snow Pond, Great Pond Truro, Turtle Pond, Great Pond Wellfleet, and Blackwater (Table 30). Annual differences in diversity were not statistically significant, but there were highly significant between-site differences in the Shannon index (Table 28). There were no significant differences in mean diversity indices for sites versus those calculated from pooled data (Table 30).

Table 27. Mean abundance (individuals/survey) of all individuals identified to family (AllFamilies) recorded at 3YearSites, by site and year at Cape Cod National Seashore.

Site	Habitat	2016	2017	2018	Site Mean	Site CV% *
Blackwater Pond	Inter-dune Pond	108	120	131	120	8
E09	Vernal Pool	262	418	307	329	20
E10	Vernal Pool	170	246	214	210	15
Great Pond Truro	Kettle Pond	57	71	118	82	31
Great Pond Wellfleet	Kettle Pond	81	118	208	136	39
Herring Pond	Kettle Pond	208	303	520	343	38
Horseleech Pond	Kettle Pond	126	168	394	229	51
Snow Pond	Kettle Pond	90	106	160	119	25
T01	Bog	118	97	236	150	41
Turtle Pond	Kettle Pond	141	166	116	141	14
–	All Sites Annual Mean	136	181	240	186	23
–	Between Sites CV	43%	57%	52%	46%	–
–	Kettle Ponds Annual Mean	117	155	253	175	33
–	Between Kettle Ponds CV	42%	48%	60%	50%	–

* Site CV represents coefficient of variation across years.

Table 28. Analysis of annual and between site variation in species diversity, richness, and abundance at 3YearSites at Cape Cod National Seashore.

Diversity Metric	ANOVA or Kruskal-Wallis p		Tukey HSD Q test p values		
	Sites	Years	2016-2017	2016-2018	2017-2018
#Species (S)	0.003 *	0.005 *	0.022 *	0.798	0.006 *
Shannon Diversity Index	0.001 *	0.422	0.637	0.407	0.918
Simpson Index **	–	0.897	–	–	–
Individuals / Survey (All Families)	0.001 *	0.009 *	0.305	0.007 *	0.145

* Values of $p < 0.05$ were considered significant

** Based on Kruskal-Wallis ANOVA.

Table 29. Number of species recorded at 3YearSites, by site and year at Cape Cod National Seashore.

Site	Habitat	2016	2017	2018	Total Species	Site Mean	Site CV% *
Blackwater Pond	Inter-dune Pond	27	18	23	32	22.7	16
E09	Vernal Pool	19	22	20	25	20.3	8
E10	Vernal Pool	18	18	21	26	19.0	7
Great Pond Truro	Kettle Pond	25	23	31	37	26.3	13
Great Pond Wellfleet	Kettle Pond	27	23	29	41	26.3	9
Herring Pond	Kettle Pond	31	24	28	34	27.7	10
Horseleech Pond	Kettle Pond	25	21	26	33	24.0	9
Snow Pond	Kettle Pond	22	22	27	33	23.7	10
T01	Bog	25	17	21	27	21.0	16
Turtle Pond	Kettle Pond	27	26	27	36	26.7	2
–	All Sites Annual Mean	24.6	21.4	25.3	–	23.8	7
–	Between Sites CV	15%	13%	14%	–	12%	–
–	All Sites Pooled Total Species	61	53	58	65	–	6
–	Kettle Ponds Annual Mean	26.2	23.2	28.0	–	25.8	8

* Site CV represents coefficient of variation across years.

Table 30. Measures of species diversity at 3YearSites, identified to species, at Cape Cod National Seashore.

Sites	Shannon Diversity Index H' log E					Simpson Index				
	2016	2017	2018	Mean	Pooled	2016	2017	2018	Mean	Pooled
Blackwater Pond	2.20	2.23	2.32	2.25	2.51	0.83	0.85	0.87	0.85	0.90
E09	2.04	2.21	2.08	2.11	2.25	0.81	0.86	0.83	0.83	0.85
E10	1.90	1.57	1.73	1.73	1.97	0.80	0.71	0.72	0.74	0.81
Great Pond Truro	2.42	2.40	2.53	2.45	2.60	0.88	0.89	0.88	0.88	0.90
Great Pond Wellfleet	2.61	2.41	2.10	2.37	2.57	0.89	0.88	0.82	0.87	0.89
Herring Pond	2.50	2.33	1.86	2.23	2.26	0.89	0.86	0.75	0.83	0.84
Horseleech Pond	2.16	1.64	0.99	1.60	1.52	0.82	0.63	0.35	0.60	0.56
Snow Pond	2.40	2.41	2.67	2.49	2.62	0.89	0.89	0.92	0.90	0.91
T01	1.71	1.29	1.37	1.46	1.65	0.74	0.52	0.60	0.62	0.71
Turtle Pond	2.11	2.42	2.79	2.44	2.65	0.78	0.87	0.92	0.86	0.90
Annual Mean	2.21	2.09	2.04	2.11	–	0.83	0.80	0.77	0.80	–
Sites Pooled	3.08	3.04	2.91	–	3.08	0.94	0.93	0.92	–	0.94

Annual Variation by Habitat

Annual variation in abundance by habitat was not consistent within families or habitats (Table 31) and shows patterns of fluctuation similar to those seen among taxonomic groups (Table 25). For example, the dramatic increase in pond damsel numbers in 2018 was very evident in three of the four habitats (riparian marsh and dune slack habitats were not represented in the 3-year data), the one exception being inter-dune ponds where numbers of that family declined somewhat over the three years. Note, however, that inter-dune ponds (and bogs) were represented by just one site each in the 3-year data, and thus the sample sizes for those habitats were small.

At the community level, there was significant between-year and between-habitat variation in community composition, with year effects accounting for 9.2% of variation and habitat effects 42.3% (Table 22).

The six kettle ponds provide some insight into annual variation within a single habitat type. Among them, there was significant variation in total abundance between years ($F_{2,10}=6.02$, $p=0.02$) and ponds ($F_{5,10}=5.66$, $p=0.01$). Between-site variation in abundance (CV range from 42% to 60%) was generally greater than between-years (site CV ranged from 14% to 51%) (Table 27). For species richness, the pattern of variation differed. There was still significant variation in species richness across years ($F_{2,10}=9.43$, $p=0.005$) but not between-sites ($F_{5,10}=9.43$, $p=0.165$). This lower within-year variability in species richness between kettle pond sites is reflected in the lower between-site CV (6% overall) compared to between-years (8%) (Table 29).

For the six kettle ponds, Permanova found significant differences in community composition due to both years and sites, with years accounting for 17% of variation and between-sites 48%. Within-site similarity, which is the inverse of annual variation at a pond, ranged from 83% to 69% (mean 75%) whereas between-site similarity was lower, ranging from 71% to 50% (mean 61%) (Table 32). Thus, similar to abundance, between-year variation at kettle ponds was less than between-site variation. On average, Snow Pond was most similar to the other five kettle ponds (mean between-site similarity of 66%), followed by Turtle (65%), Great Truro (64%), Horseleeche (63%), Great Wellfleet (62%), and Herring (59%).

Table 31. Annual variation in abundance (individuals/survey) by habitat among the most numerous families of odonates at Cape Cod National Seashore. Based on 3YearSites, identified to species, genus, family.

Habitat Type	Pond Damsels (Coenagrionidae)			Spreadwings (Lestidae)			Skimmers (Libellulidae)			Total Individuals
	2016	2017	2018	2016	2017	2018	2016	2017	2018	
Inter-dune Pond (1 site)	44	40	32	15	55	25	46	22	62	2367
Vernal Pool (2 sites)	47	36	109	23	138	40	140	154	104	10562
Kettle Pond (6 sites)	62	86	183	7	17	6	44	50	58	20186
Bog (1 site)	30	25	140	32	5	6	53	66	83	2933
Total #/Survey	54	65	149	13	44	15	65	70	70	36048

Table 32. Average similarity within and between kettle ponds sampled for 3 years at Cape Cod National Seashore.

Kettle Pond Name	Great Pond Truro	Great Pond Wellfleet	Herring Pond	Horseleech Pond	Snow Pond	Turtle Pond
Great Pond Truro	72 *	—	—	—	—	—
Great Pond Wellfleet	60	69 *	—	—	—	—
Herring Pond	53	50	83 *	—	—	—
Horseleech Pond	60	68	52	75 *	—	—
Snow Pond	71	61	58	60	77 *	—
Turtle Pond	67	62	58	61	69	74 *

*Within (across years) in a given pond.

Annual Variation of Individual Species

Of the 65 species recorded at the 3YearSites, 50 were recorded in all three years, seven were recorded in two, and eight species were only recorded in one year. Despite the relative stability of overall dragonfly numbers during the survey period, there was substantial variability within some species. Moreover, the extent of that variability was variable itself, with species-specific Coefficient of Variation ranging from 0 to 141% (Table 33). For example, the common and widespread Blue Dasher, the most numerous dragonfly on these surveys, declined from 16/survey in 2016 to 12/survey in 2017, a 25% decline, then doubled to 24/survey in 2018 (CV 27%). Another common and widespread species, the Eastern Pondhawk, declined from 9/survey in 2016 to 4/survey in 2017, a 56% decline, then increased somewhat to 5/survey in 2018 (CV47%).

The greatest variability among damselflies occurred in the Atlantic Bluet (increasing from 6/survey in 2016, to 12/survey in 2017, and 38/survey in 2018, CV 70%). Less dramatic changes were recorded in Skimming Bluet (10/survey in 2016 and 2017, increasing to 23/survey in 2018, CV 35%), Sweetflag Spreadwing (7/survey in 2016, increasing to 18/survey in 2017, then falling back to 6/survey in 2018, CV 47%), Eastern Forktail (16/survey in 2016, 19/survey in 2017, and 28/survey in 2018, 17%), and Sphagnum Sprite (3/survey in 2016, 1/survey in 2017, and 13/survey in 2018, CV90%) (Table 33).

Annual variation of individual species sometimes drove variation at individual sites. For example, at Great Pond Wellfleet the total number of individuals more than doubled over the three years (81/survey in 2016 to 118/survey in 2017, then 208/survey in 2018, CV 39%) (Table 27). This change was almost entirely among damselflies, in particular the bluets (*genus Enallagma*), which increased from 30/survey in 2016 to 54/survey in 2017, then dramatically to 142/survey in 2018. The change in numbers of Atlantic Bluet were especially striking: 2/survey in 2016, just 1/survey in 2017, then 52/survey in 2019. Little Bluets dropped from 18/survey to 11/survey over the first two years, then rose abruptly to 49/survey the final year.

Horseleech Pond in Truro exhibited similar extreme variation, with overall odonate numbers ranging from 126/survey to 168/survey then 394/survey over the three years (CV 51%); as at Great Pond, the change was driven by damselfly totals. Atlantic Bluet again showed the largest changes (41/survey to 98/survey to 308/survey). One dragonfly, the Autumn Meadowhawk, exhibited a contrary trend, declining from 15/survey to 14/survey to just 2/survey over the three years.

Table 33. 3-year totals by species at Cape Cod National Seashore. Based on 3YrSitesByYears, includes individuals identified to species, genus, family, or sub-order.

Species	# Individuals			Total Individuals	% of Total	Average #/Survey			CV % *
	2016	2017	2018			2016	2017	2018	
Damselfly species	8	5	158	171	0.5	0.1	0.1	2.6	125
Spreadwing species	114	829	179	1122	3.1	1.4	14.0	3.0	86
Spotted Spreadwing	2	2	2	6	0.0	0.0	0.0	0.0	0
Northern Spreadwing	1	0	0	1	0.0	0.0	0.0	0.0	141
Amber-winged Spreadwing	139	156	161	456	1.3	1.8	2.6	2.7	6
Sweetflag Spreadwing	526	1083	367	1976	5.5	6.7	18.0	6.1	47
Elegant Spreadwing	7	21	7	35	0.1	0.1	0.4	0.1	57
Slender Spreadwing	6	54	7	67	0.2	0.1	0.9	0.1	100
Swamp Spreadwing	267	465	171	903	2.5	3.4	7.8	2.9	41
Ebony Jewelwing	3	6	15	24	0.1	0.0	0.1	0.3	64
Variable Dancer	205	313	387	905	2.5	2.6	5.2	6.5	25
Bluet species	130	67	118	315	0.9	1.6	1.1	2.0	26
Northern Bluet	316	80	85	481	1.3	4.0	1.3	1.4	69
Azure Bluet	20	96	384	500	1.4	0.3	1.6	6.4	94
Familiar Bluet	42	123	213	378	1.0	0.5	2.1	3.6	55
Attenuated Bluet	139	69	85	293	0.8	1.8	1.2	1.4	31
Atlantic Bluet	471	699	2264	3434	9.5	6.0	12.0	37.7	70
Skimming Bluet	777	617	1373	2767	7.7	9.8	10.0	22.9	35
New England Bluet	1	3	29	33	0.1	0.0	0.1	0.5	116
Little Bluet	157	135	338	630	1.7	2.0	2.3	5.6	43
Pine Barrens Bluet	108	90	95	293	0.8	1.4	1.5	1.6	8
Orange Bluet	27	90	41	158	0.4	0.3	1.5	0.7	51
Slender Bluet	45	0	11	56	0.2	0.6	0.0	0.2	103

* Coefficient of variation (CV) calculated using # individuals recorded each year.

Table 33 (continued). 3-year totals by species at Cape Cod National Seashore. Based on 3YrSitesByYears, includes individuals identified to species, genus, family, or sub-order.

Species	# Individuals			Total Individuals	% of Total	Average #/Survey			CV % *
	2016	2017	2018			2016	2017	2018	
Vesper Bluet	2	0	3	5	0.0	0.0	0.0	0.1	75
Forktail species	13	122	789	924	2.6	0.2	2.0	13.2	111
Citrine Forktail	3	4	3	10	0.0	0.0	0.1	0.1	14
Lilypad Forktail	249	47	61	357	1.0	3.2	0.8	1.0	77
Fragile Forktail	83	88	137	308	0.9	1.1	1.5	2.3	24
Rambur's Forktail	0	0	1	1	0.0	0.0	0.0	0.0	141
Eastern Forktail	1297	1136	1705	4138	11.5	16.4	19	28.4	17
Sprite species	0	55	0	55	0.2	0.0	0.9	0.0	141
Sphagnum Sprite	203	62	800	1065	3.0	2.6	1.0	13.3	90
Dragonfly species	0	0	2	2	0.0	0.0	0.0	0.0	141
Darner species	3	0	4	7	0.0	0.0	0.0	0.1	73
Mosaic Darner species	30	25	14	69	0.2	0.4	0.4	0.2	29
Mottled Darner	46	11	17	74	0.2	0.6	0.2	0.3	62
Black-tipped Darner	33	5	9	47	0.1	0.4	0.1	0.2	79
Green-striped Darner	1	0	0	1	0.0	0.0	0.0	0.0	141
Common Green Darner	142	104	116	362	1.0	1.8	1.7	1.9	13
Comet Darner	2	5	7	14	0.0	0.0	0.1	0.1	44
Harlequin Darner	3	2	0	5	0.0	0.0	0.0	0.0	75
Lancet Clubtail	6	3	8	17	0.0	0.1	0.1	0.1	36
Common Sanddragon	9	16	37	62	0.2	0.1	0.3	0.6	58
Illinois River Cruiser	0	0	3	3	0.0	0.0	0.0	0.1	141
Emerald species	0	1	0	1	0.0	0.0	0.0	0.0	141
Petite Emerald	0	0	1	1	0.0	0.0	0.0	0.0	141

* Coefficient of variation (CV) calculated using # individuals recorded each year.

Table 33 (continued). 3-year totals by species at Cape Cod National Seashore. Based on 3YrSitesByYears, includes individuals identified to species, genus, family, or sub-order.

Species	# Individuals			Total Individuals	% of Total	Average #/Survey			CV % *
	2016	2017	2018			2016	2017	2018	
Common Baskettail	7	2	11	20	0.1	0.1	0.0	0.2	55
Prince Baskettail	4	8	9	21	0.1	0.1	0.1	0.2	31
Skimmer species	2	7	2	11	0.0	0.0	0.1	0.0	64
Calico Pennant	485	330	373	1188	3.3	6.1	5.5	6.2	16
Halloween Pennant	44	12	23	79	0.2	0.6	0.2	0.4	50
Banded Pennant	26	12	9	47	0.1	0.3	0.2	0.2	47
Martha's Pennant	186	159	212	557	1.5	2.4	2.7	3.5	12
Eastern Pondhawk	731	266	323	1320	3.7	9.3	4.4	5.4	47
Blue Corporal	0	4	10	14	0.0	0.0	0.1	0.2	88
White Corporal	18	35	45	98	0.3	0.2	0.6	0.8	34
Frosted Whiteface	2	0	0	2	0.0	0.0	0.0	0.0	141
Dot-tailed Whiteface	114	168	119	401	1.1	1.4	2.8	2.0	18
Golden-winged Skimmer	1	0	0	1	0.0	0.0	0.0	0.0	141
Spangled Skimmer	50	17	25	92	0.3	0.6	0.3	0.4	46
Slaty Skimmer	703	657	757	2117	5.9	8.9	11	12.6	6
Needham's Skimmer	2	2	0	4	0.0	0.0	0.0	0.0	71
Twelve-spotted Skimmer	2	4	5	11	0.0	0.0	0.1	0.1	34
Four-spotted Skimmer	4	0	0	4	0.0	0.1	0.0	0.0	141
Painted Skimmer	91	13	85	189	0.5	1.2	0.2	1.4	56
Blue Dasher	1245	716	1454	3415	9.5	15.8	12.0	24.2	27
Wandering Glider	2	0	1	3	0.0	0.0	0.0	0.0	82
Spot-winged Glider	1	0	1	2	0.0	0.0	0.0	0.0	71
Eastern Amberwing	168	282	131	581	1.6	2.1	4.7	2.2	33

* Coefficient of variation (CV) calculated using # individuals recorded each year.

Table 33 (continued). 3-year totals by species at Cape Cod National Seashore. Based on 3YrSitesByYears, includes individuals identified to species, genus, family, or sub-order.

Species	# Individuals			Total Individuals	% of Total	Average #/Survey			CV % *
	2016	2017	2018			2016	2017	2018	
Common Whitetail	2	1	1	4	0.0	0.0	0.0	0.0	35
Meadowhawk species	78	311	21	410	1.1	1.0	5.2	0.4	92
Saffron-winged Meadowhawk	17	10	12	39	0.1	0.2	0.2	0.2	23
Ruby Meadowhawk	859	901	386	2146	6.0	10.9	15.0	6.4	33
Autumn Meadowhawk	208	212	114	534	1.5	2.6	3.5	1.9	25
Saddlebag species	2	0	0	2	0.0	0.0	0.0	0.0	141
Carolina Saddlebags	67	56	76	199	0.6	0.8	0.9	1.3	12
Black Saddlebags	1	2	2	5	0.0	0.0	0.0	0.0	28
Totals	10758	10876	14414	36048	–	136	181	240	–
Zygoptera	5361	6517	9989	21867	60.7	68	109	166	–
Anisoptera	5397	4359	4425	14181	39.3	68	73	74	–

* Coefficient of variation (CV) calculated using # individuals recorded each year.

Flight Seasons

The surveys were timed to coincide with the peak flight seasons of most odonate species, and thus were not well suited to capturing the earliest emergence of “spring” fliers or the last of the late flying fall species. Thus, the historical data provides better data on flight periods, though even that data does not capture the extremes for some species. The earliest and latest recorded seasonal flight dates (Table 34) in many cases are conservative.

Table 34. Recorded flight seasons at Cape Cod National Seashore. ("mmdd" date format); includes historical data.

Species	First Date	Last Date
Spotted Spreadwing	0706	1113
Northern Spreadwing	0619	0920
Amber-winged Spreadwing	0523	0809
Sweetflag Spreadwing	0604	1029
Elegant Spreadwing	0614	0809
Slender Spreadwing	0602	1105
Lyre-tipped Spreadwing	0707	0817
Swamp Spreadwing	0602	0914
Ebony Jewelwing	0610	0816
Eastern Red Damsel	0610	0712
Variable Dancer	0608	0921
Taiga Bluet	0609	0609
Northern Bluet	0515	0704
Azure Bluet	0527	0920
Boreal Bluet	0530	0530
Familiar Bluet	0523	0909
Attenuated Bluet	0617	0820
Atlantic Bluet	0523	0910
Stream Bluet	0730	0823
Skimming Bluet	0602	0914
New England Bluet	0530	0715
Little Bluet	0523	0908
Scarlet Bluet	0707	0710
Pine Barrens Bluet	0523	0706
Orange Bluet	0615	0904
Slender Bluet	0617	0814
Vesper Bluet	0609	0823
Citrine Forktail	0608	01002
Lilypad Forktail	0528	0914

Table 34 (continued). Recorded flight seasons at Cape Cod National Seashore. ("mmdd" date format); includes historical data.

Species	First Date	Last Date
Fragile Forktail	0416	0917
Furtive Forktail	0602	0602
Rambur's Forktail	0730	0730
Eastern Forktail	0426	1011
Sphagnum Sprite	0530	0816
Sedge Sprite	0530	0807
Canada Darner	0728	0831
Mottled Darner	0720	0921
Spatterdock Darner	0529	0712
Black-tipped Darner	0706	1027
Shadow Darner	1011	1011
Green-striped Darner	0814	0914
Common Green Darner	0426	1113
Comet Darner	0615	0810
Swamp Darner	0601	0822
Harlequin Darner	0611	0614
Lancet Clubtail	0514	0720
Common Sanddragon	0621	0823
Stream Cruiser	0531	0604
Illinois River Cruiser	0715	0802
Petite Emerald	0608	0714
Common Baskettail	0511	0713
Prince Baskettail	0606	0907
Calico Pennant	0531	0914
Halloween Pennant	0625	0826
Banded Pennant	0629	0909
Martha's Pennant	0625	0917
Eastern Pondhawk	0528	0914
Seaside Dragonlet	0712	0915
Blue Corporal	0609	0716
White Corporal	0526	0723
Frosted Whiteface	0530	0626
Dot-tailed Whiteface	0501	0730
Golden-winged Skimmer	0625	0819
Bar-winged Skimmer	0614	0813

Table 34 (continued). Recorded flight seasons at Cape Cod National Seashore. ("mmdd" date format); includes historical data.

Species	First Date	Last Date
Spangled Skimmer	0523	0818
Slaty Skimmer	0610	0917
Needham's Skimmer	0701	0915
Twelve-spotted Skimmer	0529	0914
Four-spotted Skimmer	0504	0712
Painted Skimmer	0602	0814
Great Blue Skimmer	0606	0628
Elfin Skimmer	0623	0702
Blue Dasher	0528	0917
Wandering Glider	0606	0913
Spot-winged Glider	0512	0914
Eastern Amberwing	0621	0914
Common Whitetail	0528	0914
Saffron-winged Meadowhawk	0703	0914
Ruby Meadowhawk	0604	1105
Band-winged Meadowhawk	0714	0902
Autumn Meadowhawk	0707	1129
Striped Saddlebags	0712	0712
Carolina Saddlebags	0606	0914
Black Saddlebags	0606	0825

Species Richness and Geography

The known odonate fauna of CACO currently comprises 86 species, a far more diverse assemblage than recorded at other coastal National Park Service sites within the Northeast, such as Sagamore Hill (22 species), Fire Island (27 species), and Gateway NRA (37 species) (Briggs et al. 2010 a, b, c). This is primarily due to the much more diverse and numerous wetland habitats present within CACO, although much more survey effort over the years is also a factor.

The species richness of CACO odonates is far less than the state of Massachusetts (165+ species; Buchsbaum et al. 2016, Nikula et al. 2003) and somewhat less than Cape Cod as a whole (100+ species). This reflects the much greater area and habitat diversity found at the state level and the somewhat greater area and habitat diversity found at the Barnstable county level, which includes the larger and more geologically variable upper and mid Cape.

Of the nine families of odonates known from Massachusetts, eight, five dragonfly (suborder Anisoptera) and three damselfly (suborder Zygoptera), have been recorded at CACO. The ninth, Anisopteran family, spiketails (Cordulegastridae), has three species in MA, all absent from Cape Cod. Among the eight families recorded at CACO, the skimmers (family Libellulidae) are the most

speciose, represented by 32 species (31 on the surveys plus one additional vagrant species recorded historically), followed by the pond damselfly (family Coenagrionidae), 27 species (21 on surveys plus five historical and one new species recorded after the surveys). Statewide, these families are represented by 41 species of skimmers and 35 pond damselflies (Table 5). Most notably lacking on the outer Cape and CACO are riverine (lotic) systems and the associated odonates, in particular the family Gomphidae (Clubtails), which number 27 species in Massachusetts, but only three in CACO. A second family, the Corduliidae (Emeralds), are most often associated with boreal bogs and to a lesser extent lotic habitats and are also very underrepresented on Cape Cod and within CACO (23 species in Massachusetts, four on Cape Cod, and three in CACO) (Table 5).

Most notably lacking on the outer Cape and CACO are riverine (lotic) systems and the associated odonates, in particular the family Gomphidae (Clubtails), which number 27 species in Massachusetts, but only three in CACO. A second family, the Corduliidae (Emeralds), are most often associated with boreal bogs and to a lesser extent lotic habitats and are also very underrepresented on Cape Cod and within CACO (23 species in Massachusetts, four on Cape Cod, and three in CACO).

As is true with many taxa (e. g., breeding birds, amphibians, reptiles, flora), odonate species richness generally declines from western portions of Cape Cod eastward, then northward through the outer Cape. Reasons for this appear related to the distribution of habitat types, which in turn reflect geologic history: Outwash plain glacial deposits, with an abundance of kettle ponds and vernal pools, extend up to High Head in North Truro. Beyond, the younger Provincetown dunes dominated by short hydroperiod dune slacks and more permanent inter-dune ponds, were formed by the deposition of sand eroded from them (Winkler 1992). Within CACO, amphibians such as Spotted Salamander, Four-toed Salamander, Pickerel Frog, and Wood Frog have not been recorded beyond High Head and are absent from Provincetown (Cook 2014). Similarly, less than half the odonate species recorded in CACO have been found there, and the number of individuals/survey is substantially lower than towns to the south, on the outwash plain (Table 9).

Classic kettle ponds, which are among the highest in odonate species richness and abundance at CACO (Tables 11, 12, 13), are absent north of South Truro. Some of the inter-dune ponds, found only in Provincetown and the dominant habitat sampled there, appear—to the untrained eye at least—very similar to kettle ponds, with much of the same emergent and floating vegetation (including *Juncus militaris*). But they are shallower than the kettle ponds, and roughly half the age (Winkler 1992). How this might impact odonate populations is unknown, but in terms of community composition, the similarity between kettle ponds and inter-dune ponds is relatively low (45.1%), which is ranked 11 among 15 between-habitat similarities (Table 24). Paradoxically, although the habitat most similar to kettle ponds is inter-dune ponds, from the perspective of inter-dune ponds, kettle ponds are the least similar.

These surveys targeted those habitats known to harbor the greatest diversity of odonates, but a few species are rarely found in these habitats. One such species, the Seaside Dragonlet, is the only salt marsh breeding odonate in North America, and a common inhabitant within the appropriate habitats in CACO. The only individual recorded on these surveys was a wandering male at a pond (E23) in Eastham about 400 meters north of Nauset marsh, but historical records exist for several salt marsh

sites. Needham's Skimmer, an uncommon species throughout Cape Cod, is most often found in brackish and/or disturbed habitats and is likely present in a few more sites than the one (Salt Meadow Big Pool) at which it was recorded on the surveys. The two migratory glider species, Spot-winged and Wandering, are both common within CACO, but seldom seen at wetlands and were poorly represented on the surveys. Several other species that are more often encountered over upland fields and clearings, such as Common Baskettail and Prince Baskettail, were also underrepresented on the surveys. All of these species are better represented in the historical data, which include a greater diversity of habitats, including several upland sites.

These surveys were based entirely upon the presence—and detection—of adult odonates. Adults, especially dragonflies, are strong fliers, capable of wandering considerable distances from the natal sites. Thus, their presence at a particular site, especially if only one or two individuals, cannot be interpreted to represent a breeding population in the absence of breeding activity. Even where breeding activity is observed, the site may not be suitable for the survival of the aquatic nymphs—the site may be a population sink. This makes determination of the importance of a particular site difficult to calculate. However, it can be argued that the mere presence of a species at a site, even if only one non-breeding individual, indicates that the site has some value to the species, just as upland sites have value to odonates despite not being used for breeding.

Historical Changes

Although the historical record of odonate work on Cape Cod dates back well over a century to the late 1880s, apparently none of the early work took place on the outer Cape at sites that eventually became part of CACO. The most extensive field work was conducted by R. H. Gibbs and S. P. Gibbs during the years 1950–1953 (Gibbs and Gibbs 1954), but their efforts were focused on the mid and upper Cape and only one of their surveys sites was within the current CACO boundaries: “Nauset Bay.” Not surprisingly, given the habitat, the only species they recorded there were the salt marsh breeding Seaside Dragonlet and the migratory Wandering Glider.

The first published data on odonates within the park was that of Virginia Carpenter, who initiated a Cape Cod dragonfly survey in 1982 that continued through 1990 (Carpenter 1983, 1984, 1986, 1987, 1988, 1989, 1990). Some, but unfortunately not all, of the resultant data has been incorporated into the CACO database. Beginning in 1994, Jackie Sones and the senior author, subsequently joined by Jeremiah Trimble and occasionally others, began surveying odonates within the park and elsewhere. Much of the available historical data results from their efforts, especially from 1994–2000. More recently, and continuing through the present, Ken Shea, a former naturalist with CACO, has conducted regular surveys within the park, and many, but again not all, of his records have been incorporated into the database.

For purposes of this report, “historical” refers to all records preceding the initiation of this study—a period dating back only 34 years, from 1982–2015, with the vast majority of records from the 1990s.

The extensive annual variation in odonate populations, coupled with the fact that most of the historical data from CACO were not collected in a systematic fashion, and that which was collected systematically (*e. g.*, Colburn 2005) used a different protocol, requires that great caution be used in

comparing the historical record with the results from this survey. No conclusions can be drawn on changes in overall odonate numbers within CACO. However, the change in the status of some species is too dramatic to be ignored.

The obvious changes seem related to climate change, involving at least four southern species that have clearly increased within CACO (and elsewhere on Cape Cod and southern New England in general), and at least one northern species that apparently is nearly extirpated from the area.

Among the southern species, the Attenuated Bluet has exhibited by far the most dramatic change. This species was unrecorded within CACO historically, or elsewhere on Cape Cod, and within Massachusetts was known from only a few sites in southeastern portions (Bristol & Plymouth counties). In 2004, Shea found the first CACO and Cape Cod record at Herring Pond in Wellfleet. The population apparently expanded rapidly, and the species is now common at a number of sites, known from 12 sites within CACO, with a peak count of 50 individuals, and many observations of breeding activity (Appendix 3).

Three southern dragonflies have shown less striking increases. The Bar-winged Skimmer was first recorded on Cape Cod at a small vernal pool (E01) in Eastham in 1997, but there were no additional records over the next 19 years (to some extent reflecting very limited field work during that period). However, during this project the species was recorded on nine surveys at seven sites, and breeding activity was seen at a vernal pool in Eastham (E06).

Although recorded at only one site on two surveys during this project, the Great Blue Skimmer has also increased significantly; the paucity of survey records reflects the species tendency to occur away from permanent wetlands, most often being found in upland areas, near large puddles along dirt roads, or even ornamental wetlands in residential areas.

The Painted Skimmer is another southern dragonfly that has become considerably more common over the past few decades. Uncommon and rather local 30 years ago, with occasional migratory influxes, it is now very common and widespread, recorded from 27 sites on 84 surveys, with a high count of 20 individuals.

Although the historical data is sparse, the Spot-winged Glider appears to be one of the first southern species to show a dramatic increase in this area. The species was unrecorded in Massachusetts until 1967 (White et al. 1974) and Carpenter recorded it infrequently during her field work in the 1980s. By the mid-1990s it was appearing in abundance during northbound migratory movements along the coast and remains a very common species. However, it still is seen only occasionally at the wetlands that most other odonates inhabit, being most often encountered along the immediate coast or over upland clearings and may have been overlooked to some extent by earlier workers.

At the other end of the spectrum, the Four-spotted Skimmer, a northern species near the southern edge of its range on Cape Cod, appears to be on the verge of extirpation from CACO, and perhaps Cape Cod as a whole. Though never common, it was found regularly in small numbers during the 1980s and 1990s, primarily at vernal pools and bogs. During this project it was recorded on only one survey and was not found at several sites where it occurred regularly 20-30 years ago.

Ten species recorded historically within CACO (i.e., prior to 2016) were not found during these surveys (Table 35). However, two of these, Swamp Darner and Stream Cruiser, were seen during the survey period but not during any formal surveys, while a third, Stream Bluet, was present in numbers in 2019 at Gull Pond in Wellfleet, a site not surveyed but a known historical site for the species. Two species, Furtive Forktail and Striped Saddlebags, are rare vagrants in the Northeast, each recorded just once in CACO during the 1990s. The Boreal Bluet is extremely similar to the very common Northern Bluet, requiring in-hand examination to identify, and may well have been overlooked as very few of the latter were captured and examined critically during the surveys. Similarly, the Lyre-tipped Spreadwing is very similar to the abundant Sweetflag Spreadwing and also may have been overlooked, as might have the Sedge Sprite, which is extremely similar to the locally common Sphagnum Sprite, though the two species typically segregate by habitat. The Shadow Darner is an elusive, strong-flying dragonfly, known from just one historical record, which may have been a wandering individual. Small numbers of Scarlet Bluets were present at Turtle Pond, Wellfleet in 1990 (Carpenter, unpublished data) and at Great Pond, Truro in 1999 (Gibbons, pers. comm.); both sites were surveyed 20 times each over the 3-year project and it seems very likely the species is extirpated from those sites and probably the entire park. More details on the status of these species are presented in the species accounts.

Table 35. Historical species not recorded during formal 2016–2018 surveys at Cape Cod National Seashore.

Common Name	Scientific Name
Lyre-tipped Spreadwing	<i>Lestes unguiculatus</i>
Boreal Bluet	<i>Enallagma boreale</i>
Stream Bluet *	<i>Enallagma exsulans</i>
Scarlet Bluet	<i>Enallagma pictum</i>
Furtive Forktail	<i>Ischnura prognata</i>
Sedge Sprite	<i>Nehalennia irene</i>
Shadow Darner	<i>Aeshna umbrosa</i>
Swamp Darner *	<i>Epiaeschna heros</i>
Stream Cruiser *	<i>Didymops transversa</i>
Striped Saddlebags	<i>Tamea calverti</i>

* Encountered outside of the formal surveys.

During the summer of 2019, after completion of the formal surveys, the senior author discovered two species at Gull Pond in Wellfleet not previously known from CACO: Big Bluet (*Enallagma durum*) and Black-shouldered Spinyleg (*Dromogomphus spinosus*). Big Bluet is a southern species near the northern edge of its range in Massachusetts, and is scarce on Cape Cod, recorded primarily at a few brackish sites on the southern coast of the peninsula. It is unlikely a population exists on Gull Pond, the single male photographed on 21 July likely being a wandering individual. The Black-shouldered Spinyleg, on the other hand, was a freshly emerged teneral male, flushed from the emergent vegetation on 30 June, and thus evidence of successful breeding at the site. This species is a fairly

common inhabitant of the larger, sandy-bottomed ponds and lakes through the mid and upper Cape, but the Wellfleet record is the first east of Brewster.

Gull Pond was not surveyed during this project, though some historical data exists for the site, including some point counts conducted during Colburn's study (Colburn 2005). It is a large (44 hectares), sparsely vegetated, sandy-bottomed wetland. The known odonate fauna is rather modest, numbering 25 species, several of those represented by just a single individual, though more extensive coverage would likely yield a few more. However, the paucity of aquatic vegetation is a limiting factor to the species diversity here. In addition to the two species discovered in 2019, it is also the only known site within CACO (or the outer Cape) for the Stream Bluet, a species whose habitat affinities are similar to those of the Black-shouldered Spinyleg.

Spatial and Annual Variation

Although historic surveys of CACO odonates have documented variability in abundance, species richness, and community composition, the current surveys provided an opportunity to quantify that variability in a more systematic fashion and identify some patterns.

Spatial Variation – All Sites 1 Year Each

Given the number of sites and the habitat diversity they represent, the range in abundance (site mean from 18 to 385 individuals/survey) and species recorded (site total from 11 to 29) in single year surveys is not unexpected (Table 6). Grouping these 41 sites by habitat type provides some order and reveals significant between-habitat differences in abundance and species richness (Table 11). Statistically, the differences in abundance appear to be driven by the low abundance at riparian sites (23 individuals/survey), as all other between-habitat comparisons were non-significant (Table 12). Similarly, the high numbers of species recorded at kettle pond sites (mean 23.3) sets that habitat apart from all the others in terms of species richness (Table 13). Given the high abundance and number of species found at kettle ponds in these surveys, it is understandable how historic survey efforts came to identify the importance of this habitat type, particularly for the rare species present. However, as noted previously, sampling effort and intensity varied by habitat type due to stratified sampling, and the higher species richness recorded in kettle ponds and vernal pools may partly be due to a greater amount of sampling. While the mean number of surveys/site for these data is comparable among habitats (Table 11), the number of sites sampled by habitat had a significant positive correlation with total species recorded in a habitat ($r(10)=0.99$, $p<0.001$) and mean number of species/site by habitat ($r(10)=0.94$, $p=0.005$).

Habitats also differed significantly in their community composition (Table 23), with sites tending to cluster by habitat type in MDS space (Figure 7). Although many sites at CACO occur along ecological gradients and there is a subjective element to assigning them to a "habitat type", the fact that such clustering occurred, and that similarity was greater within-habitat (mean 61%) than between-habitat (mean 49%) (Table 24), suggests that most of our categorizations are valid. However, it is also clear that differences between bogs, vernal pools, and inter-dune ponds are not as clear cut as for deep kettle ponds and riparian sites (Figure 7). Moreover, with the lowest within-habitat similarity (52.6%), there is also considerable variability among kettle ponds, likely related to differences in size and depth among the 15 sites sampled.

Annual Variation – 3YearSites

Among the 3YearSites, we found significant annual variation in abundance and number of species, but not in diversity indices (Table 28, 30). However, there was also significant between-site variation in these metrics (Table 28) and generally, between-site variation was greater than between years. For example, among these 10 sites, variation in abundance (CV) across years at sites was 23% and between sites it was 46% (Table 27). The same was true for species richness, but variability was smaller, as one would expect (Table 29). As it turned out, annual variation in abundance was not uniform in all taxonomic groups, with the greatest variation among the pond damselflies (Coenagrionidae) and Spreadwings (Lestidae), whose mean annual abundance often varied dramatically from one year to the next (Table 25, 26). Over the three years of surveys, the CV for damselflies (Zygoptera) was 35%, whereas it was 5% for dragonflies (Anisoptera) (Table 25). Reasons for this taxonomic difference in variability are unknown. There was also significant annual variability at the community level, with annual variation within sites accounting for roughly 9 to 12% of variation (Table 22). Although some variation in this group of 10 ponds may be attributable to the fact that they represent four different habitat types, even among the six kettle pond sites, there was significant annual variation in abundance. In fact, the six kettle ponds tended to be more variable across years (mean Site CV of 33%) than the other four sites (mean CV 23%).

Detecting Population Changes

The considerable annual variation in odonate numbers detected within these surveys and detailed above, both within and between sites as well as habitats, presents a significant challenge in attempting to discern long-term changes. Day-to-day variation in numbers present at a wetland can be extreme, as shown by Carpenter's almost daily surveys of Pine Barrens Bluet at Turtle Pond in Wellfleet (Carpenter 1990), where the peak number, recorded on just one day at the onset of the flight season, was an order of magnitude higher than any other count that season. Had that one day been missed, a very different conclusion would have been drawn about that species' population level that year. On the other hand, one could ask if that peak count accurately represents the population or are the lower, more stable numbers a better representation.

Although odonate population dynamics have been studied rather extensively over the short term, and at the individual level, especially for the larvae (e. g., survivorship, impacts of predation), studies of long-term population changes are scarce and have focused on changes in species composition based upon simple presence/absence data (e. g., Shiffer and White 1994, 2014), rather than population levels. As we've seen in our surveys, species richness is generally less variable than abundance, but annual variation can still be statistically significant. In addition, annual variation at the species level was often greater, suggesting that monitoring abundance of particular species may be even more challenging.

In addition to the daily variation in numbers, many other factors confound attempts to determine population levels in odonates. Adults are very weather dependent, and active only under sunny conditions, requiring that surveys be conducted only when conditions are favorable. In some species the adult flight season can be as short as 5-6 weeks, so that surveys conducted only once or twice

during that period can miss the often much shorter period of peak abundance, thus underestimating the population level.

Another confounding factor is the detectability of adults, which varies by species, and also can be affected by environmental conditions. For example, high water levels (an issue throughout the three years of these surveys) can reduce the extent of emergent vegetation, used as perches by most species, resulting in many individuals perching at higher levels in shoreline shrubs and trees where they are much less conspicuous. Nikula (2001) compared the results of some informal, mid-summer surveys at a kettle pond in Dennis over a five-year period and noted much lower totals for most species in years when water levels were very high, but it was not clear whether the totals represented actual population declines, a reduction in detectability, or some combination of the two.

Some of the smallest damselflies remain well-hidden in shoreline vegetation and therefore are consistently undercounted. Somewhat paradoxically, some of the largest dragonfly species (e. g., darners in the family Aeshnidae) are also poorly surveyed as they occur at very low densities, rarely more than 3-4 detected per survey, resulting in small sample sizes. Additionally, they typically visit wetlands only for brief periods, are constantly in flight when present (making identification very difficult), and perch only in upland areas away from the breeding sites, usually high in trees.

Aside from these complications, the three-year time frame of the CACO surveys is much too short to draw any conclusions, and the available historical data was not collected systematically, making any comparisons tenuous. However, going forward, the data from this project and estimates of the Coefficient of Variation presented in this report, could be used with software such as TrendPowerTool (Weiser et al. 2021) to estimate statistical power to detect population trends of different potential monitoring programs and determine what might be feasible. Alternatively, given the high variability in abundance, approaches based on species presence, such as Occupancy (MacKenzie et al. 2018) might provide a more achievable approach to statistically testable monitoring.

Impacts of Climate Change

A rapidly warming climate may impact odonates in a variety of ways, including range expansion (primarily northward), range contraction (at the southern edge of the range), changes in community structure, changes in phenology (e. g., expanding adult flight seasons, especially an earlier onset), or changes in the development rate of eggs and/or larvae (Beatty et al. 2010, Catling 2012, Cerini et al. 2020, Corser et al. 2015, Hassall et al. 2007, 2008, McAlpine et al. 2017, McCauley et al. 2018, Parr, 2010, Richter et al. 2008).

As with most taxonomic groups, some odonate species are habitat generalists, other specialists, and the former are presumably better able to adapt to changes in their environment. It is the latter that are the most likely to disappear in the face of a changing climate and are thus of the greatest concern. Shallow wetlands (e. g., vernal pools) are likely to reflect impacts of climate change more rapidly than deeper sites, as they are more responsive to changing temperature regimes and precipitation levels, as well as a variety of more subtle factors (Matthews 2010).

Smith et al. (2016) reported warming surface water temperatures at 10 kettle ponds within CACO over the period 1988–2013; seven of these ponds were surveyed in this study. Temperature increases at those seven sites ranged from 1.3 °C to 2.6 °C per pond, averaging 1.9 °C during that period. Surface water temperatures were significantly correlated with July and August air temperatures. Acidity also decreased at every site during the same time frame. Increasing water temperatures can impact ponds in a variety of ways, many not well understood, including, but not limited to, increased productivity, increased algal biomass, reduced water clarity, and reduced oxygen levels. The impacts on odonates are speculative at best and likely varies considerably from species to species. Presumably, species with southerly affinities would more likely benefit from these changes.

There is little data upon which to draw any conclusions about effects of climate warming on the odonate fauna within CACO. However, it is clear that a few southern species, formerly very rare to absent anywhere in southern New England, have established populations within the park. Most notable among these are Attenuated Bluet, Bar-winged Skimmer, and Great Blue Skimmer. Additionally, the Painted Skimmer and Spot-winged Glider have become much more common than previously. At the other extreme, one northern species, the Four-spotted Skimmer, may be on the verge of extirpation from CACO—and possibly all of Cape Cod (see “Historical Changes” above).

We’re not able to draw any conclusions about changes in phenology given the limited data on adult flight dates. These surveys were conducted during the seasonal peak of odonate activity from the second week of June through early September and thus missed the emergence period of the “spring” fliers and the last dates for many of the summer/fall fliers. Most early and late dates for odonates, within CACO and elsewhere, result from incidental observations rather than focused surveys, so this data tends to be patchy and less than thorough.

Odonates have been around for over 300 million years, making them among the oldest taxa on earth. They have survived dramatic climate perturbations in the past, outliving the dinosaurs, and thus may be unusually resilient to changes in their environment. The adults are strong fliers (especially the larger dragonflies) with considerable dispersal and colonization capabilities, likely providing them with the ability to respond more rapidly to climate change than many other organisms. This, combined with their relative conspicuousness and complex life cycles, makes odonates good barometers for climate change (Hassall 2015).

Odonate Migration

Although not a focus of this study, several species of odonates that occur within CACO are migratory, and significant migratory movements have been recorded within the park (Sones 1995a, b, Nikula pers. obs.). The largest numbers have been recorded during northbound movements, which occur from late May through mid-July, with a peak from mid-June through early July. Southbound movements, generally smaller in scale, occur from early August through early October, peaking from late August through early September.

Most migrants are encountered along the outer beaches, following the same “leading lines” used by migrant hawks and other diurnal avian and insect migrants. At times, especially during northbound movements, the rate of passage can number dozens of individuals per minute. As with most diurnal

migrants, weather is an important factor determining when these movements occur. Clear skies and favorable (generally light) tail winds (i.e., southerly for northbound migrants and northerly or westerly for southbound migrants) are the most important variables. Rarely do significant movements occur under less than ideal conditions.

The most numerous migrant species is the Spot-winged Glider, which can be present by the thousands during northbound movements from mid-June through mid-July. (It is interesting to note that, in sharp contrast to its current abundance in the region, this southern species was unrecorded in Massachusetts until 1967.) Also common are Common Green Darner and Wandering Glider, both most numerous during southbound movements. Less common but regular migrants include Swamp Darner, Painted Skimmer, Carolina Saddlebags, Black Saddlebags, and Blue Dasher. Occasionally an individual or two of other species appear among migrant swarms, though it is unclear whether these are true migrants or simply wandering individuals that end up along the coast.

Conservation

Odonates are considered to be a significant indicator of the health of wetlands. Both adults and nymphs are aggressive, voracious predators of other aquatic invertebrates, and thus reliant upon healthy populations of these ‘lesser’ taxa. Protecting the diversity and uniqueness of Cape Cod’s odonate fauna depends on protecting the integrity of the habitats that support them. Fortunately, CACO wetlands, lying within federal jurisdiction, are relatively well-protected. Shoreline residential developments are absent to sparse at most of the kettle ponds, and even where more extensive, such as at Great Pond in Wellfleet, never reach the extent of those invading many Cape Cod ponds outside of the park. No housing developments are present on the shorelines of any inter-dune ponds, bogs, vernal pools, or riparian marshes.

Several species of conservation concern inhabit CACO wetlands, in particular the kettle ponds. Two Massachusetts Threatened species are present, Attenuated Bluet and Pine Barrens Bluet, and both were recorded at nine kettle ponds, though there was not complete overlap as each was found at two ponds the other was not (Table 36). The former was most numerous at Herring Pond, Higgins Pond, and Snow Pond, while the latter was most numerous at Great Pond (Truro) and Snow Pond. Historical records for Pine Barrens Bluet also exist from Ryder Pond and Southeast Pond, two sites that were not covered by the present surveys. Additionally, there are two historical records for Scarlet Bluet (Massachusetts Threatened), both from kettle ponds: Great Pond (Truro) and Turtle Pond.

The Attenuated Bluet has increased dramatically in the area over the past 15 years and may be a candidate for de-listing. Both the Pine Barrens and Scarlet bluets, however, are Northeast endemics, of high conservation concern; both have apparently expanded northward somewhat over the past two decades. Populations of the former seem to be reasonably stable, but the apparent extirpation of Scarlet Bluet within CACO is of concern, though it is not clear whether a population was ever well established within the park. Future targeted surveys for this species would be very desirable.

Table 36. State-listed species at Cape Cod National Seashore (historical records only for Scarlet Bluet). # of Surveys is # of surveys recorded at a site, see Table 4 for #conducted.

Pond/Site Name	Attenuated Bluet		Pine Barrens Bluet		Scarlet Bluet	
	High Count	# of Surveys	High Count	# of Surveys	High Count	# of Surveys
Dyer Pond	0	0	5	2	0	0
Great Pond Truro *	8	3	30	4	7	1
Great Pond Wellfleet *	2	1	25	1	0	0
Herring Pond *	38	10	0	0	0	0
Higgins Pond	50	3	0	0	0	0
Horseleeche Pond *	1	1	2	1	0	0
Little Spectacle Pond	8	3	0	0	0	0
Round Pond East	0	0	3	1	0	0
Round Pond West	5	2	5	1	0	0
Snow Pond *	50	10	70	5	0	0
Spectacle Pond	19	2	1	1	0	0
Turtle Pond *	0	0	3	2	3	1
W07	1	1	0	0	0	0

* 3YearSites, others are 1YearSites.

Two additional damselfly species present in CACO are Northeast endemics and of conservation concern: New England Bluet (formerly listed as Special Concern) and Little Bluet (Hunt 2020, Hunt et al. 2020, White et al. 2014). The New England Bluet was recorded at eight sites, most frequently at inter-dune ponds (where it may avoid competition with the closely related Pine Barrens Bluet, which occurs exclusively at kettle ponds) and less frequently at kettle ponds. The Little Bluet was found at seven sites, all kettle ponds; it prefers the larger, sparsely vegetated, sandy-bottomed ponds. In addition, two species of damselfly, the Spatterdock and Comet, both recorded in very small numbers (Table 3), are currently on a Massachusetts list of Species of Greatest Conservation Concern (SGCC) (Massachusetts Wildlife 2015).

Stressors

Odonates on Cape Cod are potentially affected by numerous stressors, which can be global, regional, or site specific in their origins, and can often interact with each other. Global stressors tend to affect large geographic areas that are often far removed from their ultimate cause or source. Global stressors include atmospherically transported pollutants such as mercury and acid rain, as well as climate change and sea level rise.

Mercury is transported atmospherically and often deposited far from the source. Upon entering aquatic ecosystems, particularly acidified ones, mercury is biologically and chemically converted to methylmercury, a biologically active and highly toxic form (Eagles-Smith et al. 2020) that can be accumulated by aquatic organisms to the point of causing lethal or sub-lethal effects. Mercury deposition is occurring throughout the Northeast, including National Parks such as Acadia NP and

CACO. In a nationwide sample of 100 NPS Units, total mercury levels in odonate nymphs at CACO had an overall geometric mean of 120 ng/g dry weight, which was close to the overall national average of 125 (Eagles-Smith et al. 2020). Two of the 5 sites sampled at CACO had geometric means of 240 and 180 ng/g of total mercury. Further evidence of mercury bioaccumulation in CACO's aquatic ecosystems is seen in fish: Mercury levels in fish fillets from CACO kettle ponds exceed public health standards and the Seashore posts advisories against their consumption (NPS 2018). However, although the negative impacts of mercury consumption on humans and some vertebrates are known, it is unclear if it is causing any negative impacts to odonate survival, populations, or communities.

Acid deposition occurs at CACO, where ecosystem sensitivity is “very high”, and the risk of acidification effects is high (Sullivan et al. 2011). However, recent data indicate the rainfall acidity is decreasing and although still acidic, kettle pond pH is increasing (NPS 2018, Smith et al. 2016). Atmospheric nutrient input, i.e., nitrogen, is relatively high regionally in spite of declines in recent decades but does not appear to be affecting algal growth in kettle ponds (Smith et al. 2018a). Atmospheric warming and sea level rise are also acting on the Seashore's freshwater systems, with summertime air and pond water temperatures increasing (Smith et al. 2016, Smith et al. 2018b) and increasingly high levels of ground and pond water may be driven, in part, by sea level rise (Smith and Medeiros 2019).

Interacting with these global stressors are those that are more regional and site specific. The Cape Cod region was affected by the mid to late 20th Century boom in development and human recreation which has impacted habitats important to odonates in many ways. These have included water level drawdown for municipal water supply; alteration of and continuing impacts to pond shore and littoral zone vegetation for beach development and recreation; alteration of uplands habitats for beach, residential, commercial, and industrial development; use of pesticides for commercial and residential purposes; nutrient enrichment from fertilizers and septic systems (Carpenter 1986, 1988, 1990).

One of the principal motivations for creating Cape Cod National Seashore in 1961 was to preserve a portion of the Cape Cod landscape, scenery, wildlife and flora from the anticipated impacts of this regional development boom. As a result, the extent and intensity of negative impacts to habitat integrity inside the Seashore is much less than outside, and the ponds, wetlands, and natural landscapes of Cape Cod National Seashore are relatively well-protected from many of the local stressors noted above. However, some of these do occur, sometimes acting in tandem with global stressors.

Most of the local, site-specific stressors identified in Seashore reports and planning documents (e. g., NPS 2018, Smith 2012) that could affect odonates are related to development and recreation in the park, particularly their impacts to freshwater habitats. Shoreline residential development is largely absent from inter-dune ponds, bogs, vernal pools, and riparian marshes, and most of the Seashore's 20 named kettle ponds have only a few houses within 100m of the pond. However, five of them have more: Gull (41), Long (28), Ryder (18), Great W (10), and Higgins (10) (Smith et al. 2018a). The Seashore's kettle ponds, particularly those that are large, deep, and clear, with low levels of nutrients, have long been favorite sites for residential development prior to the Seashore's creation and

recreation, and remain highly popular (Smith et al. 2018a). Because Seashore kettle ponds are highly sensitive to cultural eutrophication, particularly from the septic systems of nearby residences, and climate change, they have been the focus of significant research and monitoring. Recent analyses of long term data on kettle pond water clarity found no evidence of adverse impact of housing densities on water clarity or nutrient concentrations, perhaps because residential development in the Seashore is very low compared to the rest of Cape Cod, and/or because most of the homes were built around deeper ponds with clearer water, or because a large proportion of these houses are located at points in the watershed where groundwater flow is away from the ponds (Smith et al. 2018a).

Although nutrient inputs from nearby homes or the atmosphere do not appear to be affecting kettle pond vegetation, changes are occurring. Vegetation monitoring at 10 kettle ponds, some since 1995, has shown changes in species composition and declines in species richness and plant cover at many ponds. There has been an overall narrowing of the littoral zone vegetation, and within it, a relative reduction in emergent zone vegetation and an increase in the floating leaved and submergent zone species. Some of these changes appear to be due to increasing water levels, driven by sea level rise (Smith and Medeiros 2019). In addition, declines in species that thrive under acidic conditions may also be related to decreased kettle pond acidity as rainfall has become less acidic (Smith 2018). Most of the plant species affected are emergent, and include military rush (*Juncus militaris*) (Smith 2018), a species important for oviposition in damselflies such as the MA Threatened Pine Barrens Bluet (Carpenter 1990, 1991, Gibbons 2001, Gibbons et al. 2002).

While kettle pond macrophytes appear to be under stress from increasing water levels and reduced pond acidity (Smith 2018), an additional source of stress at some kettle ponds is human trampling—impacts to bank and littoral vegetation at some ponds has been a long-standing concern at CACO (Smith 2012, Smith et al. 2018a, b). Recreational use of kettle ponds throughout the warm months is common, especially at the mid to large sized ones. In Wellfleet, the town manages public beaches and parking lots in summer at Duck, Great, Long, and Gull ponds. Recreational use also occurs at Dyer, Herring, Higgins, Horseleeche, Snow, Spectacle, and Great (Truro) ponds, but is limited at these sites by parking availability. In addition to the people who enter these ponds through public access points are those with private access. The four ponds with formal, managed parking lots also account for 63% of the houses near kettle ponds (data in Smith et al. 2018a). For the most part recreational activity occurs in front of a limited section of shoreline, where shoreline vegetation is scarce or lacking (in most cases probably due to longstanding human activity). Although empirical data is lacking, observations made by one of us (R. Cook), as well as by past and present CACO staff (Sophia Fox, pers. comm., John Portnoy, pers. comm.) show that people, once in the water, wade outward and/or walk/wade along the shoreline, and over time, the extent of vegetation loss increases.

Based on these observations, the most disturbed ponds appear to be Duck and Gull, and to a lesser extent Great (Wellfleet), Long, and Dyer. Others with modest damage are Horseleeche, Spectacle, and Snow. Most of these ponds are oligotrophic or meso-oligotrophic ponds, low in nutrients and with aquatic vegetation that is sparser than the vegetation of the naturally eutrophic ponds (Coe and Soukup 1978, Roman et al. 2000, Portnoy et al 2001). The naturally less dense vegetation of these low nutrient ponds makes them inherently more attractive for activities such as wading and

swimming, and also more vulnerable to trampling. In recognition of these localized human impacts, and their potential to compound the loss of littoral zone vegetation due to global stressors, Smith (2018) recommended, “Because littoral zone macrophytes appear to be under some stress, as evidenced by their reduced abundance in many cases, it is important that CACO continues to support current efforts to restore/rehabilitate denuded pond shorelines where visitors have trampled the vegetation. These direct management activities can help offset some of the other losses that are not within the park’s control (e. g., hydrology, climate change).” Ponds where CACO staff have taken action to repair damage from visitor impacts and restore vegetation are Duck, Dyer, Great (Truro), and Spectacle (Sophia Fox, pers. comm.).

In addition to its role in providing odonates with oviposition and emergence sites, littoral zone vegetation provides shelter from predators (Carpenter 1991, Butler and deMaynadier 2008), which at CACO includes several species of predaceous fish. Most are native, but non-native trout have been stocked for more than a half century in Gull Pond (brown trout, brook trout, rainbow trout) and Great Truro (brook trout) (Smith et al. 2018a, Massachusetts Wildlife 2021). Thus, in ponds where littoral zone vegetation has been reduced, increased predation pressure is likely an additional stressor.

Three ponds in South Truro (Great, Snow, and Round West) lie near Route 6 and road run-off is a concern at these sites. Exposure to high levels of salt, such as from road run-off, has recently been shown to decrease the immune response in the larvae of Common Green Darners (Mangahas et al. 2019).

Freshly emerged odonates leave their natal wetlands as soon as they are able to fly (in most cases within an hour or two of emergence) and spend up to several days in upland areas feeding and maturing, before returning to the wetlands to breed. Only mature males spend much time at the breeding sites, and then only a few hours/day and only when weather conditions are favorable. Mature females spend virtually all their time in upland areas, returning to breeding sites only for brief periods when ready to mate and lay eggs. Thus, the upland buffer around wetlands is vitally important to odonate survival and the viability of the breeding sites. How extensive the upland buffer needs to be is difficult to ascertain and the subject of ongoing research, but certainly the more the better. Fortunately, most of the wetlands within CACO have a fairly extensive buffer, but every effort should be made to prevent alteration, disturbance, or reduction in size of this critical buffer.

Recommendations

As noted above, it would be best to use the insight into odonate population and community variation obtained from these surveys to develop a monitoring program designed to meet standards of statistical confidence and power currently employed in NPS monitoring programs. Until then, the next best option would be to continue the survey efforts employed in this project on a regular basis in the future, following the protocols established for this project (at least six 40-minute surveys spaced evenly throughout the mid-June through mid-September season), focused especially, if time is limited, on the 10 3-year sites. Surveys should be conducted minimally every five years. Given the effects that sampling effort can have on total numbers recorded and on measures of species richness noted throughout, it is important to have equal numbers of surveys at each site, and recognize that the number of sites sampled in a given habitat will influence its species total.

For state-listed species, targeted surveys should be conducted periodically, focused especially on the nine kettle ponds where Pine Barrens Bluet and Scarlet Bluet have been recorded, to determine if a population of the latter species is still extant within CACO. Targeted surveys for those species not well-surveyed previously are desirable, in particular the few species that are more active late in the day (e. g., Vesper Bluet, Orange Bluet) or late in the season (e. g., Spotted Spreadwing, Autumn Meadowhawk). Another very poorly surveyed species, the Seaside Dragonlet, breeds exclusively in salt marshes and, given climate-related concerns over the future of this habitat in the face of rising sea levels, is very much a species of conservation concern. Incidental observations (Nikula pers. obs.) suggest this species may have declined at Nauset Marsh over the past 30 years. Formal surveys for this species are strongly recommended.

Although not covered in these surveys (regrettable in hindsight), Gull Pond in Wellfleet, the largest pond within CACO, appears to support several odonate species that are absent or rare elsewhere in the park. It is also the most impacted pond, with a heavily used public beach and numerous dwellings ringing its perimeter. Further surveys to fully document the odonate fauna at this site are warranted.

Although most of the wetlands within CACO are relatively well protected, the park should continue its efforts to reduce and repair damage to vegetation at those kettle ponds that receive heavy summer use. CACO should also consider expanding its kettle pond monitoring to better capture the spatial extent and intensity of human activity and its impacts, perhaps through the use of a Disturbance Index (Butler and deMaynadier 2008).

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Appendix 1: Sample Data Sheet

Data were recorded manually on one side of a sheet of water-resistant paper (Figure 8), with definitions of cloud, wind and vegetation cover categories and other survey notes/instruction on the other side (Figure 9).

[illegible]

Figure 8. An example of the Cape Cod National Seashore Odonate Survey data sheet, page 1.

Cloud Cover Categories

1	0 – 25% Cloud Cover
2	25 – 50% Cloud Cover
3	50-75% Cloud Cover
4	75 - 100% Cloud Cover

Beaufort Wind Scale

Force	Wind (Knots)	WMO Classification	Appearance of Wind Effects On Land
0	Less than 1	Calm	Calm, smoke rises vertically
1	1-3	Light Air	Smoke drift indicates wind direction, still wind vanes
2	4-6	Light Breeze	Wind felt on face, leaves rustle, vanes begin to move
3	7-10	Gentle Breeze	Leaves and small twigs constantly moving, light flags extended
4	11-16	Moderate Breeze	Dust, leaves, and loose paper lifted, small tree branches move
5	17-21	Fresh Breeze	Small trees in leaf begin to sway
6	22-27	Strong Breeze	Larger tree branches moving, whistling in wires
7	28-33	Near Gale	Whole trees moving, resistance felt walking against wind

Vegetation Zone (Emergent and Floating) Categories

NP	Not Present (e.g., bogs)
0	Dry
1	<25% of the zone has standing water in it
2	25% to 75% of the zone has standing water in it
3	>75% of the zone has standing water in it (is inundated)

Notes:

Survey Period: Should be a number from 1-8, to correspond to the 8 survey periods

Recording UTM and Distance Traveled: Coordinates should be recorded in UTM. The starting UTM, as well as the direction of travel, should be the same for every survey at a site, in which case the starting UTM can be recorded as simply "same." Only if the starting point changes (to be avoided if at all possible), does the starting UTM need to be recorded.

The ending UTM should be recorded for every survey, as it will vary depending upon the activity level, which will affect the distance traveled during the 40-minute survey.

The distance traveled should be recorded with the GPS in meters and transcribed to the data sheet. If, for some reason, this is not possible, the distance can be computed later from the start and end points.

Surveys should be avoided when cloud cover exceeds 50% and/or Beaufort Wind Scale exceeds category 5 (along the survey transect).

The Time column is optional; it will be used to determine species accumulation curves (in 10-minute time blocks).

Please make copies of the datasheets before turning them in, and keep the copies in your files (for security purposes).

Figure 9. An example of the Cape Cod National Seashore Odonate Survey data sheet, page 2.

Appendix 2: Species Accounts

In the following species accounts we provide a brief description of the status of every species recorded from CACO, both current and historical. For each species we also include a description of its range in North America, general habitat preferences, number of sites at which it was recorded on these surveys plus the number of historical sites, the number of surveys on which it was recorded, the average number per survey, and the highest count recorded. For those species for which there is sufficient data, we present charts showing habitat occurrences (if recorded at more than four sites during the current surveys, AllSitesAllYears) and flight periods (including historical data).

Damselflies (Zygoptera)

Spread-winged Damselflies (Lestidae)

Spotted Spreadwing (*Lestes congener*) (Hagen, 1861)

- Range: British Columbia, Northwest Territories and Newfoundland south to California, New Mexico, Nebraska, Alabama, and Virginia
- Habitat: Vegetated lakes, ponds, and pools
- Number of CACO Sites: 8 (plus 3 historical)
- Number of Surveys: 10 (3%)
- Average Number/Survey: 2
- High Count: 3

The limited data from the current surveys indicate a distinct preference for vernal pools, with the remainder found at inter-dune ponds (Figure 10). The Spotted Spreadwing has the latest flight season in its family and one of the latest of any local odonate. It was recorded very infrequently on the formal surveys (only 10 surveys), primarily because the surveys ended well before the peak flight season. The historical data indicates the species is fairly common from mid-September through October (Figure 11)

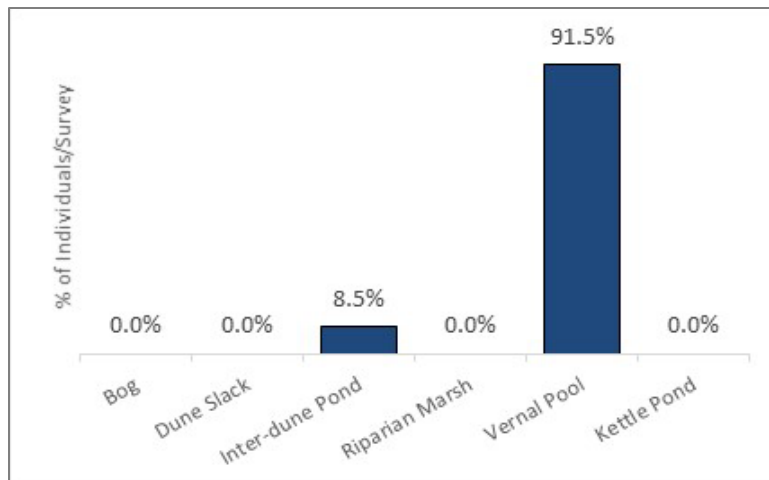


Figure 10. Spotted Spreadwing distribution by habitats at Cape Cod National Seashore.

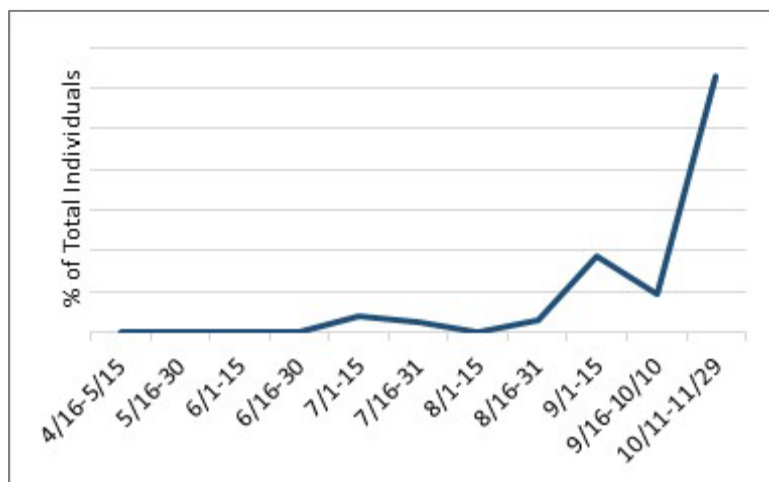


Figure 11. Spotted Spreadwing flight season at Cape Cod National Seashore.

Northern Spreadwing (*Lestes disjunctus*) (Selys, 1862)

- Range: Alaska, Northwest Territories and Labrador south to California, New Mexico, Kansas, West Virginia and New Jersey
- Habitat: Well-vegetated ponds, pools, and boggy wetlands
- Number of CACO Sites: 4 (plus 6 historical)
- Number of Surveys: 6 (2%)
- Average Number/Survey: 14
- High Count: 120

The status of the Northern Spreadwing is unclear due to confusion with the very similar and much more numerous Sweetflag Spreadwing. Some records may involve misidentifications, while in some cases it may have been overlooked among the masses of the more common species. Almost all (98%)

were found at just one site, T27 in Truro, with just single individuals at three additional sites. The vast majority (85%) of historical records come from just two sites, Clapps Pond and E01. The limited data suggest it inhabits vernal pools, shallow kettle ponds, and inter-dune ponds (Figure 12). (Although T27 is classified as a kettle pond, it is very shallow and in many respects is more similar to an inter-dune pond.) The flight season seems to peak from late July through mid-August (Figure 13), overlapping with, but averaging about two weeks later than, Sweetflag Spreadwing. It is not possible to draw any conclusions about a change in status, although it is interesting to note that 100 individuals (with numerous pairs—one collected) were estimated at Clapps Pond on 7/29/95, but only a single individual was found there during six surveys in 2017.

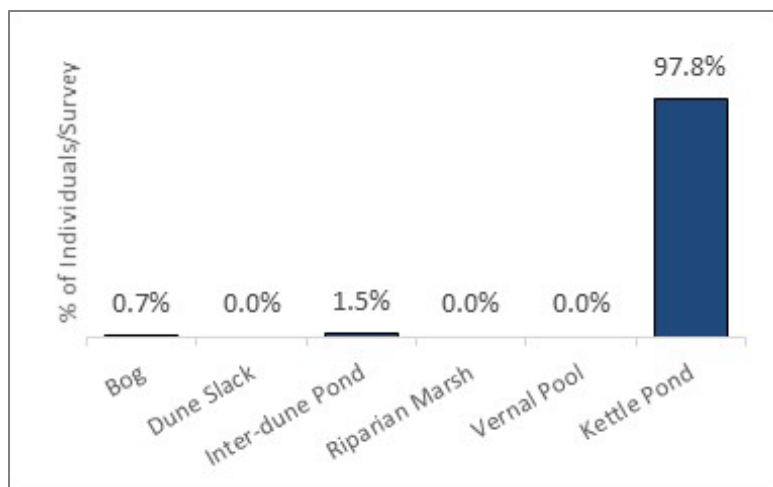


Figure 12. Northern Spreadwing distribution by habitats at Cape Cod National Seashore.

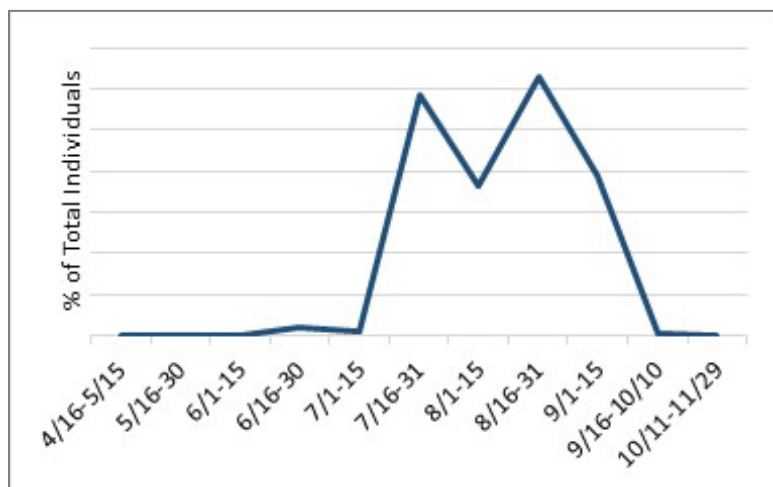


Figure 13. Northern Spreadwing flight season at Cape Cod National Seashore.

Another complication is the possible presence of the virtually identical (until recently considered the same species) Southern Spreadwing (*Lestes australis*). Although not yet recorded in Massachusetts, this nascent species has been recorded, infrequently, in Rhode Island and Connecticut and could be

present but overlooked within CACO. However, it has an earlier flight season than its closely related congener, and the late summer flight season recorded on these surveys (and historically) suggest they are not the southern species.

Amber-winged Spreadwing (*Lestes eurinus*) (Say, 1839)

- Range: Minnesota and Quebec south to Oklahoma and South Carolina
- Habitat: Variety of vegetated wetlands, usually where fish are absent
- Number of CACO Sites: 18 (plus one historical)
- Number of Surveys: 57 (15%)
- Average Number/Survey: 11
- High Count: 50

The largest of the spreadwing species on Cape Cod was recorded primarily at vernal pools and inter-dune ponds (Figure 14). It has the earliest flight season of the regularly occurring spreadwings, peaking in late June; the historical data indicates emergence beginning in late May (Figure 15). Though fairly common and widespread (44% of sites), it occurs at relatively low densities, with an average of 11 individuals per survey. Typically associated with fish-less wetlands, fish are present at several of the sites at which the species was recorded during the surveys.

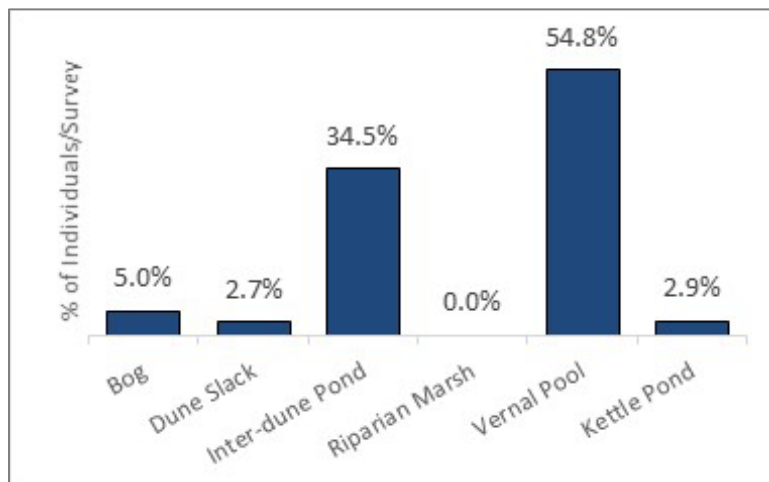


Figure 14. Amber-winged Spreadwing distribution by habitats at Cape Cod National Seashore.

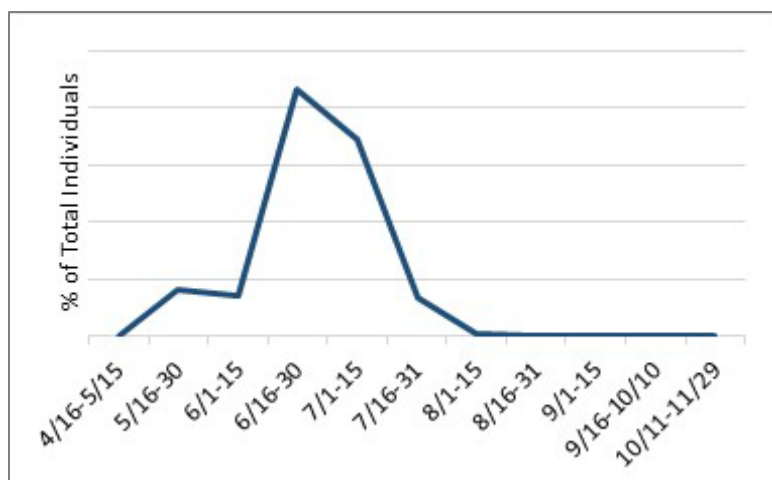


Figure 15. Amber-winged Spreadwing flight season at Cape Cod National Seashore.

Sweetflag Spreadwing (*Lestes forcipatus*) (Rambur, 1842)

- Range: British Columbia, Saskatchewan and Nova Scotia south to Oregon, Colorado, Oklahoma, Alabama and North Carolina
- Habitat: Well-vegetated ponds, vernal pools, and boggy wetlands
- Number of CACO Sites: 27 (plus 5 historical)
- Number of Surveys: 112 (29%)
- Average Number/Survey: 37
- High Count: 800

The Sweetflag Spreadwing is the most numerous, and one of the most widespread, of the local spreadwings. It was recorded in five of the six habitat types, though the preponderance was found in vernal pools (Figure 16). At favored sites (e. g., E09) it can be the most common odonate, numbering hundreds of individuals. The flight season peaks in mid-summer (late July–early August) (Figure 17).

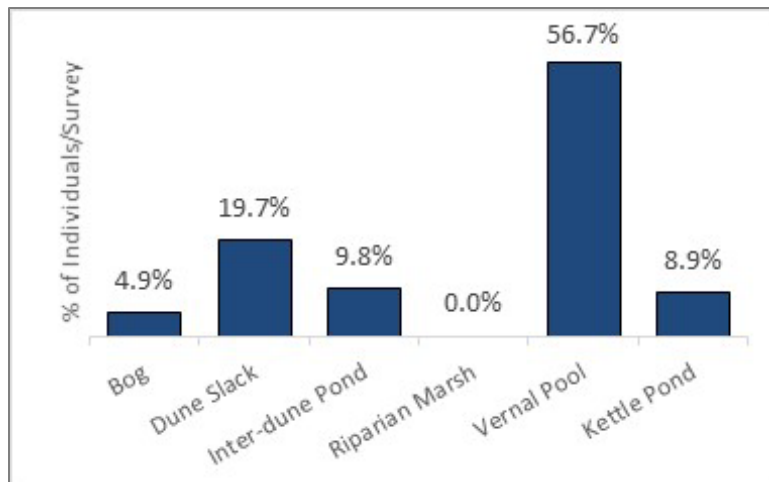


Figure 16. Sweetflag Spreadwing distribution by habitats at Cape Cod National Seashore.

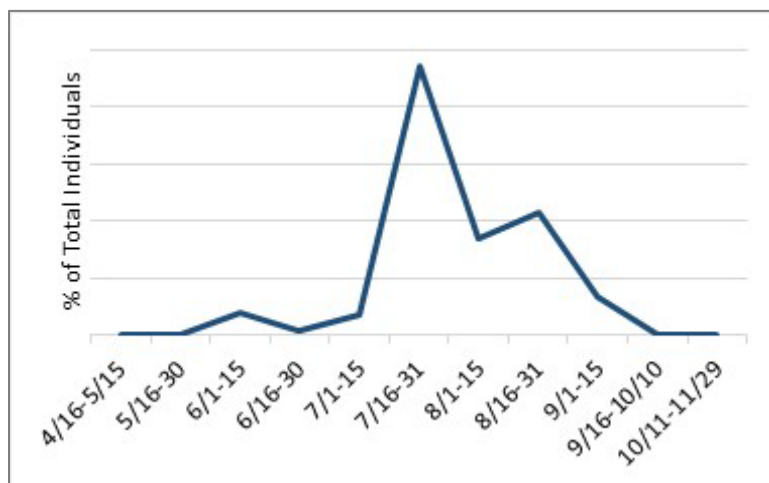


Figure 17. Sweetflag Spreadwing flight season at Cape Cod National Seashore.

Elegant Spreadwing (*Lestes inaequalis*) (Walsh, 1862)

- Range: Manitoba, Ontario and New Brunswick south to Texas and Florida
- Habitat: Well-vegetated ponds and lakes; sluggish streams
- Number of CACO Sites: 11 (plus 5 historical)
- Number of Surveys: 22 (6%)
- Average Number/Survey: 3
- High Count: 9

The Elegant Spreadwing is the second largest of the genus within the seashore and is uncommon and local in distribution. It is very similar to the more common and widespread Swamp Spreadwing, usually requiring in-hand examination to confirm identification; thus a few of the sight-only records may involve misidentifications (especially those after early August). It was recorded in four of the

six habitat types, but over 94% of the total was distributed between inter-dune ponds and kettle ponds (Figure 18). It has a relatively early flight season, peaking between late June and mid-July (Figure 19).

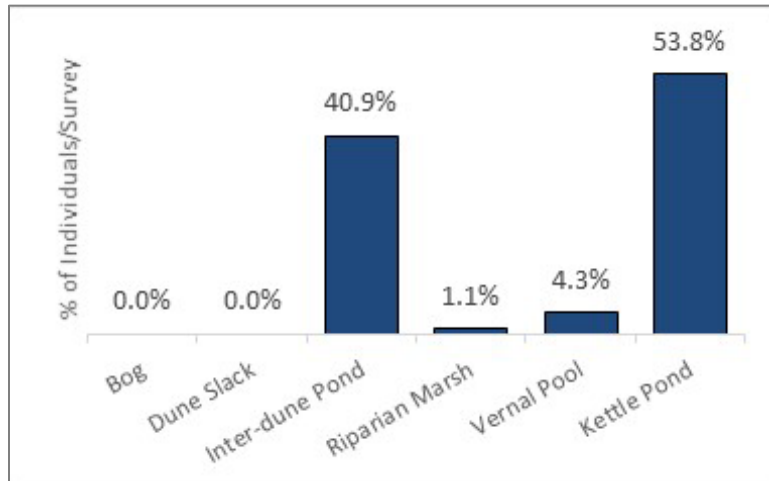


Figure 18. Elegant Spreadwing distribution by habitats at Cape Cod National Seashore.

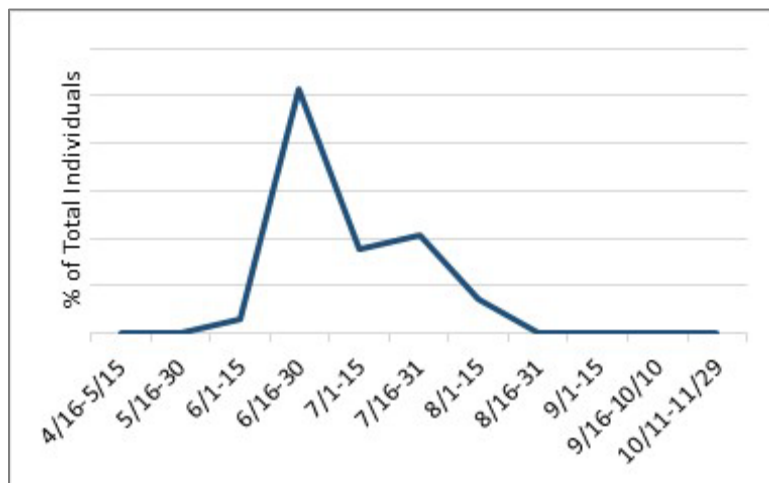


Figure 19. Elegant Spreadwing flight season at Cape Cod National Seashore.

Slender Spreadwing (*Lestes rectangularis*) (Say, 1839)

- Range: Manitoba and Nova Scotia south to Colorado, Texas and Florida
- Habitat: Variety of vegetated wetlands, including sluggish streams and vernal pools
- Number of CACO Sites: 33 (plus 5 historical)
- Number of Surveys: 80 (20%)
- Average Number/Survey: 3
- High Count: 16

The Slender Spreadwing is widespread but uncommon, occurring in low numbers in all seven habitat types, though the preponderance of records is from vernal pools and bogs (Figure 20). It is frequently encountered along woodland trails and roads, well away from wetlands, and thus not often recorded during the official surveys. Unlike others in the genus, females often oviposit unattended by the males. The lengthy flight season runs from mid-June through mid-September (Figure 21).

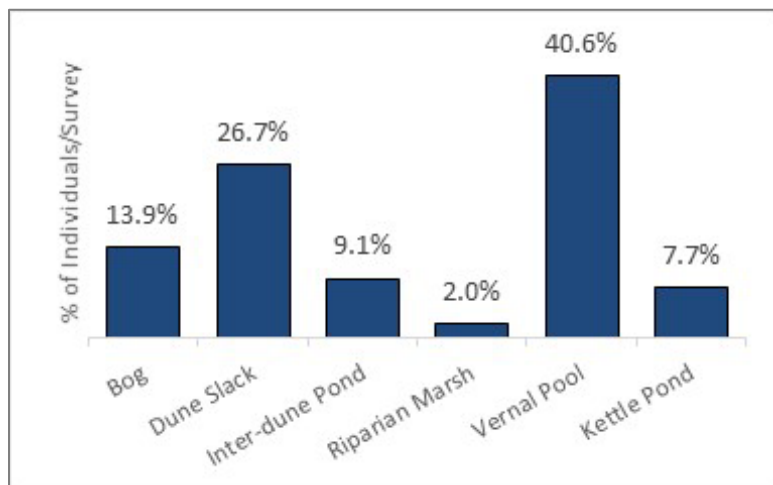


Figure 20. Slender Spreadwing distribution by habitats at Cape Cod National Seashore.

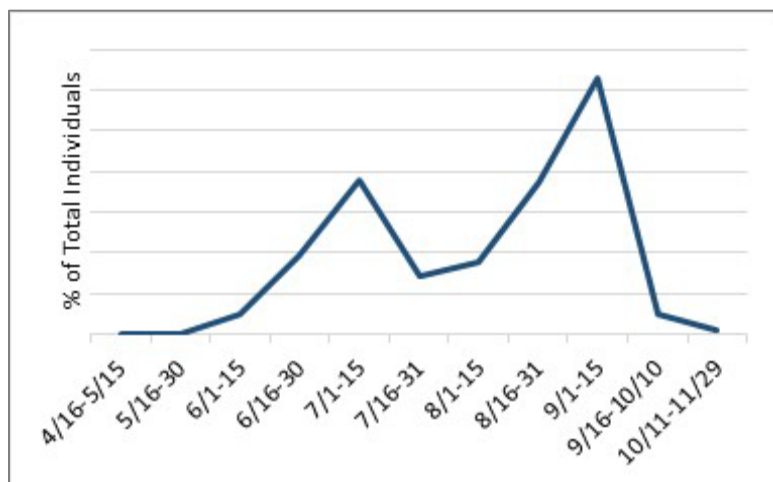


Figure 21. Slender Spreadwing flight season at Cape Cod National Seashore.

Lyre-tipped Spreadwing (*Lestes unguiculatus*) (Hagen, 1861)

- Range: British Columbia, Manitoba and Nova Scotia south to California, Colorado, Texas, Tennessee and Maryland
- Habitat: Grassy marshes and ponds; temporary wetlands
- Number of CACO Sites: 3 (all historical)
- Number of Surveys: NA

- Average Number/Survey: NA
- High Count: NA

The Lyre-tipped Spreadwing was not recorded during the current survey, and within the seashore is known only from three historical records at vernal pools in Eastham: a single male collected at E09 on 7/30/1995; one on 8/17/1996 at E08; and three males, one collected, at E12 in Eastham on 7/7/2001. It is a rare and very local species throughout southern New England and whether there is a viable population within the seashore is unknown. It is very similar to the abundant and widespread Sweetflag Spreadwing, occurring in similar habitats, and easily could be overlooked among the masses of that species.

Swamp Spreadwing (*Lestes vigilax*) (Hagen in Selys, 1862)

- Range: Minnesota, Ontario and Nova Scotia south to Texas and Florida
- Habitat: Well-vegetated ponds and lakes
- Number of CACO Sites: 17 (plus 4 historical)
- Number of Surveys: 105 (27%)
- Average Number/Survey: 12
- High Count: 110

The Swamp Spreadwing is the “default” mid-summer spreadwing at kettle ponds and inter-dune ponds throughout the seashore (Figure 22). It was unrecorded from vernal pools and a single record from a bog is anomalous and may involve a misidentification or a wandering individual. The flight season extends from mid-June through the end of August (Figure 23).

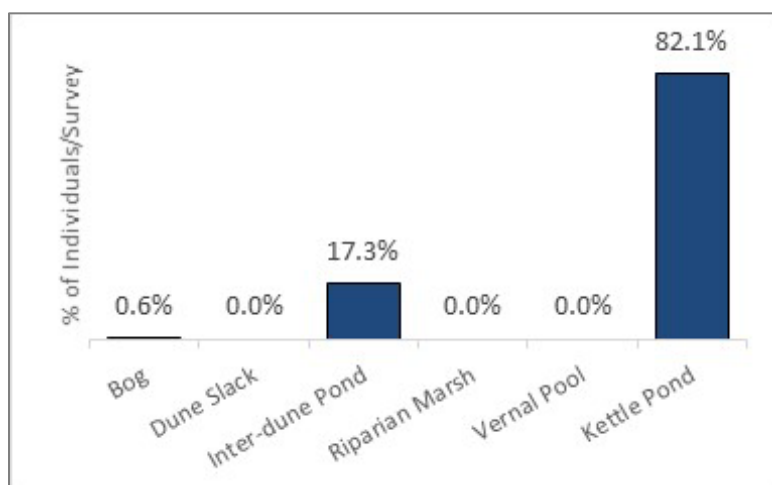


Figure 22. Swamp Spreadwing distribution by habitats at Cape Cod National Seashore.



Figure 23. Swamp Spreadwing flight season at Cape Cod National Seashore.

Broad-winged Damselfs (Calopterygidae)

***Ebony Jewelwing (Calopteryx maculata)* (Palisot de Beauvois, 1805)**

- Range: Wyoming, Manitoba and Nova Scotia south to Texas and Florida
- Habitat: Slow moving, shaded streams
- Number of CACO Sites: 2 (plus one historical)
- Number of Surveys: 14
- Average Number/Survey: 2
- High Count: 6

The striking Ebony Jewelwing inhabits only moving (lotic) water and thus its distribution within the seashore is confined to the Herring River watershed in Wellfleet (Figure 24). The preponderance of records during the surveys were from Herring Pond, but from the river outlet at the southwest corner of the pond. Unlike most odonates, females are seen as often as males. The flight season extends from mid-June through mid-August (Figure 25).

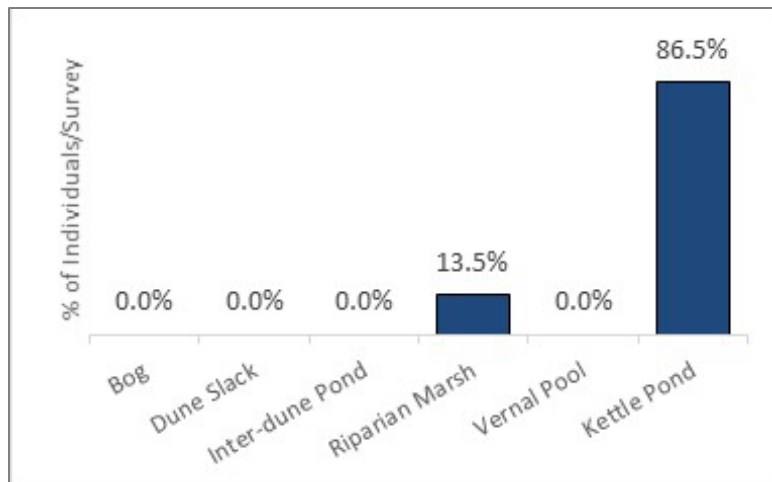


Figure 24. Ebony Jewelwing distribution by habitats at Cape Cod National Seashore.

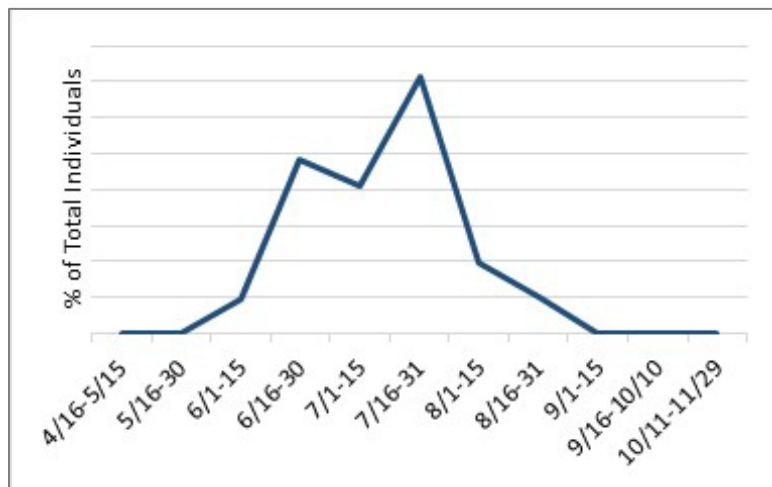


Figure 25. Ebony Jewelwing flight season at Cape Cod National Seashore.

Pond Damsels (Coenagrionidae)

Eastern Red Damsel (*Amphiagrion saucium*) (Burmeister, 1839)

- Range: Wisconsin, Ontario and Nova Scotia south to Mississippi and Georgia
- Habitat: seepage areas and sedge marshes
- Number of CACO Sites: 2 (plus one historical)
- Number of Surveys: 3
- Average Number/Survey: 6
- High Count: 10

The tiny, red Eastern Red Damsel has very restricted habitat requirements and within the seashore is known only from three sites within the Herring River floodplain in Wellfleet, where it occupies seepage areas, mostly well back from the river proper (Figure 26). It flies early in the season, with

the few records extending from the second week of June through the second week of July (Figure 27).

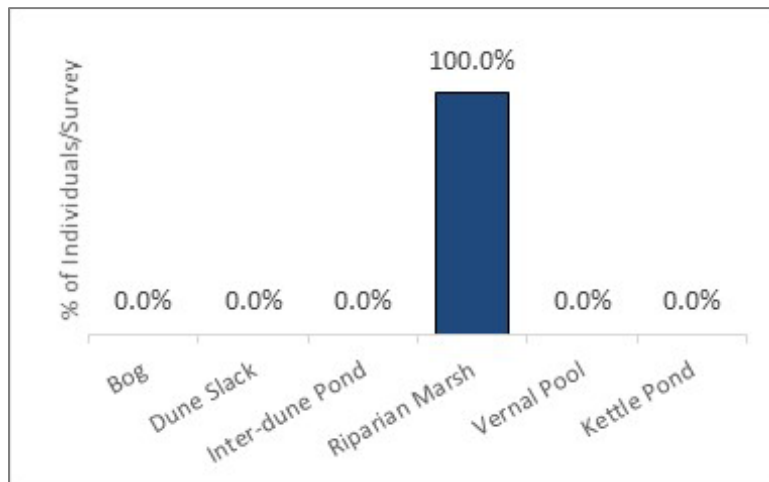


Figure 26. Eastern Red Damsel distribution by habitats at Cape Cod National Seashore.

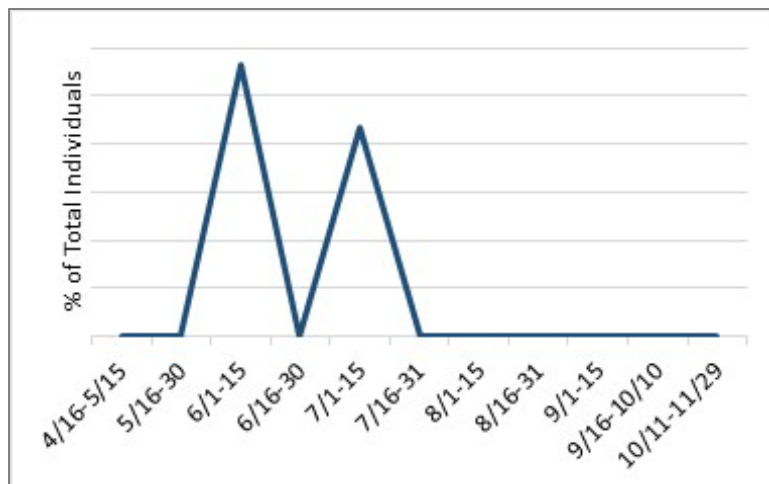


Figure 27. Eastern Red Damsel flight season at Cape Cod National Seashore.

Variable Dancer (*Argia fumipennis*) (Burmeister, 1839)

- Range: Arizona, far southern Saskatchewan, Ontario and Nova Scotia south to Hidalgo and Florida
- Habitat: A wide range of wetland habitats, though most common at vegetated ponds
- Number of CACO Sites: 15 (plus 5 historical)
- Number of Surveys: 141 (36%)
- Average Number/Survey: 11
- High Count: 126

Although a habitat generalist, the distinctive Variable Dancer was recorded almost exclusively at kettle ponds during the surveys (the exceptions being single records from a vernal pool and an inter-dune pond) (Figure 28). It was recorded only rarely in Provincetown, despite an abundance of seemingly suitable habitat. The flight season is lengthy, extending from mid-June through mid-September (Figure 29).

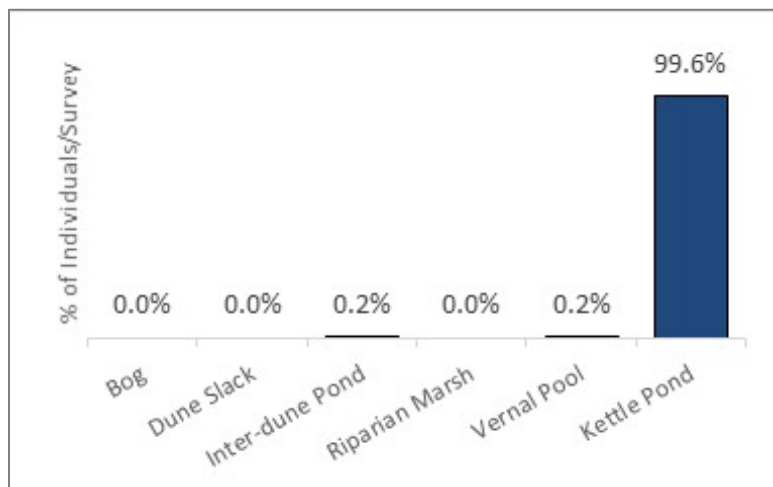


Figure 28. Variable Dancer distribution by habitats at Cape Cod National Seashore.

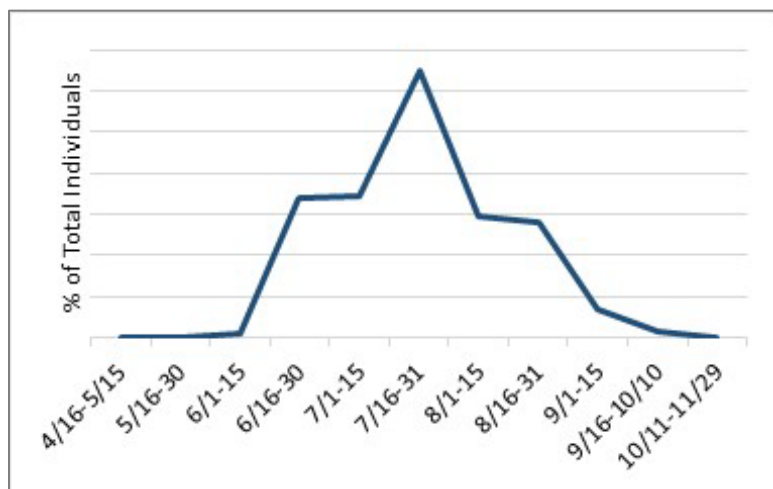


Figure 29. Variable Dancer flight season at Cape Cod National Seashore.

Taiga Bluet (*Coenagrion resolutum*) (Selys, 1876)

- Range: Alaska, Northwest Territories and Labrador south to California, New Mexico, Iowa, Ohio and Connecticut
- Habitat: Well-vegetated wetlands, including marshes and fens
- Number of CACO Sites: 1
- Number of Surveys: 1

- Average Number/Survey: NA
- High Count: 1+

One or two males of this northern damselfly were seen at W07 in Wellfleet on 6/9/18, providing a first record for the seashore and only the second record for Cape Cod. Although the Wellfleet individual(s) could not be captured or photographed, the males of this species are distinctive and easily identified. This northern species has a very early flight season. Whether the record indicates a local population or a wandering individual is unknown. The one other Cape site is 35+ miles to the southwest where a single male was collected in 1996.

Northern Bluet (*Enallagma annexum*) (Hagen, 1861)

- Range: Alaska, Northwest Territories and Labrador south to Baja California Norte, New Mexico, Nebraska, Indiana, West Virginia and New Jersey
- Habitat: Vegetated ponds, bog pools, marshes
- Number of CACO Sites: 10
- Number of Surveys: 16 (4%)
- Average Number/Survey: 39
- High Count: .250

The Northern Bluet occurs primarily at wetlands where fish are absent, and within the seashore has been recorded predominantly at inter-dune ponds and large vernal pools (Figure 30), where it typically is a common to abundant early season damselfly. The flight season extends from mid-May through the first week of July (Figure 31). (See comments under Boreal Bluet.)

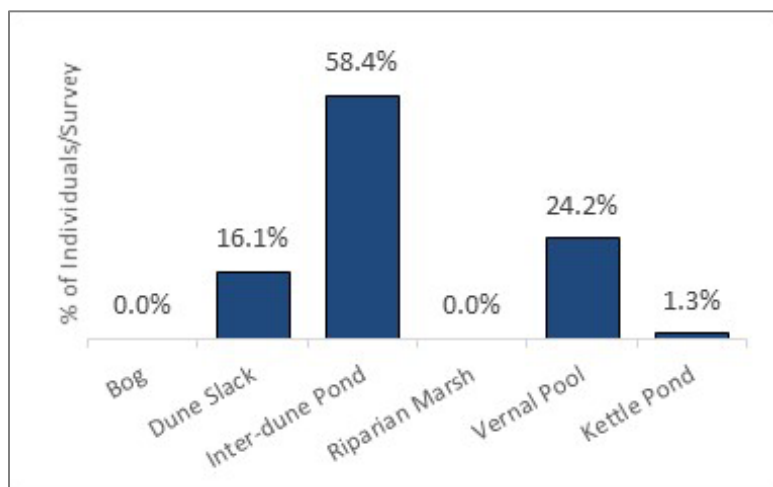


Figure 30. Northern Bluet distribution by habitats at Cape Cod National Seashore.

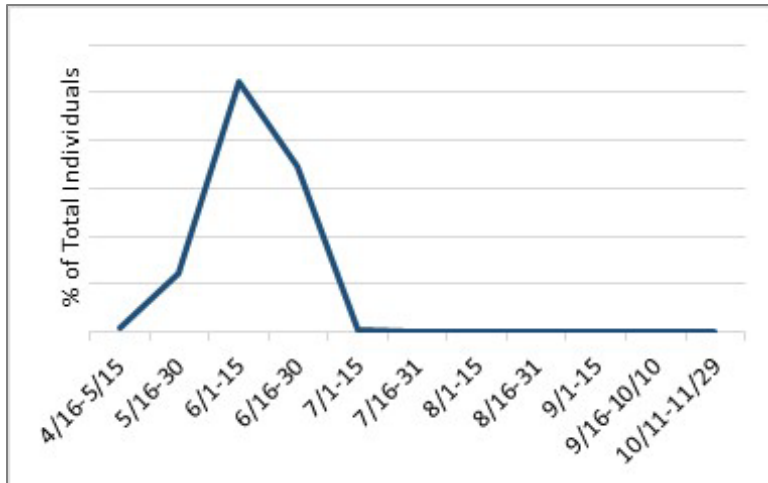


Figure 31. Northern Bluet flight season at Cape Cod National Seashore.

Azure Bluet (*Enallagma aspersum*) (Hagen, 1861)

- Range: Nebraska, Wisconsin, Quebec and Nova Scotia south to Texas, Mississippi and Georgia
- Habitat: Vegetated ponds, bog pools, vernal pools; primarily fish-less wetlands
- Number of CACO Sites: 14 (plus 4 historical)
- Number of Surveys: 45 (12%)
- Average Number/Survey: 24
- High Count: 200

The Azure Bluet is a common early to mid-summer species. It is fairly widespread, including sites where fish are present, occurring commonly at vernal pools, inter-dune ponds, and some small, well-vegetated kettle ponds (Figure 32). The flight season extends from late May through mid-August (Figure 33).

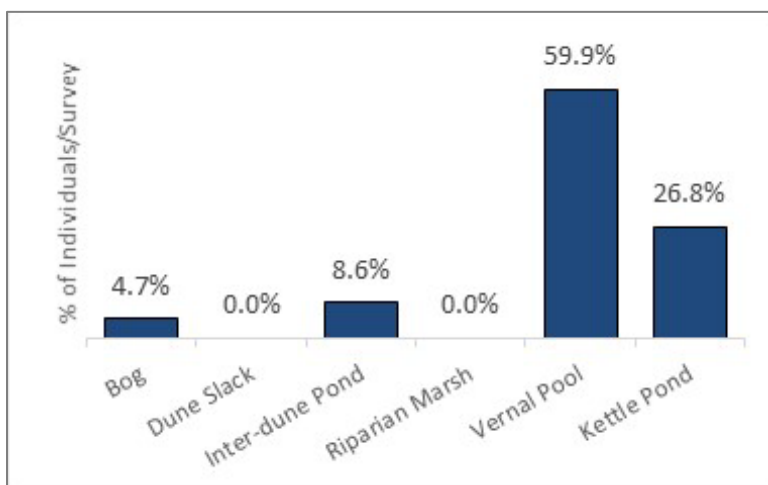


Figure 32. Azure Bluet distribution by habitats at Cape Cod National Seashore.

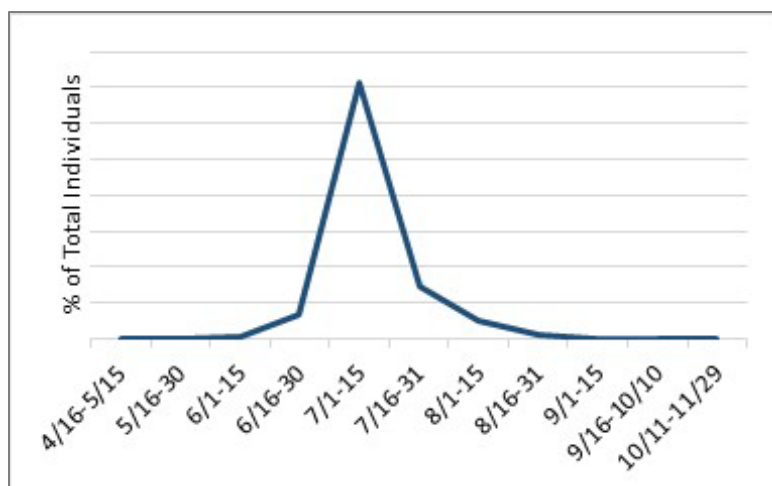


Figure 33. Azure Bluet flight season at Cape Cod National Seashore.

Boreal Bluet (*Enallagma borealis*) (Selys, 1875)

- Range: Alaska, Northwest Territories and Labrador south to Durango, Iowa and West Virginia
- Habitat: Vegetated ponds, bog pools; primarily fish-less wetlands
- Number of CACO Sites: 1 (historical)
- Number of Surveys: NA
- Average Number/Survey: NA
- High Count: NA

The Boreal Bluet is known from only one record of two males, one collected, at T01 in Truro on 5/30/98. This species is extremely similar to the Northern Bluet, requiring examination of the male's terminal appendages under magnification, and its status within the seashore (and elsewhere in southeastern Massachusetts) remains very uncertain. The identity of the 1998 specimen was re-confirmed recently by the senior author. It's possible that at least some of the Northern Bluet records involved Boreal Bluets, as very few were captured and critically identified. The flight season is early, like the Northern, running from late May through late June.

Familiar Bluet (*Enallagma civile*) (Hagen, 1861)

- Range: Oregon, Saskatchewan and Newfoundland south to Venezuela and Florida; also, Bahamas, Greater Antilles and Curaçao; introduced to Hawaii
- Habitat: Variety of wetlands, including large, poorly vegetated ponds and lakes; also, brackish wetlands
- Number of CACO Sites: 6 (plus 5 historical)
- Number of Surveys: 25 (6%)
- Average Number/Survey: 22
- High Count: 100

The Familiar Bluet is a common inhabitant of large, sparsely vegetated, sandy bottomed ponds and lakes. During the surveys it was recorded only at some of the larger, sparsely vegetated kettle ponds (Figure 34). It is a mid-summer flier, with the flight season extending from early June through early September (Figure 35). This species is very similar in appearance, and has a similar flight season, to the Atlantic Bluet, though the two species tend to segregate by habitat. Though both are found exclusively at kettle ponds, the Atlantic favors more heavily vegetated sites (see additional comments under that species). The Familiar also occurs occasionally in brackish habitats.

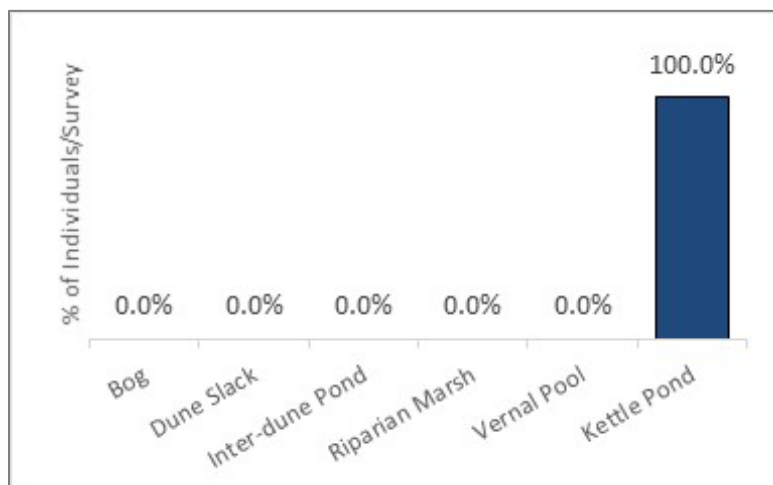


Figure 34. Familiar Bluet distribution by habitats at Cape Cod National Seashore.

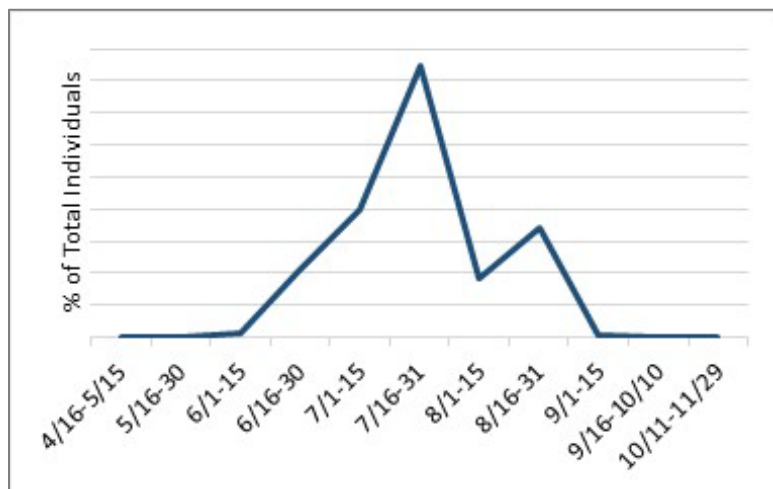


Figure 35. Familiar Bluet flight season at Cape Cod National Seashore.

Attenuated Bluet (*Enallagma daeckii*) (Calvert, 1903)

- Range: Oklahoma, Indiana and Massachusetts south to Texas and Florida
- Habitat: Vegetated ponds
- Number of CACO Sites: 10 (plus 2 historical)

- Number of Surveys: 35 (9%)
- Average Number/Survey: 11
- High Count: 50

The distinctive Attenuated Bluet was unknown from Cape Cod until 2004 when Shea discovered the species at Herring Pond in Wellfleet. Over the intervening 15 years the population has expanded rapidly and it has now been recorded at 12 sites within the seashore. During the surveys it was found exclusively at kettle ponds with moderate to extensive emergent vegetation (Figure 36). One record from a vernal pool involved a single male at a site adjacent to two kettle ponds. The recorded flight season extends from mid-June through mid-August (Figure 37). This is a southern species at the northern edge of its range here and its recent expansion may well be a response to climate warming. Currently listed as Threatened by the state, its recent population growth may warrant de-listing.

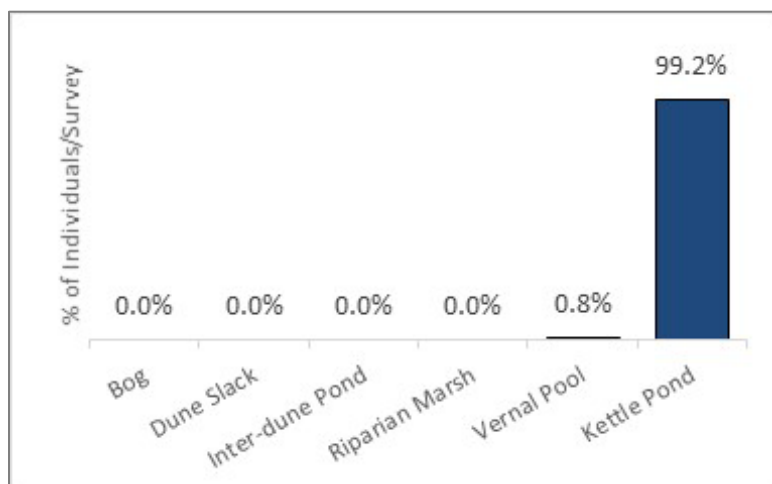


Figure 36. Attenuated Bluet distribution by habitats at Cape Cod National Seashore.

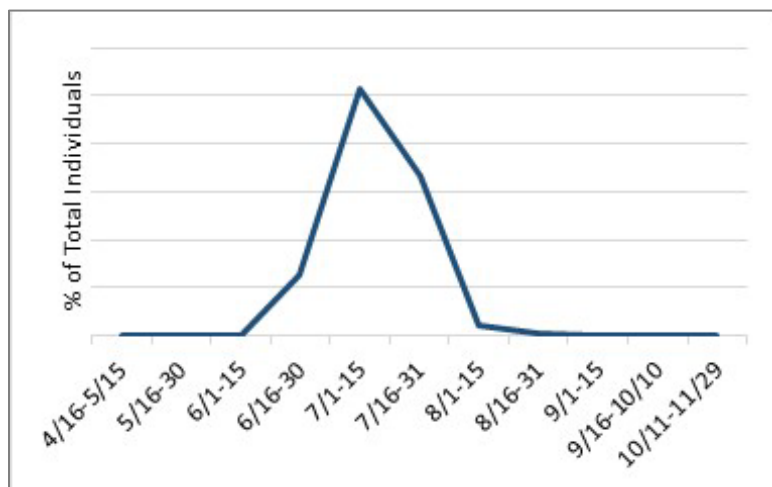


Figure 37. Attenuated Bluet flight season at Cape Cod National Seashore.

Atlantic Bluet (*Enallagma doubledayi*) (Selys, 1850)

- Range: Oklahoma, Tennessee and New Hampshire south to Texas and Florida; also, Cuba
- Habitat: Vegetated, often shallow and sandy bottomed, ponds
- Number of CACO Sites: 10 (plus 3 historical)
- Number of Surveys: 67 (17%)
- Average Number/Survey: 71
- High Count: 1056

The Atlantic Bluet is a southern, coastal plain specialist, near the northern edge of its range on Cape Cod. It is found exclusively at kettle ponds with moderate to extensive vegetation (Figure 38), where often it is the most numerous odonate, occasionally occurring in great abundance. However, like a number of coastal plain specialists, it is absent from seemingly suitable habitat in Provincetown. The flight season extends from early June through mid-September, with a peak in late July (Figure 39). This species and the very similar Familiar Bluet seem to segregate by habitat. Although both occur exclusively in kettle ponds, the Familiar typically inhabits larger ponds with sparse emergent vegetation. In cases where both have been recorded at the same sites, it most often is in situations where a heavily vegetated site is adjacent to a sparsely vegetated site, such as Turtle Pond and Great Pond Wellfleet, where individuals are wandering back and forth from the more suitable site (i.e., Turtle Pond for Atlantic and Great Pond Wellfleet for Familiar) to the less suitable. It is also likely that misidentifications have clouded the relative distributions somewhat.

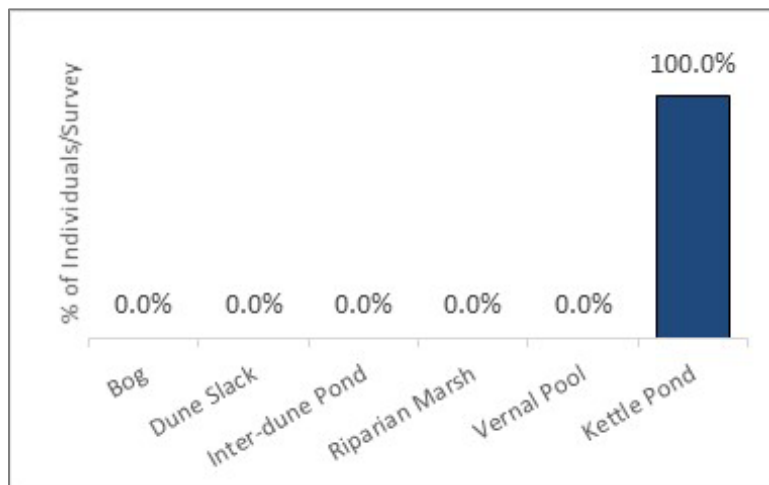


Figure 38. Atlantic Bluet distribution by habitats at Cape Cod National Seashore.

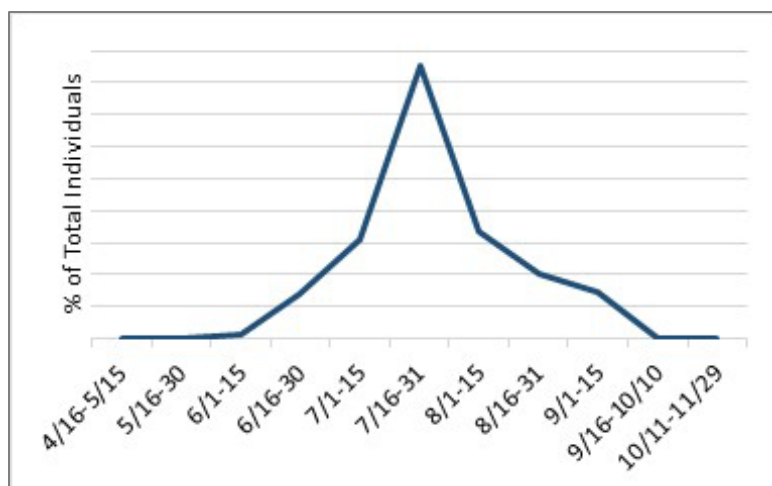


Figure 39. Atlantic Bluet flight season at Cape Cod National Seashore.

Stream Bluet (*Enallagma exsulans*) (Hagen, 1861)

- Range: North Dakota, Ontario and Nova Scotia south to Hidalgo and Georgia
- Habitat: Streams and rivers; also large, sparsely vegetated, wind-swept lakes
- Number of CACO Sites: 1 (historical)
- Number of Surveys: NA
- Average Number/Survey: NA
- High Count: NA

The Stream Bluet, as its name implies, is found primarily in lotic habitats, though it also occurs in large, poorly vegetated, wind-swept lakes and ponds, and it is in such sites that is found on Cape Cod. The only known site within the seashore is Gull Pond in Wellfleet, a site that was not covered during the current surveys. There are three records from Gull Pond, during the period 1998–2004, each involving several individuals, and a visit to that site in 2019, after completion of this project, found the species still present. Thus, it seems likely a viable population exists there—the only known location on the outer Cape. Curiously, it has not been recorded from Herring River, the one lotic site within the seashore.

Skimming Bluet (*Enallagma geminatum*) (Kellicott, 1895)

- Range: Nebraska, Minnesota, Ontario and New Brunswick south to Texas and Florida
- Habitat: Well-vegetated ponds, usually with extensive floating vegetation; also, sluggish streams
- Number of CACO Sites: 15 (plus one historical)
- Number of Surveys: 105 (27%)
- Average Number/Survey: 29
- High Count: 512

The Skimming Bluet is one of the most common of its genus within the seashore. Although its distribution is almost exclusively limited to well-vegetated kettle ponds, a few individuals were recorded at vernal pools and riparian habitats as well (Figure 40). The males often perch flat on lily pads and other floating vegetation. The flight season extends from early June through mid-September (Figure 41).

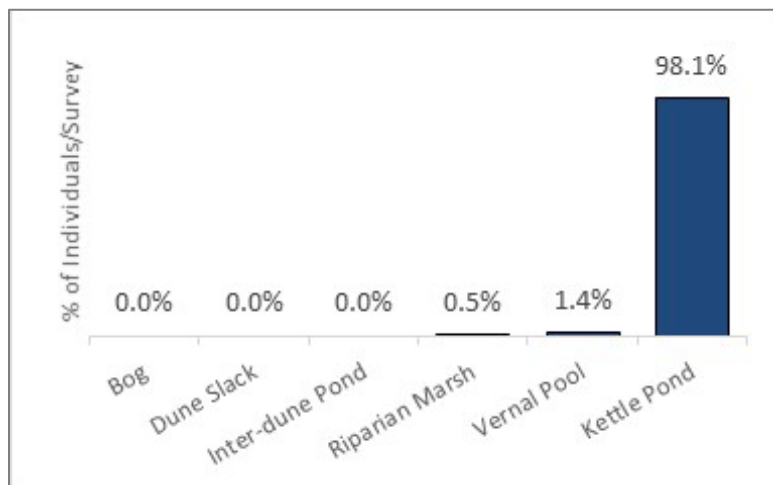


Figure 40. Skimming Bluet distribution by habitats at Cape Cod National Seashore.

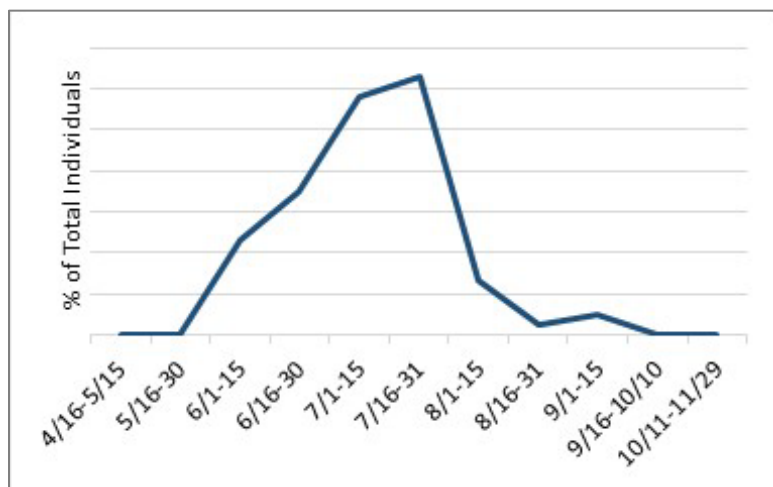


Figure 41. Skimming Bluet flight season at Cape Cod National Seashore.

New England Bluet (*Enallagma laterale*) (Morse, 1895)

- Range: Maine to Pennsylvania and New Jersey
- Habitat: Vegetated, often sandy bottomed, ponds
- Number of CACO Sites: 8 (plus 3 historical)
- Number of Surveys: 10
- Average Number/Survey: 10

- High Count: 40

The New England Bluet is a Northeast endemic, known only from Maine south to New Jersey. It is very similar to the state-listed Pine Barrens Bluet, though is less of a habitat specialist. Within the seashore it is found primarily at inter-dune ponds and kettle ponds (Figure 42); one record of several individuals from a vernal pool may involve a misidentification. It was found at three sites in Provincetown, whereas the Pine Barrens Bluet is apparently absent from that town despite the presence of seemingly suitable habitat. The flight season is early, extending from late May through early July (Figure 43).

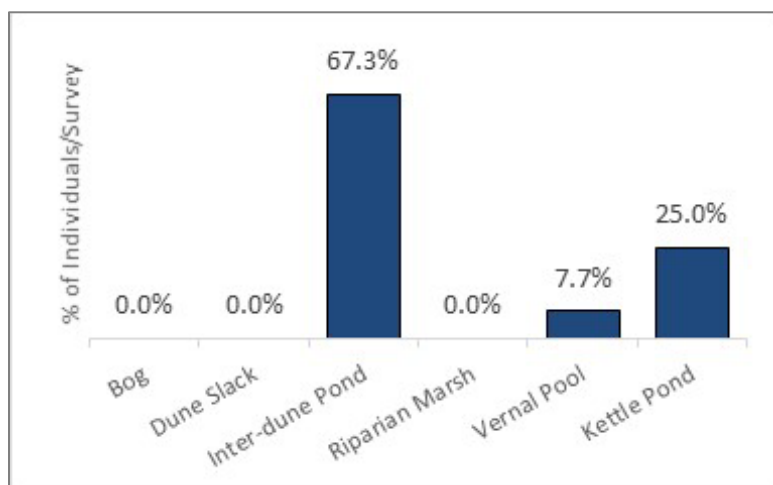


Figure 42. New England Bluet distribution by habitats at Cape Cod National Seashore.

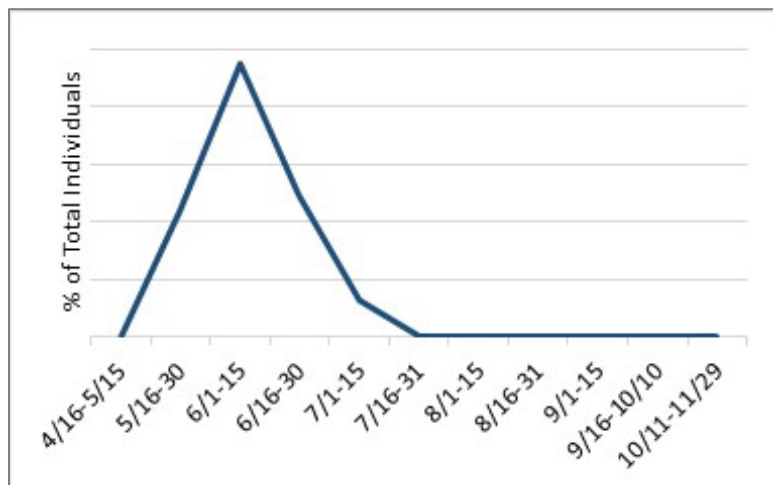


Figure 43. New England Bluet flight season at Cape Cod National Seashore.

Little Bluet (*Enallagma minusculum*) (Morse, 1895)

- Range: Maine and New Brunswick south to New York and Connecticut, isolated records in New Jersey and North Carolina

- Habitat: Clear, sandy bottomed ponds and lakes, with sparse to moderate levels of vegetation
- Number of CACO Sites: 7 (plus 4 historical)
- Number of Surveys: 24 (6%)
- Average Number/Survey: 31
- High Count: 162

The Little Bluet is a Northeast endemic, inhabiting sparsely vegetated, sandy bottomed ponds and lakes; all of the survey records come from kettle ponds (Figure 44), though a limited subset of those sites. There is almost complete overlap in habitat preferences between this species and the Familiar Bluet (correlation coefficient = 0.90). The flight season is fairly long, extending from late May through late August, with an early summer peak (Figure 45).

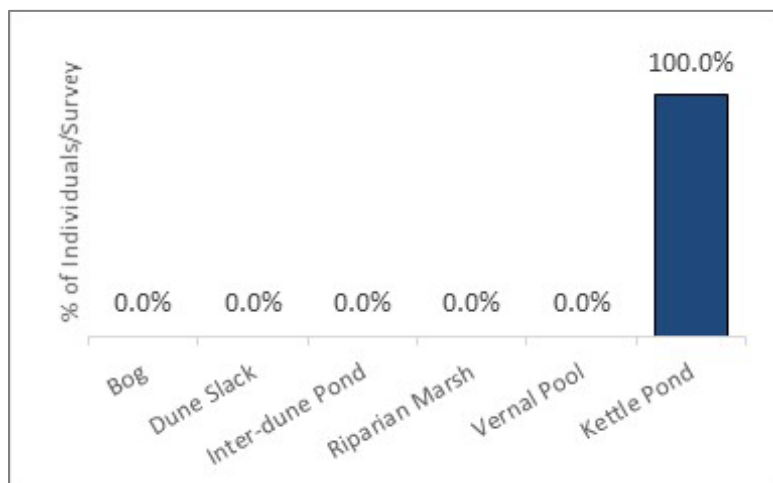


Figure 44. Little Bluet distribution by habitats at Cape Cod National Seashore.

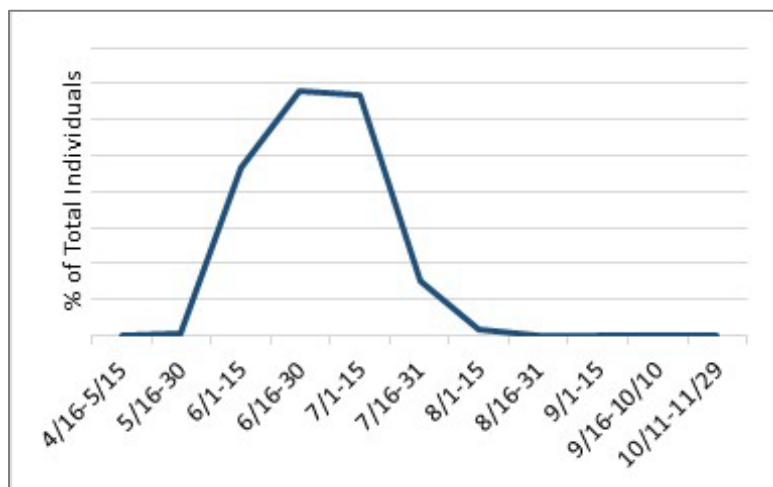


Figure 45. Little Bluet flight season at Cape Cod National Seashore.

Scarlet Bluet (*Enallagma pictum*) (Morse, 1895)

- Range: Extreme southern New Brunswick south to New Jersey
- Habitat: Ponds with extensive floating vegetation
- Number of CACO Sites: two historical
- Number of Surveys: NA
- Average Number/Survey: NA
- High Count: NA

The state-listed Scarlet Bluet is another Northeast endemic with a very restricted range. Though known from a number of sites through the mid and upper Cape, there are but two historical records within the seashore: three individuals at Turtle Pond in Wellfleet on 7/10/90 (Carpenter, unpublished data) and seven individuals at Great Pond, Truro, on 7/7/99 (Gibbons, pers. comm.). The presence of multiple individuals at two sites suggests at least a small population was present at that time, but numerous surveys at both sites and elsewhere since have failed to detect the species. The apparent absence of the species within the seashore is puzzling, as its preferred habitat, ponds with extensive floating vegetation, is well represented. Further surveys for this distinctive species are warranted. The species has a summer flight season and should be looked for from early July through mid-August.

Pine Barrens Bluet (*Enallagma recurvatum*) (Davis, 1913)

- Range: Southern Maine south to New Jersey
- Habitat: Vegetated ponds, especially those with *Juncus militaris*
- Number of CACO Sites: 9 (plus one historical)
- Number of Surveys: 18 (5%)
- Average Number/Survey: 17
- High Count: 70

The state-listed Pine Barrens Bluet is another Northeast endemic whose center of abundance is in southeastern Massachusetts; however, it is more tightly restricted to the coastal plain than its congeners. Within the seashore it is found exclusively at kettle ponds with extensive vegetation (Figure 46), with a particular affinity for ponds with Military Rush (*Juncus militaris*). However, it is absent in Provincetown, even at seemingly suitable sites where Military Rush is present; reasons for its absence north of south Truro are unknown but mirror the distribution of several other coastal plain specialists. It is an early flier, the flight season running from late May through early July (Figure 47).

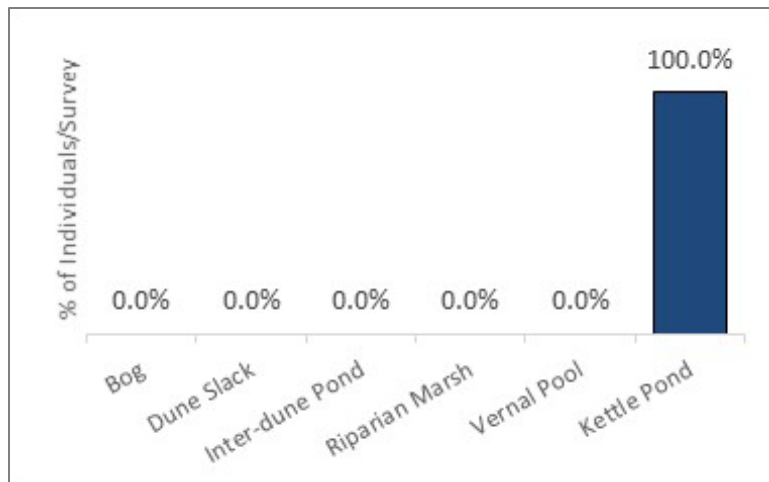


Figure 46. Pine Barrens Bluet distribution by habitats at Cape Cod National Seashore.

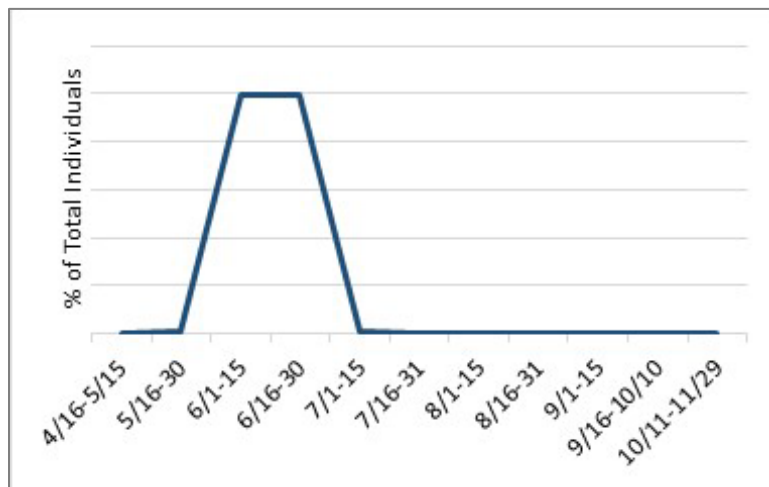


Figure 47. Pine Barrens Bluet flight season at Cape Cod National Seashore.

Orange Bluet (*Enallagma signatum*) (Hagen, 1861)

- Range: Colorado, Minnesota and New Brunswick south to Tamaulipas and Florida
- Habitat: Variety of ponds, lakes, and sluggish streams; tolerant of degraded habitats.
- Number of CACO Sites: 4 (plus 3 historical)
- Number of Surveys: 17 (4%)
- Average Number/Survey: 9
- High Count: 64

The Orange Bluet, although a habitat generalist, apparently is uncommon and local within the seashore. However, it is most active during the late afternoon, after most survey efforts ended, and thus may be more common than the existing data indicate. All records are from kettle ponds (Figure

48), the vast majority from shallow ponds with at least moderate vegetation. The flight season extends from early June through mid-September (Figure 49).

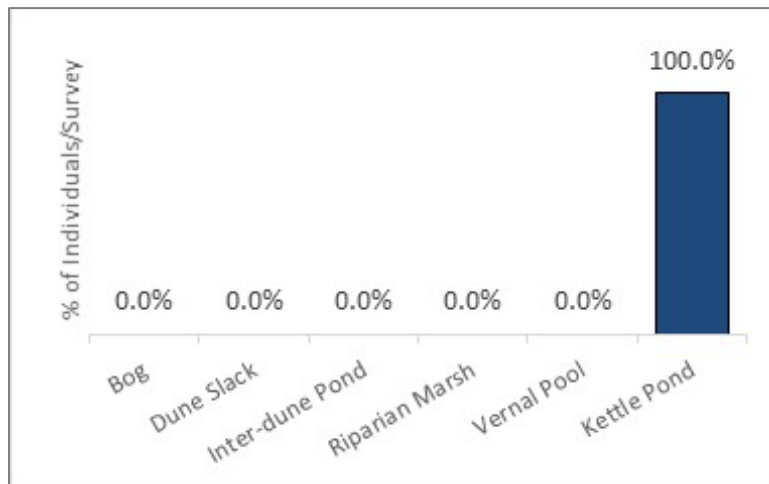


Figure 48. Orange Bluet distribution by habitats at Cape Cod National Seashore.

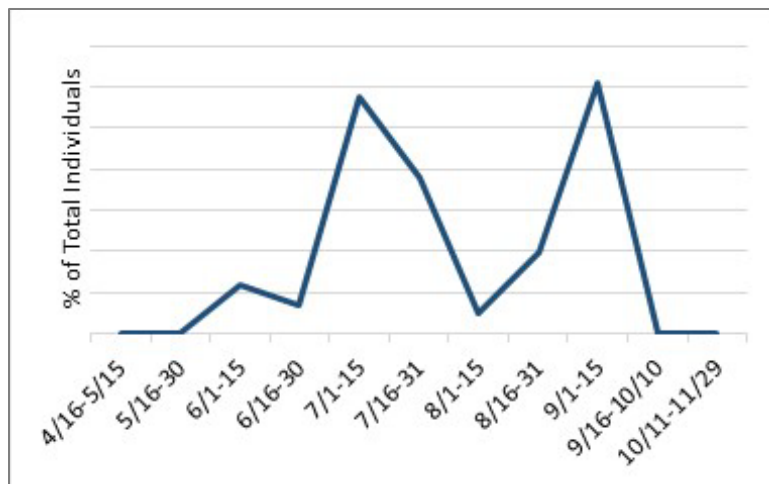


Figure 49. Orange Bluet flight season at Cape Cod National Seashore.

Slender Bluet (*Enallagma traviatum*) (Selys, 1876)

- Range: Nebraska, Wisconsin, Ontario and New Hampshire south to Texas and Georgia
- Habitat: Variety of ponds and lakes
- Number of CACO Sites: 7 (plus 2 historical)
- Number of Surveys: 14 (4%)
- Average Number/Survey: 5
- High Count: 20

The Slender Bluet is a scarce, local species within the seashore, recorded primarily at well-vegetated kettle ponds (Figure 50). Its status here is rather consistent with elsewhere in southern New England, as it is rarely seen in large numbers or with considerable frequency. The recorded flight season (based upon limited data) is from mid-June through mid-August (Figure 51).

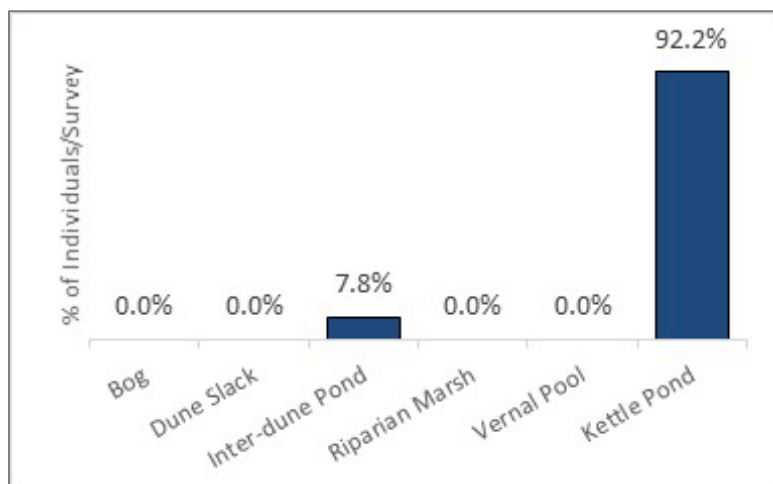


Figure 50. Slender Bluet distribution by habitats at Cape Cod National Seashore.

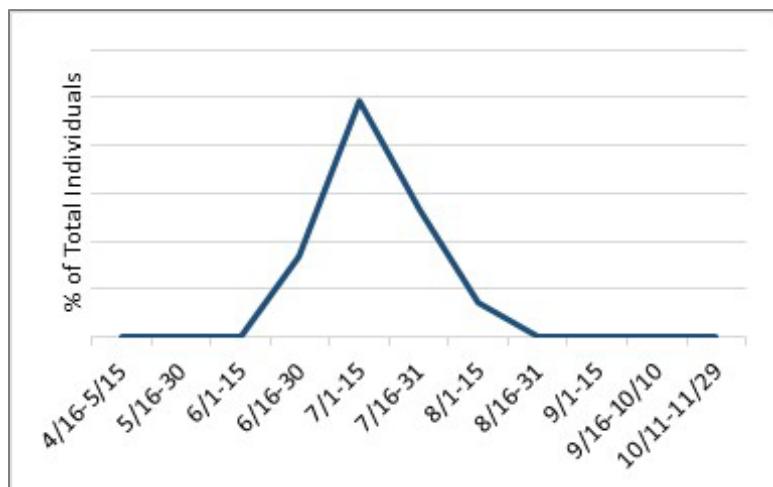


Figure 51. Slender Bluet flight season at Cape Cod National Seashore.

Vesper Bluet (*Enallagma vesperum*) (Calvert, 1919)

- Range: Colorado, Minnesota, Quebec and Nova Scotia south to Texas and Florida
- Habitat: Vegetated ponds and lakes
- Number of CACO Sites: 3 (plus 4 historical)
- Number of Surveys: 5
- Average Number/Survey: 2
- High Count: 3

As both its common and Latin names indicate, the Vesper Bluet is active late in the day, up until, and even after, dusk, and thus has been poorly surveyed within the seashore; it is likely much more common than the handful of records would suggest. The few records are exclusively from kettle ponds (Figure 52). The recorded flight season is from mid-June through mid-August (Figure 53). Targeted surveys are needed to better define this species' true status.

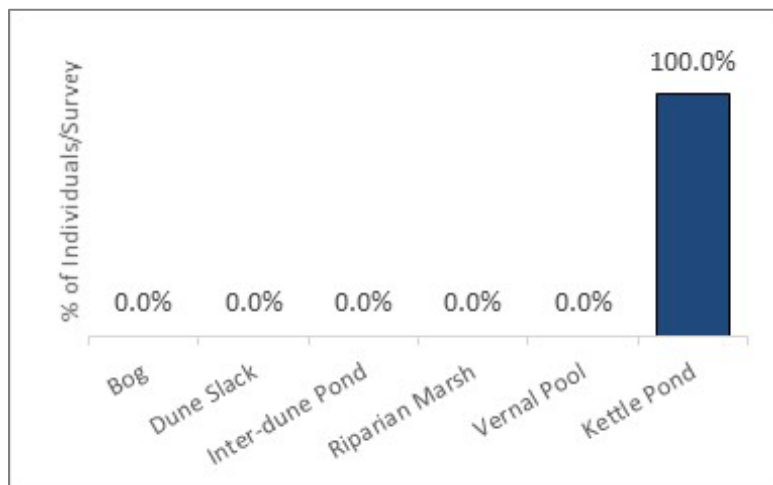


Figure 52. Vesper Bluet distribution by habitats at Cape Cod National Seashore.

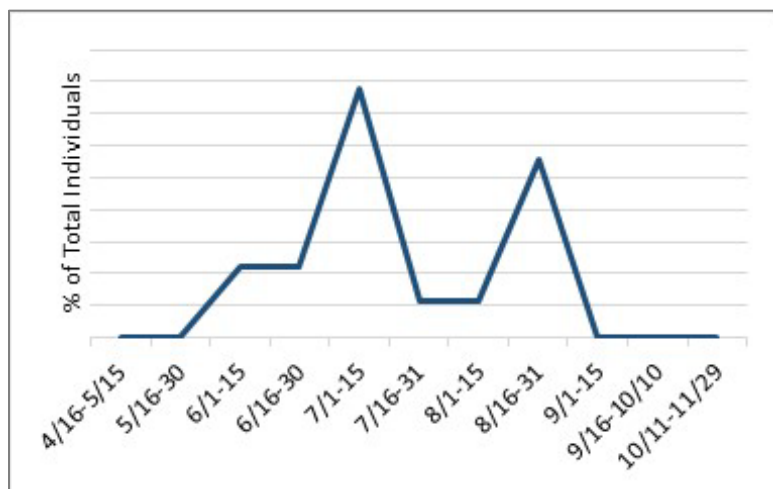


Figure 53. Vesper Bluet flight season at Cape Cod National Seashore.

Citrine Forktail (*Ischnura hastata*) (Say, 1839)

- Range: California, Nebraska, Wisconsin and Maine south to Venezuela; also, Bermuda, West Indies, Galapagos and Azores
- Habitat: Wide variety of densely vegetated, lentic wetlands, including vernal pools
- Number of CACO Sites: 9 (plus 4 historical)
- Number of Surveys: 14 (4%)

- Average Number/Survey: 2
- High Count: 5

One of the smallest odonates, the Citrine Forktail is a scarce and sporadic inhabitant of densely vegetated wetlands within the seashore. However, it is also very inconspicuous and easily overlooked, often appearing as a short piece of yellow thread weaving its way low through dense rushes and grasses, and thus may be more common than the records indicate. It is most often found in temporary wetlands (i.e., vernal pools and dune slacks) (Figure 54) and has a lengthy flight season extending from early June through late September, perhaps peaking in late summer (Figure 55).

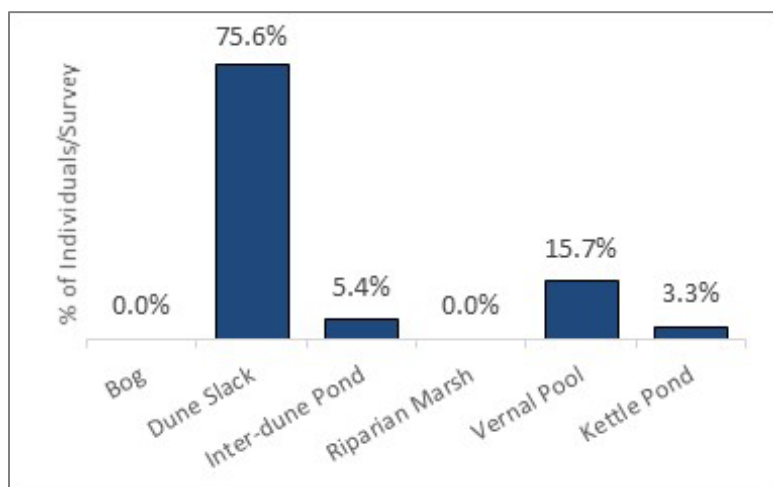


Figure 54. Citrine Forktail distribution by habitats at Cape Cod National Seashore.

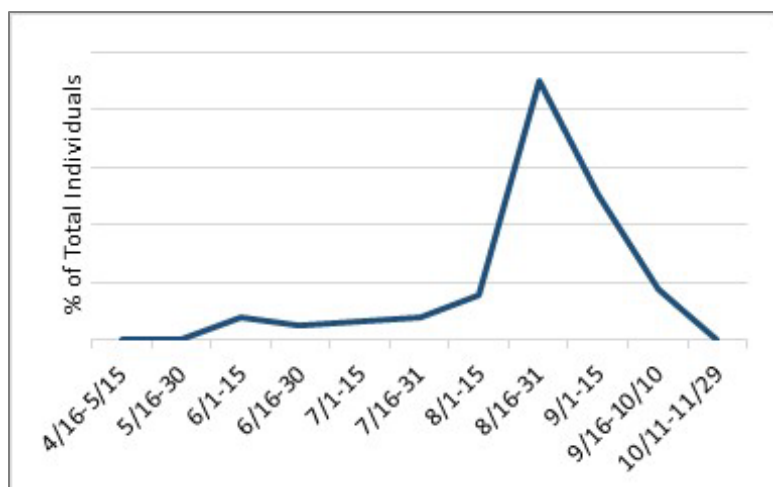


Figure 55. Citrine Forktail flight season at Cape Cod National Seashore.

Lilypad Forktail (*Ischnura kellicotti*) (Williamson, 1898)

- Range: Oklahoma, Wisconsin and Maine south to Texas and Florida
- Habitat: Ponds and lakes with extensive floating vegetation

- Number of CACO Sites: 5 (plus 3 historical)
- Number of Surveys: 20 (5%)
- Average Number/Survey: 20
- High Count: 96

As its name suggests, the Lilypad Forktail is closely associated with White Water Lily (*Nymphaea odorata*) and Water Shield (*Brasenia schreberi*); the females oviposit on the underside of lily pads. However, it apparently is absent from many sites with seemingly appropriate vegetation. Within the seashore it has been found almost exclusively at shallow kettle ponds, but was also present at Fresh Brook, which is characterized as “riparian marsh,” but has no perceptible water movement and a surface almost completely covered with floating vegetation (Figure 56). It is a southern species that appears to have increased here over the past 30+ years, though it remains rare north of south Truro, despite seemingly appropriate habitat in Provincetown. The flight season extends from late May through mid-September (Figure 57).

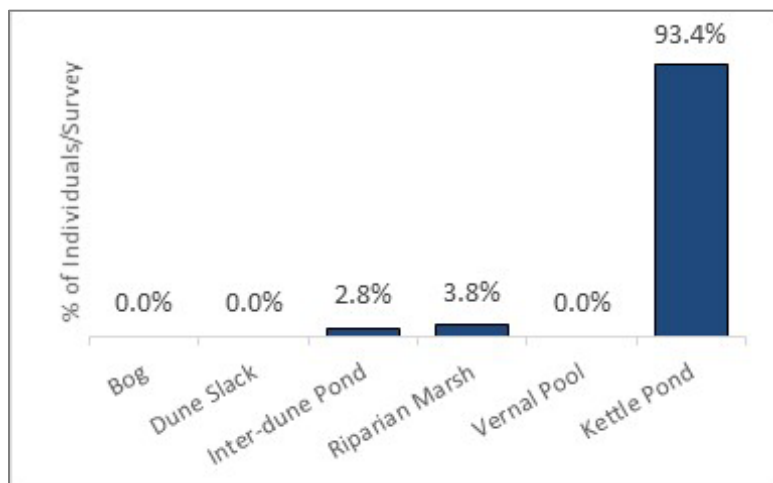


Figure 56. Lilypad Forktail distribution by habitats at Cape Cod National Seashore.

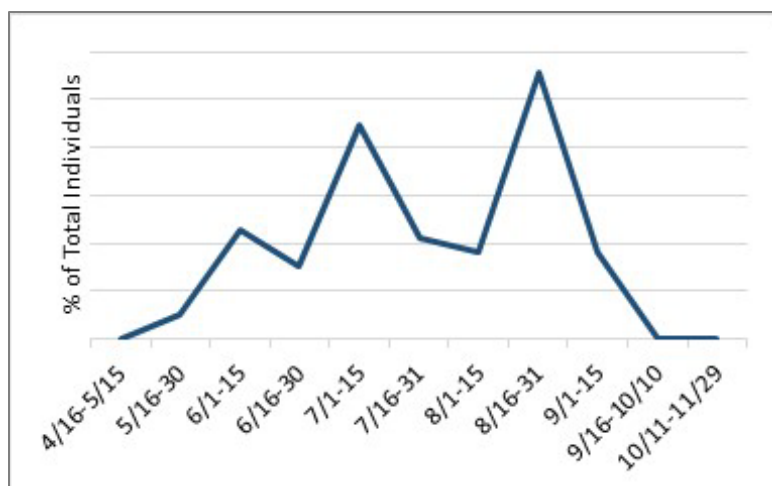


Figure 57. Lilypad Forktail flight season at Cape Cod National Seashore.

Fragile Forktail (*Ischnura posita*) (Hagen, 1861)

- Range: Southern Manitoba and Newfoundland south to Belize and Florida; introduced to Hawaii
- Habitat: Wide variety of vegetated wetlands, including sluggish streams; tolerant of degraded habitats
- Number of CACO Sites: 36 (plus 9 historical)
- Number of Surveys: 171 (44%)
- Average Number/Survey: 4
- High Count: 30

The Fragile Forktail is a common and widespread, though inconspicuous, inhabitant in a variety of wetlands throughout the seashore. It was recorded in all but five sites and every habitat type, though was most numerous in vernal pools and kettle ponds (Figure 58). The lengthy flight season extends from mid-May through late September, and seems to be bimodal, suggesting the species may be bivoltine in this area (Figure 59). Mature females are very difficult to distinguish from female Eastern Forktails and were often recorded as just “forktail species.”

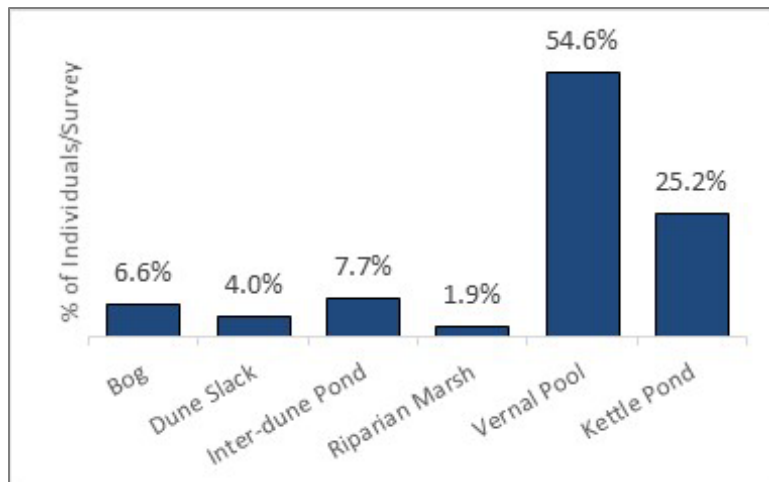


Figure 58. Fragile Forktail distribution by habitats at Cape Cod National Seashore.

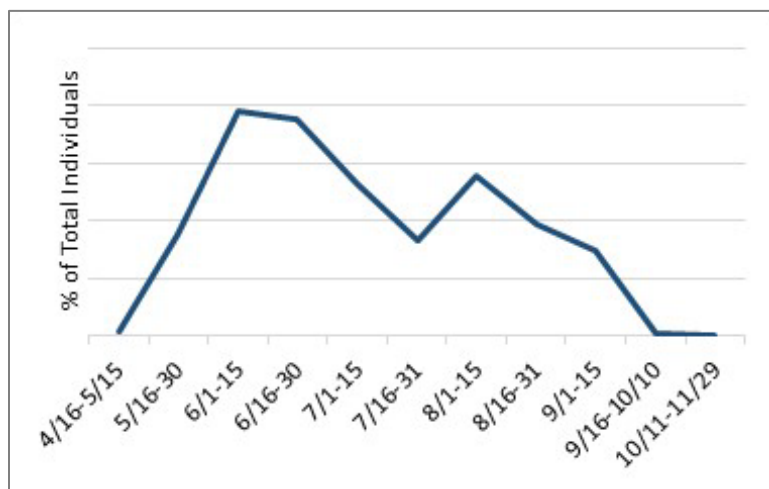


Figure 59. Fragile Forktail flight season at Cape Cod National Seashore.

Furtive Forktail (*Ischnura prognata*) (Hagen, 1861)

- Range: Arkansas, Ohio and New Jersey south to Texas and Florida; isolated records in Massachusetts
- Habitat: Densely vegetated, shaded swamps and sluggish streams
- Number of CACO Sites: one historical
- Number of Surveys: NA
- Average Number/Survey: NA
- High Count: NA

The only CACO record of this southern denizen of shaded swamps is of a single male collected at E10 in Eastham on 6/2/96 (Nikula et al. 2001). This represented the first record of the species from anywhere in New England, though it has recently been recorded at two sites on the upper Cape. As

its name suggests, it is a rather secretive species and easily overlooked. It may be a species that is colonizing southern New England in response to climate warming.

Rambur's Forktail (*Ischnura ramburii*) (Selys, 1850)

- Range: California, Oklahoma, Kentucky and Maine south to Florida, then to northern South America; also, Bermuda, Bahamas and West Indies; introduced to Hawaii
- Habitat: Wide variety of lentic wetlands, including brackish sites
- Number of CACO Sites: 1 (plus one outside of the official surveys)
- Number of Surveys: 1
- Average Number/Survey: NA
- High Count: 1

The Rambur's Forktail is a southern species near the northern edge of its range here. The one survey record involved a single male photographed at Great Pond in Wellfleet on 7/30/18. Shea also found several of this species at T27 in Truro on 9/29/17, outside of the survey period; however, follow-up surveys in 2018 failed to find the species again. Within the core of its range, it inhabits a variety of wetlands, including brackish and degraded sites. It may well occur elsewhere within the seashore, but whether a viable population exists is unknown.

Eastern Forktail (*Ischnura verticalis*) (Say, 1839)

- Range: Saskatchewan, Ontario and Newfoundland south to New Mexico, Arkansas and Georgia
- Habitat: Variety of vegetated wetlands, including sluggish streams
- Number of CACO Sites: 39 (plus 12 historical)
- Number of Surveys: 297 (76%)
- Average Number/Survey: 17
- High Count: 410

The Eastern Forktail was the most widespread and abundant species during the surveys, recorded at all but two of the sites and on 76% of the surveys. It was recorded from all habitats, though most numerous in vernal pools, kettle ponds, and the one dune slack (Figure 60). The flight seasons is one of the longest of any local odonate, extending from late April through early October; the flight season appears to be bimodal, suggesting the species may be bivoltine in this area (Figure 61). Mature females are very difficult to distinguish from female Fragile Forktails and were often recorded as "forktail species." As is true of others in this genus, and unlike other odonates, females spend as much time at the wetland breeding sites as the males.

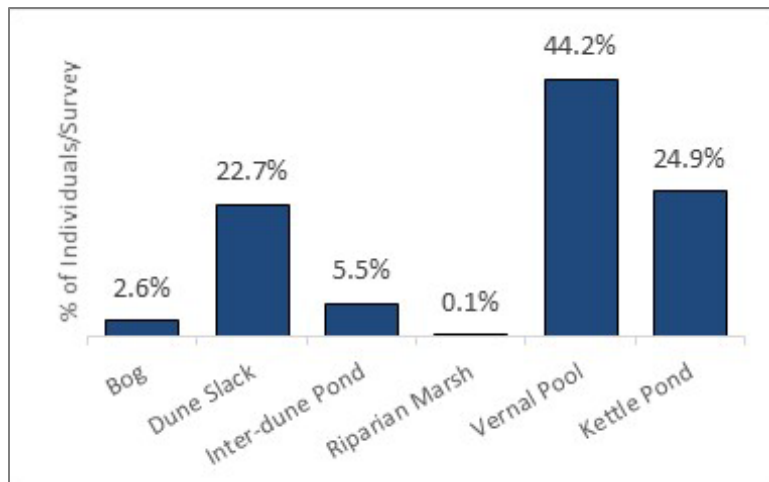


Figure 60. Eastern Forktail distribution by habitats at Cape Cod National Seashore.

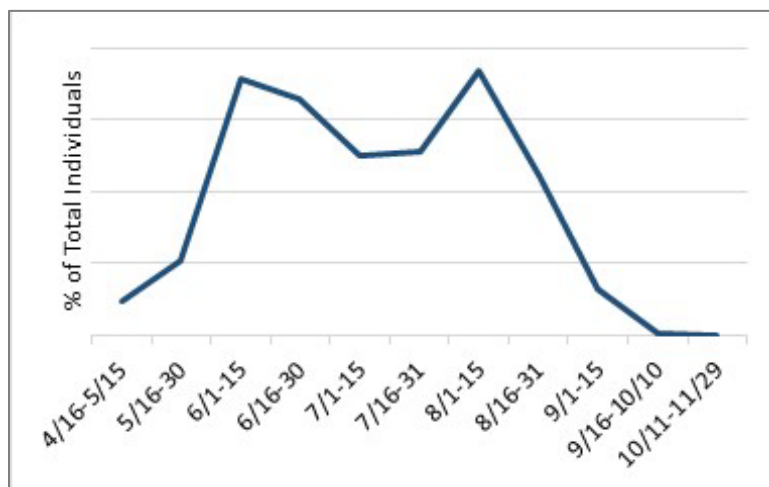


Figure 61. Eastern Forktail flight season at Cape Cod National Seashore.

Sphagnum Sprite (*Nehalennia gracilis*) (Morse, 1895)

- Range: Oklahoma, Wisconsin, Quebec and Prince Edward Island south to Texas and Florida
- Habitat: Bogs and boggy pools, almost always where sphagnum is present
- Number of CACO Sites: 11 (plus 3 historical)
- Number of Surveys: 47 (12%)
- Average Number/Survey: 50
- High Count: 275

The appropriately named Sphagnum Sprite is typically the most common odonate in bogs and boggy vernal pools within the seashore; it is very inconspicuous and likely even more numerous than the data suggests. It was recorded only at bogs and vernal pools with extensive sphagnum carpets (Figure

62). The flight season extends from the end of May through mid-August, peaking from late June through early July (Figure 63).

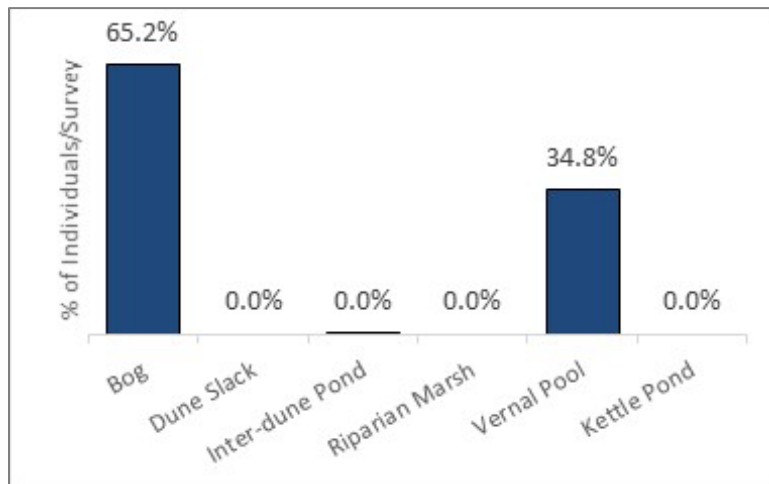


Figure 62. Sphagnum Sprite distribution by habitats at Cape Cod National Seashore.

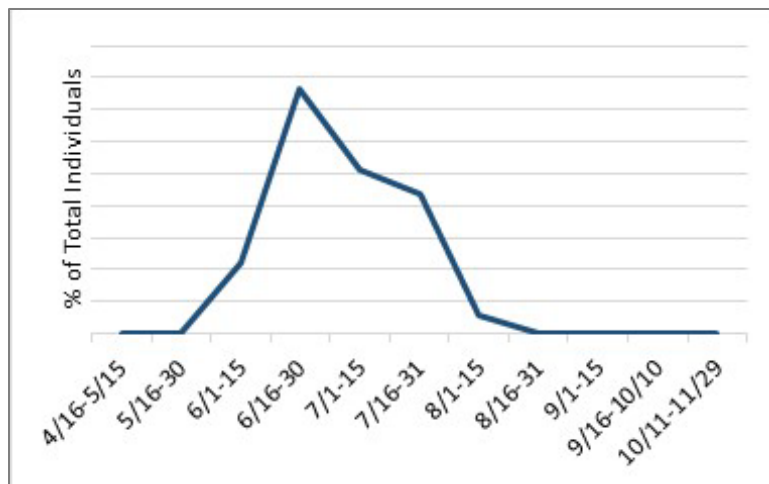


Figure 63. Sphagnum Sprite flight season at Cape Cod National Seashore.

Sedge Sprite (*Nehalennia irene*) (Hagen, 1861)

- Range: British Columbia, Northwest Territories and Newfoundland south to California, Nebraska, Kentucky and Virginia
- Habitat: Variety of well-vegetated lentic wetlands, including sedge meadows and fens
- Number of CACO Sites: 6 historical
- Number of Surveys: NA
- Average Number/Survey: NA
- High Count: NA

The Sedge Sprite was not recorded during the official surveys and is known only from several historical records. It is very similar to the Sphagnum Sprite and it may be that some of the records involve misidentifications. The two species generally segregate by habitat, the Sedge Sprite preferring grassy wetlands and generally avoiding the sphagnum mats preferred by its congener. The status of this species within CACO (and elsewhere on Cape Cod), both historically and currently, is very uncertain. The limited data suggests a flight season from late May through early August.

Dragonflies (*Anisoptera*)

Darners (Aeshnidae)

Canada Darner (*Aeshna canadensis*) (Walker, 1908)

- Range: British Columbia, Manitoba and Newfoundland south to northern California, Montana, Nebraska and West Virginia
- Habitat: Well-vegetated ponds, beaver ponds, fens, and bogs
- Number of CACO Sites: 1 (plus one historical)
- Number of Surveys: 1
- Average Number/Survey: NA
- High Count: 2

The Canada Darner is rare throughout Cape Cod and has been confirmed from only two sites within the seashore, one current (E23) and one historical (E09), the former a densely vegetated, shallow pond, the latter a large, densely vegetated vernal pool. (Two historical records from Fresh Brook and Horseleech Pond are based upon sightings from atypical habitats of individuals in flight and are questionable.) Like others in its genus, identification requires examination in the hand, or close views of perched individuals. However, it is most often seen in flight, very rarely perched, and very difficult to net, so its exact status is unclear. The two confirmed records are from late July, but the flight season likely extends into late September.

Mottled Darner (*Aeshna clepsydra*) (Say, 1839)

- Range: Wisconsin to Nova Scotia, south to Indiana and New Jersey
- Habitat: Well-vegetated ponds
- Number of CACO Sites: 15 (plus 3 historical)
- Number of Surveys: 33
- Average Number/Survey: 3
- High Count: 8

The Mottled Darner is the “default” *Aeshna* at vegetated coastal plain ponds, especially where Military Rush is present; the vast majority of records on the surveys were from kettle ponds (Figure 64). However, like all large dragonflies, it is a strong flier and wandering individuals can show up at almost any wetland. Males typically patrol the perimeter of the ponds 4-6 feet high, hovering

frequently and occasionally dipping down into emergent vegetation in search of females. The flight season extends from late July through late September (Figure 65).

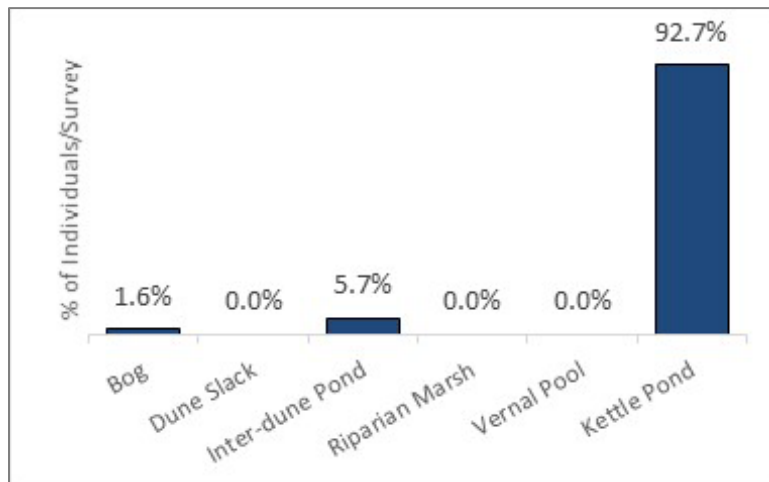


Figure 64. Mottled Darner distribution by habitats at Cape Cod National Seashore.

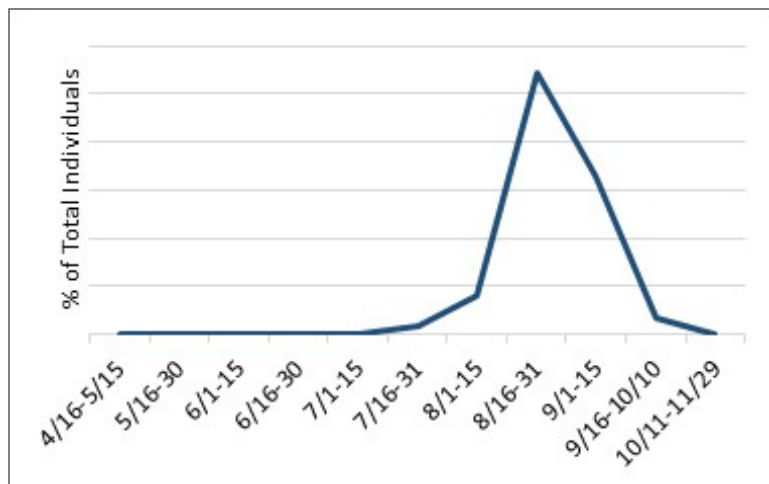


Figure 65. Mottled Darner flight season at Cape Cod National Seashore.

Black-tipped Darner (*Aeshna tuberculifera*) (Walker, 1908)

- Range: British Columbia, Saskatchewan, Quebec and Prince Edward Island south to Oregon, Montana, Minnesota, Ohio and North Carolina
- Habitat: Boggy ponds and vernal pools
- Number of CACO Sites: 9 (plus one historical)
- Number of Surveys: 21
- Average Number/Survey: 3
- High Count: 20

The Black-tipped Darner is a fairly common resident of bogs and vernal pools within the seashore; a few records from kettle ponds likely involve wandering individuals (Figure 66). Unidentified darners thought to be this species were seen at multiple inter-dune ponds, so the species may inhabit those sites as well. Males typically patrol along the edges of bog and vernal pools at heights of 5-10 feet. Like its congeners, it is difficult to sample adequately. The flight season extends from mid-July through late October (Figure 67).

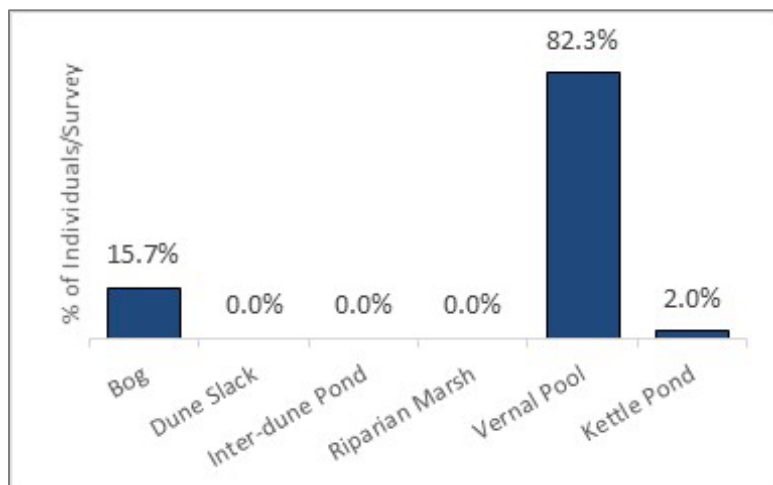


Figure 66. Black-tipped Darner distribution by habitats at Cape Cod National Seashore.

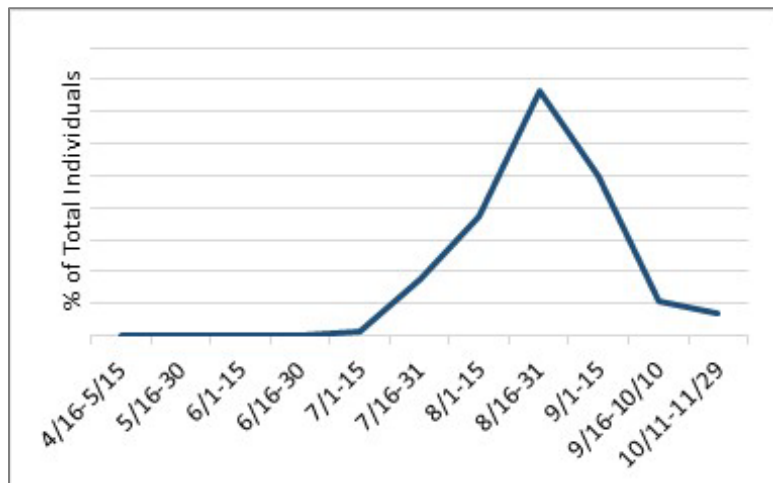


Figure 67. Black-tipped Darner flight season at Cape Cod National Seashore.

Shadow Darner (*Aeshna umbrosa*) (Walker, 1908)

- Range: Yukon, Northwest Territories and Newfoundland south to California, New Mexico, Arkansas and Georgia
- Habitat: Variety of ponds, marshes, and sluggish streams
- Number of CACO Sites: one historical

- Number of Surveys: NA
- Average Number/Survey: NA
- High Count: NA

The Shadow Darner has been recorded only once within the seashore: a male at E01 in Eastham on 10/11/97. It apparently is a rare species throughout Cape Cod, but is largely crepuscular in activity, and like its congeners is most often on the wing when encountered and thus difficult to identify. Its habits make it very inconspicuous and difficult to detect, and it may be more frequent than the sole record suggests.

Green-striped Darner (*Aeshna verticalis*) (Hagen, 1861)

- Range: Southern Manitoba, Quebec and New Brunswick south to Iowa, Kentucky and North Carolina
- Habitat: Well-vegetated ponds, bogs, and boggy vernal pools
- Number of CACO Sites: 2 (plus one historical)
- Number of Surveys: 3
- Average Number/Survey: 1
- High Count: 1

The Green-striped Darner is a rare, or at least rarely detected, inhabitant within the seashore, occurring exclusively at bogs or boggy vernal pools. Like its congeners, it is an inconspicuous and elusive species and is likely more numerous than the few records indicate. It is very similar in appearance to the Canada Darner, and in-hand examination is required to differentiate the two. The recorded flight season is from mid-August through late September.

Common Green Darner (*Anax junius*) (Drury, 1773)

- Range: British Columbia, Manitoba, Quebec and St. Pierre and Miquelon south to Honduras; also, Bermuda, Bahamas, Greater Antilles, and Hawaii; isolated records in Alaska, Yukon, eastern Asia and Tahiti
- Habitat: Variety of lakes and ponds, large vernal pools
- Number of CACO Sites: 39 (plus 8 historical)
- Number of Surveys: 229 (59%)
- Average Number/Survey: 2
- High Count: 15

The Common Green Darner is by far the most numerous and widespread member of its family, not only locally, but throughout most of its broad, continent-wide range. Indeed, it is one of the most frequently encountered, and best known, of any odonate species. Within the seashore it was recorded on 59% of the surveys. It is a habitat generalist, and during the surveys was recorded from all six

habitat categories, though it breeds primarily in vegetated ponds and large vernal pools (Figure 68). A segment of the population is highly migratory, and the species is frequently encountered in upland habitats well away from potential breeding sites; large numbers are occasionally seen migrating along the Cape's outer beaches, northbound from late May through early July, and southbound from late July through late September. The flight season is the longest of any local odonate (Figure 69), extending from late April through mid-November—invariably the first odonate to appear in the spring is a migrant green darner. The flight season for the resident population likely extends from mid-June through early to mid-September; individuals outside of that time frame are mostly if not all migrants (though there is no way to distinguish between individuals from the two populations).

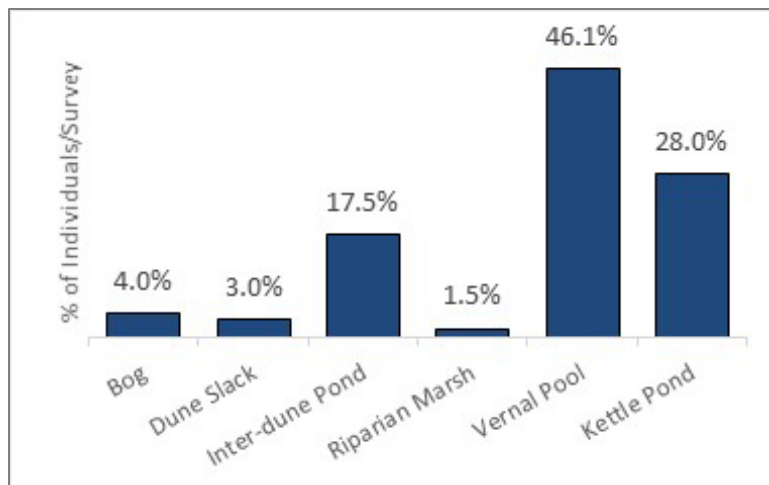


Figure 68. Common Green Darner distribution by habitats at Cape Cod National Seashore.

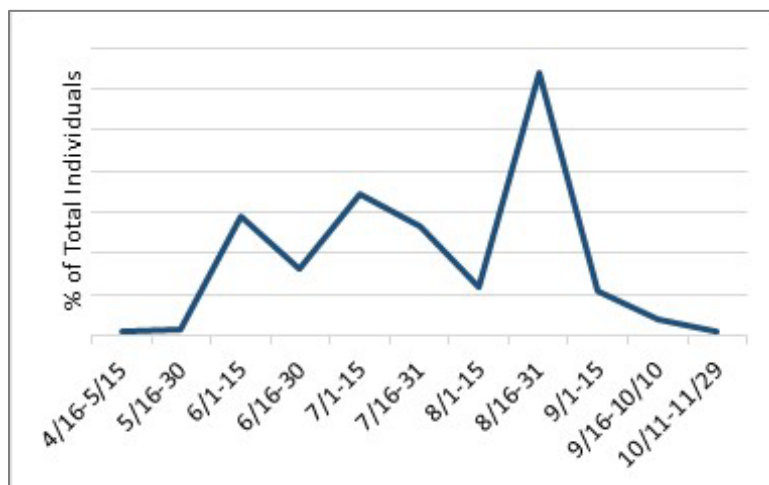


Figure 69. Common Green Darner flight season at Cape Cod National Seashore.

Comet Darner (*Anax longipes*) (Hagen, 1861)

- Range: Kansas, Wisconsin, Ontario and New Brunswick south to Texas and Florida

- Habitat: Vegetated ponds and large vernal pools; is thought to breed successfully only at sites where predatory fish, especially sunfish, are absent
- Number of CACO Sites: 9 (plus 5 historic)
- Number of Surveys: 17
- Average Number/Survey: 1
- High Count: 2

The spectacular Comet Darner, one of the largest odonates (or insect of any type) in North America, is a scarce inhabitant within the seashore. Survey records were entirely from kettle ponds and inter-dune ponds (Figure 70), though most of the historical records are from the Eastham vernal pools. No evidence of breeding was noted during the surveys (nor historically); indeed, all but one of the 19 individuals recorded were males, the sole female was photographed at Clapps Round 3 Pond in Provincetown. Patrolling males were recorded in suitable habitat on several occasions, so it seems likely the species is breeding within CACO. However, it is a strong flier that wanders widely, even occasionally appearing in migratory flights, so it's possible all of the local records involve transients. The flight season runs from early June through mid-August, with a strong peak in July (Figure 71).

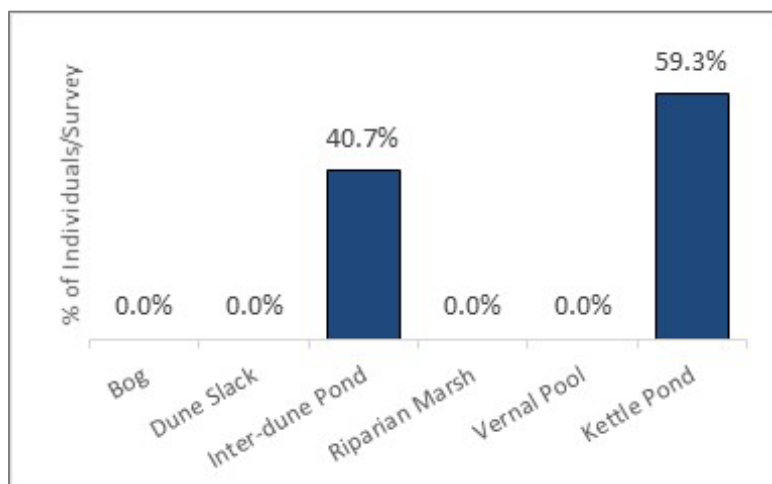


Figure 70. Comet Darner distribution by habitats at Cape Cod National Seashore.

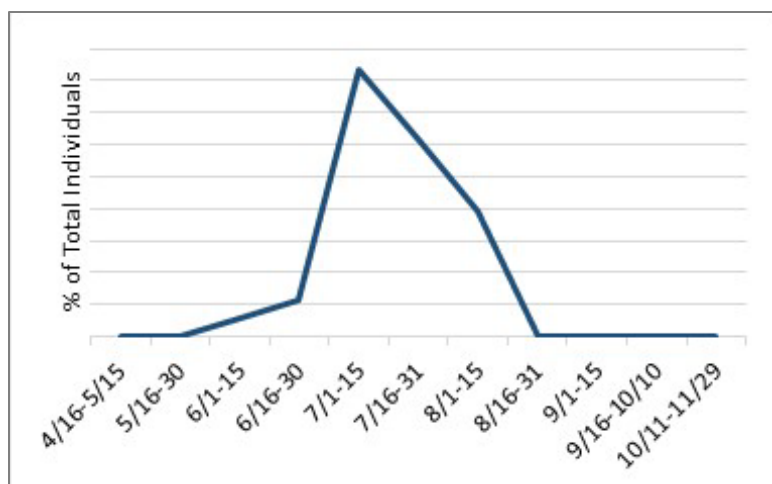


Figure 71. Comet Darner flight season at Cape Cod National Seashore.

Swamp Darner (*Epiaschna heros*) (Fabricius, 1798)

- Range: Kansas, Minnesota, Quebec and New Brunswick south to Texas and Florida
- Habitat: Swamps and woodland pools
- Number of CACO Sites: 5 historical
- Number of Surveys: NA
- Average Number/Survey: NA
- High Count: NA

The massive Swamp Darner is of very erratic occurrence on the outer Cape. Although not recorded on the official surveys, it was seen on two occasions in Provincetown during the survey period: single individuals at the Beech Forest parking lot and near Clapps Pond. It is a southern species subject to occasional northward irruptions. An unprecedented flight in early June 1995 saw 2,000 migrating past Race Point Beach on 6/2 (Sones 1995a, b), a total unsurpassed anywhere in New England. However, most records are of single individuals, or occasionally a few during migratory flights. There is no evidence of breeding within CACO. However, despite its size, it is an inconspicuous breeder, ovipositing in small, shaded, perhaps even temporary wetlands, and is thus easily overlooked. The first confirmed breeding within the state was nearby in Brewster in 2016 (Trull 2018), and suitable habitat certainly exists within the seashore. The flight season extends from late May through at least late August.

Harlequin Darner (*Gomphaeschna furcillata*) (Say, 1839)

- Range: Minnesota and New Brunswick south to Texas and Florida
- Habitat: Swamps and bogs, usually where sphagnum is present
- Number of CACO Sites: 3
- Number of Surveys: 4

- Average Number/Survey: 2
- High Count: 3

The cryptic Harlequin Darner was unrecorded within CACO until discovered at three sites during these surveys: T01 in Truro, and E04 and E06 in Eastham (Figure 72). All three sites have dense, soupy mats of sphagnum. While no evidence of breeding was observed, this species seems less prone to wander than most other darners, and thus it is likely the species is resident within the seashore. It has an early flight season, extending from late May through early July, though all of the survey records occurred within a very narrow window in mid-June (Figure 73).

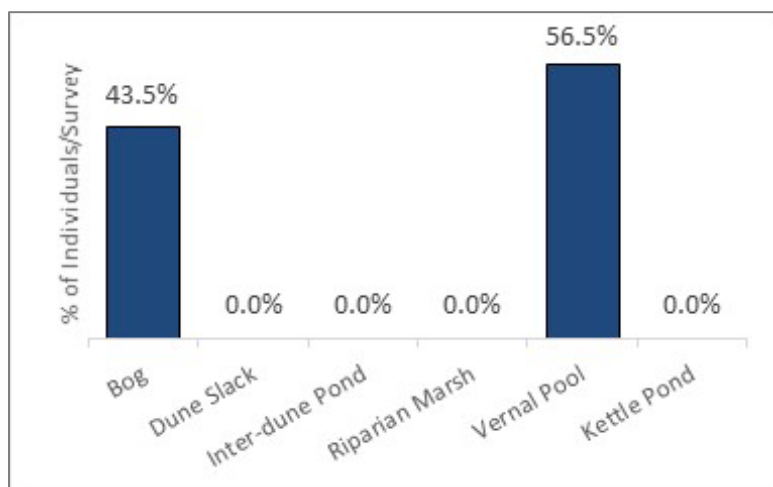


Figure 72. Harlequin Darner distribution by habitats at Cape Cod National Seashore.

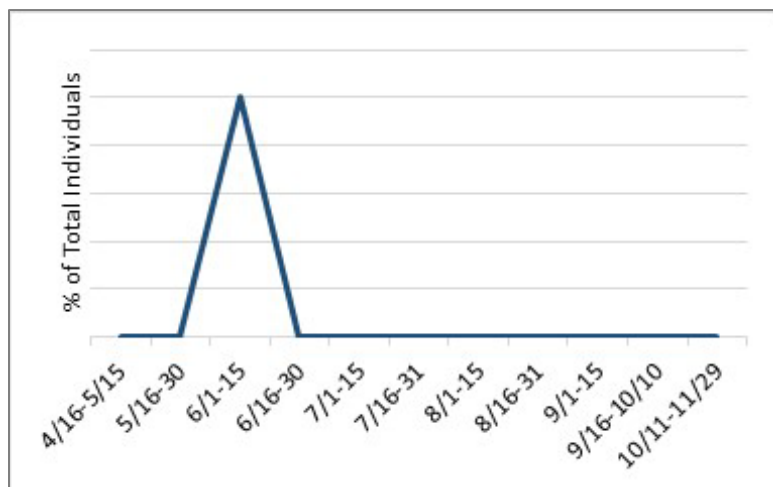


Figure 73. Harlequin Darner flight season at Cape Cod National Seashore.

Spatterdock Darner (*Rhionaeschna mutata*) (Hagen, 1861)

- Range: Minnesota, Ontario and Maine south to Missouri, Tennessee and Virginia
- Habitat: Densely vegetated ponds and large vernal pools, usually where predatory fish are absent

- Number of CACO Sites: 3 (plus 2 historical)
- Number of Surveys: 3
- Average Number/Survey: 2
- High Count: 3

Formerly state-listed, the Spatterdock Darner was de-listed just as these surveys commenced. It is a scarce resident within CACO, known from just five sites, three of them vernal pools (Figure 74). Despite the common name, it is frequently found where spatterdock (*Nuphar*) is absent. Throughout its range it is associated primarily with fish-less wetlands. The limited habitat data from these surveys suggest it is equally common at kettle ponds as at vernal pools, but this is misleading as one of the two sites characterized as a kettle pond, T27, is a very small, shallow, fish-less wetland; the one record from a true kettle pond involved the brief appearance of a male that was likely a transient. The species' presence at many sites is sporadic: although recorded frequently at E09 in Eastham during the 1990's, it was not found at this site during the three years of this survey. The ephemeral nature of the species' occurrence has been documented elsewhere in its range (Schilling et al. 2018). Additionally, the nymphal life stage is at least three years, so the species may still occupy a site despite the absence of adults in a given year or two. The stunning adults are “spring” fliers, on the wing from late May through mid-July (Figure 75).

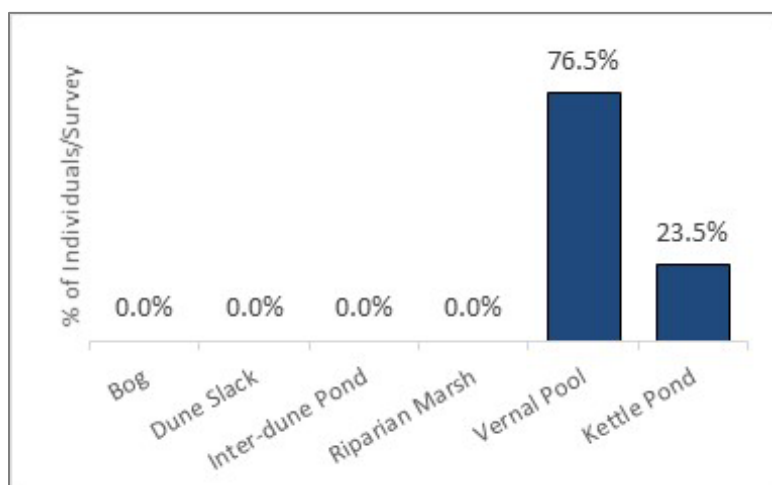


Figure 74. Spatterdock Darner distribution by habitats at Cape Cod National Seashore.

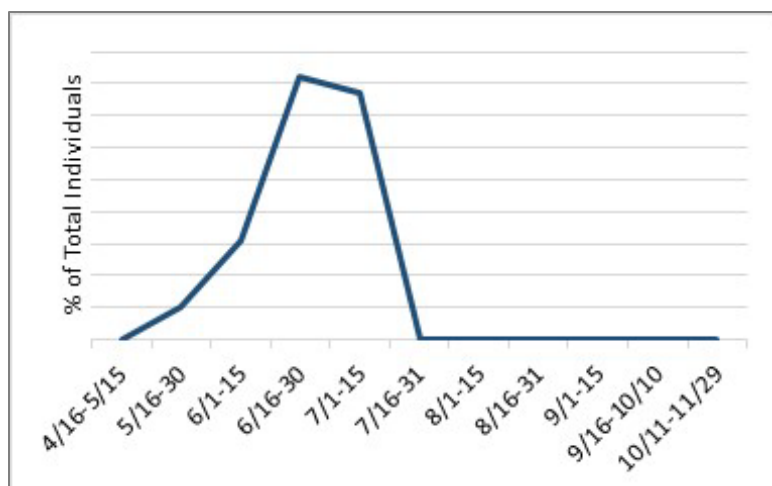


Figure 75. Spatterdock Darner flight season at Cape Cod National Seashore.

Clubtails (Gomphidae)

Black-shouldered Spinyleg (*Dromogomphus spinosus*) (Selys)

- Range: Eastern U.S., from Nova Scotia west to Minnesota, and south to eastern Texas and northern Florida
- Habitat: A variety of rivers and streams; also large, sparsely vegetated lakes and ponds
- Number of CACO Sites: 1
- Number of Surveys: NA
- Average Number/Survey: NA
- High Count: NA

The Black-shouldered Spinyleg was unknown within the seashore, or the outer Cape, until 2019, after completion of this project, when Nikula photographed a teneral individual at Gull Pond in Wellfleet on 30 June. Through the mid and upper Cape, this large clubtail is an uncommon and local inhabitant of large, poorly vegetated, sandy-bottomed ponds and lakes; Gull Pond fits this profile. The presence of a freshly emerged individual, which flushed from a stalk of emergent vegetation, confirms breeding at the site. Unlike most clubtails, the spinyleg is a summer flier, with a flight season from early July through mid-August.

Lancet Clubtail (*Phanogomphus exilis*) (Selys, 1854)

- Range: Eastern Manitoba, Quebec and Nova Scotia south to Louisiana and Florida
- Habitat: Slow streams, ponds, lakes, and occasionally bogs
- Number of CACO Sites: 11 (plus 3 historical)
- Number of Surveys: 21
- Average Number/Survey: 1
- High Count: 3

The Lancet Clubtail is the most common and widespread of its family on Cape Cod and throughout southern New England. Within CACO it occurs almost exclusively at kettle ponds, with just a single record from a bog (Figure 76). They perch horizontally on sandy shores, logs, rocks, and pond-side shrubs, and are often encountered along woodland roads and trails. They are rarely numerous but are inconspicuous and easily overlooked. No breeding activity was recorded during the surveys, though the species is undoubtedly breeding successfully within CACO. It is a “spring” flier, with a flight season extending from mid-May through late July (Figure 77).

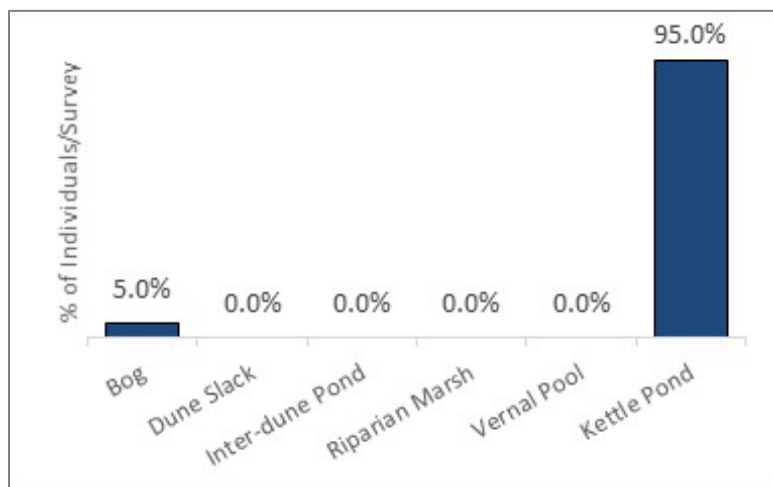


Figure 76. Lancet Clubtail distribution by habitats at Cape Cod National Seashore.

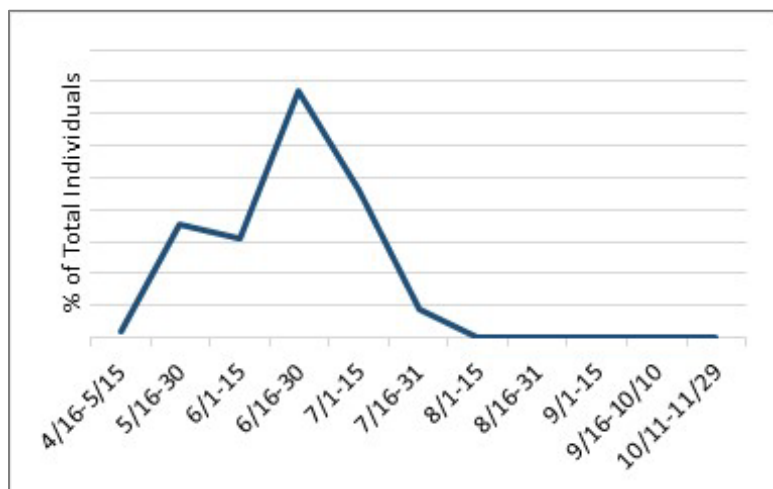


Figure 77. Lancet Clubtail flight season at Cape Cod National Seashore.

Common Sanddragon (*Progomphus obscurus*) (Rambur, 1842)

- Range: Colorado, Wisconsin and Maine south to New Mexico, Texas and Florida
- Habitat: Sandy bottomed streams and ponds
- Number of CACO Sites: 8 (plus 3 historical)

- Number of Surveys: 29
- Average Number/Survey: 2
- High Count: 4 (a report of 17 individuals from Herring Pond is anomalous and seems suspect)

The Common Sanddragon is an uncommon resident of sandy bottomed ponds, within CACO recorded exclusively at kettle ponds (Figure 78). The males perch on sandy beaches, but are very inconspicuous, often not seen until flushed, at which point they typically fly out very low over the water before returning to shore. Although undoubtedly a regular breeder within CACO, the only evidence of breeding during the surveys was of a tandem pair at Herring Pond. It is a summer flier, with a flight season extending from mid-June through late August (Figure 79).

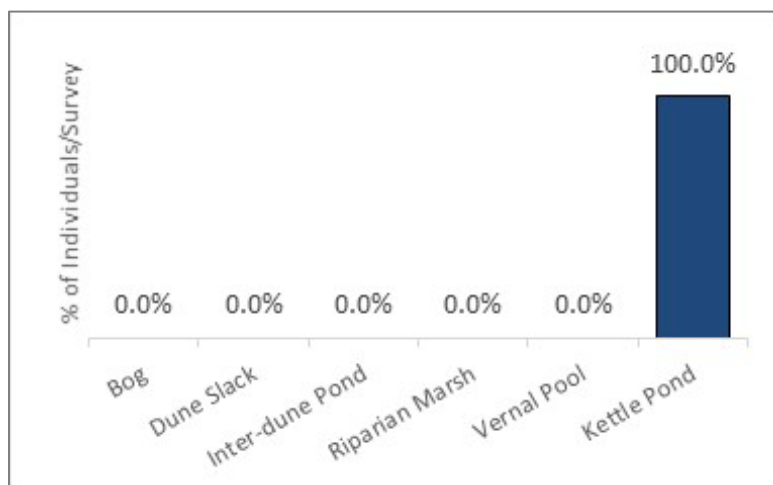


Figure 78. Common Sanddragon distribution by habitats at Cape Cod National Seashore.

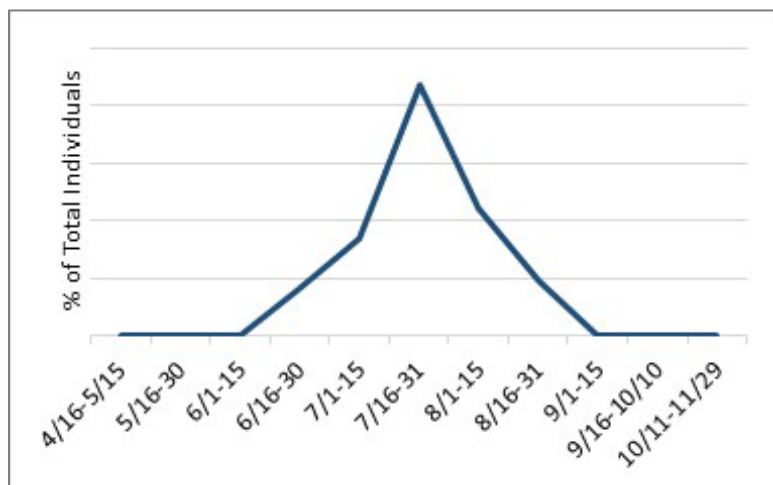


Figure 79. Common Sanddragon flight season at Cape Cod National Seashore.

Cruisers (Macromiidae)

Stream Cruiser (*Didymops transversa*) (Say, 1839)

- Range: Manitoba, Quebec and Nova Scotia south to Texas and Florida
- Habitat: Sandy bottomed, woodland streams, and large sandy bottomed ponds and lakes
- Number of CACO Sites: 0 (4 records from upland sites)
- Number of Surveys: 0
- Average Number/Survey: NA
- High Count: NA

The status of Stream Cruiser within CACO is unclear. It was not recorded on the official surveys but was seen twice during the survey period at upland sites; there are also two historical records, also from upland sites. It is a large species, capable of traveling considerable distances, so the few records on the outer Cape might represent wandering individuals. However, even where common, the species spends little time at breeding sites and breeding activity is rarely observed. Thus, the species could be breeding at the larger ponds within CACO, most likely Gull Pond and/or Great Pond, Wellfleet. It is an early flier, on the wing from mid-May through early July.

Swift River Cruiser (*Macromia illinoensis*) (Walsh, 1862)

- Range: Manitoba, Quebec and Nova Scotia south to Texas and Florida
- Habitat: A variety of streams and rivers; also large, wind-swept lakes
- Number of CACO Sites: 1 (plus 4 historical records—2 from upland sites)
- Number of Surveys: 1
- Average Number/Survey: NA
- High Count: 3

The Swift River Cruiser is a scarce resident within CACO, recorded only once during the surveys (Great Pond, Wellfleet), but historically known from two additional kettle ponds, plus two upland sites. Sones observed an ovipositing female at Duck Pond on 7/30/98, the only evidence of breeding within CACO. However, breeding activity is infrequently seen in this species and it is likely a regular breeder within the seashore; Gull Pond and Great Pond, Wellfleet are also likely breeding sites. A single report from Provincetown very likely represents a wandering individual. It is a summer flier; the few records extend from mid-July through mid-August, though the actual flight season very likely is longer.

Emeralds (Corduliidae)

Petite Emerald (*Dorocordulia lepida*) (Hagen in Selys, 1871)

- Range: New York, Maine and Nova Scotia south to West Virginia and New Jersey
- Habitat: Acidic ponds, streams, and bog pools

- Number of CACO Sites: 3 (plus 6 historical—2 of which are upland sites)
- Number of Surveys: 6
- Average Number/Survey: 1
- High Count: 2

The Petite Emerald is a scarce, though elusive and undoubtedly much overlooked, inhabitant throughout CACO. Its appearances at breeding sites are brief, and it is as likely to be encountered foraging over woodland roads and trails. The few recorded during the surveys were all at bogs (Figure 80). No evidence of breeding was noted, though the species appears to be relatively sedentary and not prone to wandering far from breeding sites. The flight season is early, running from early June through mid-July (Figure 81).

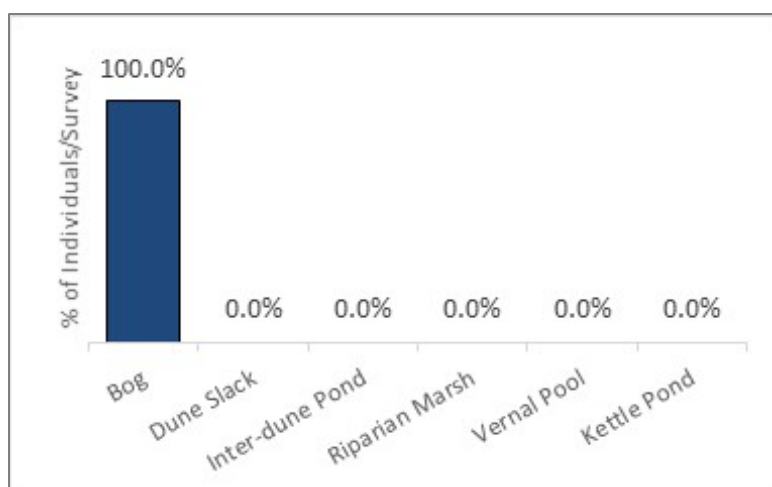


Figure 80. Petite Emerald distribution by habitats at Cape Cod National Seashore.

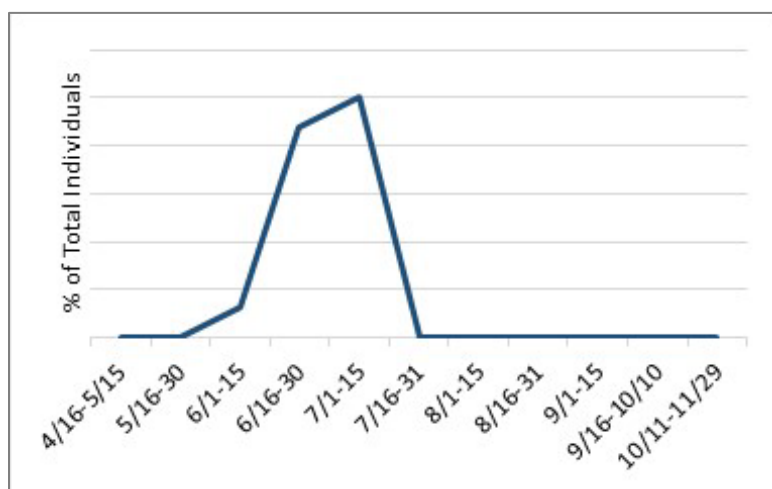


Figure 81. Petite Emerald flight season at Cape Cod National Seashore.

Common Baskettail (*Epitheca cynosura*) (Say, 1839)

Mantled Baskettail (*Epitheca semiaquea*) (Burmeister 1838)

- Range (Common Baskettail): Wyoming, Manitoba, Quebec and Nova Scotia south to Texas and Florida
- Range (Mantled Baskettail): Nova Scotia to Florida, and Louisiana, Texas, and Kansas
- Habitat: Ponds, lakes, and the backwaters of sluggish streams
- Number of CACO Sites: 15 (plus 22 historical—8 of which are upland)
- Number of Surveys: 17
- Average Number/Survey: 3
- High Count: 10

The exact status of Common and Mantled baskettails (subgenus *Tetragoneuria*) is muddled by their very similar appearance. The latter differs, on average, in have a proportionally thicker abdomen and generally more extensive dark markings at the base of the wings, but there is considerable overlap in these characteristics. Even in the hand distinguishing between the two is very difficult. The three known specimens from within CACO, all historical and originally identified as Commons, were re-determined in 2001 to be Mantled (T.W. Donnelly, pers. com.). Prior to that, all small baskettails in this region were assumed to be Commons; thus, all historical records in the database refer to that species, and for the sake of simplicity, all small baskettails recorded on these surveys were recorded as Commons (none were collected). The Mantled Baskettail is a southern species at the northern edge of its range in southern New England and may be increasing here in response to climate warming.

Small baskettails, of one or the other species, are common and widespread within CACO. Small foraging swarms are frequently encountered over fields, woodland clearings, and dirt roads during June. Although widespread (Figure 82), they are not often seen at presumed breeding sites: they were recorded at 15 sites during the surveys, but on only 17 surveys total. Evidence of breeding was noted at just four sites, all kettle ponds, but they undoubtedly breed at a number of additional sites. Although the largest number of individuals was recorded at bogs, there is no evidence of breeding at those sites. These are among the earliest odonates to emerge locally, with a flight season extending from mid-May through early July (Figure 83).

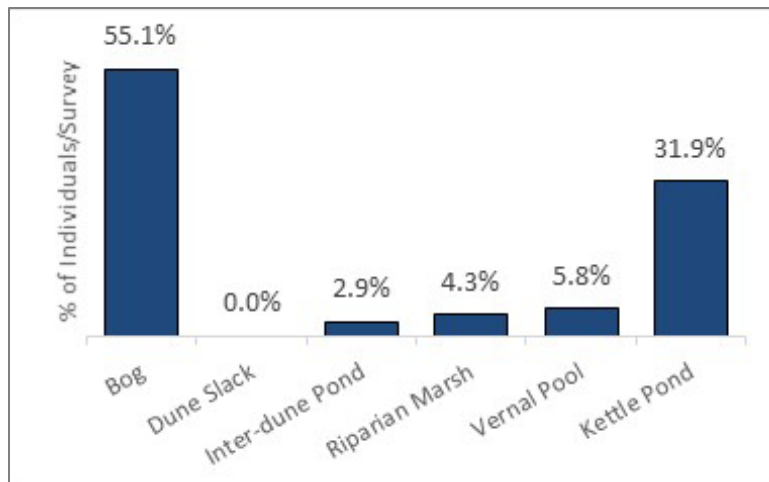


Figure 82. Common/Mantled Baskettail distribution by habitats at Cape Cod National Seashore.

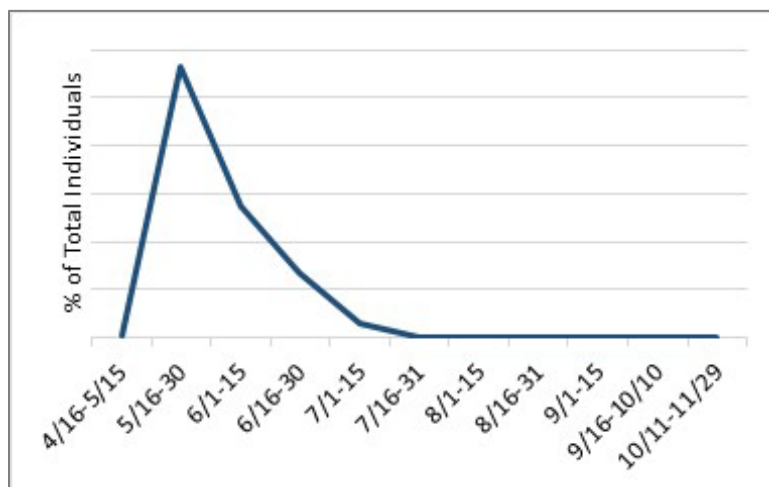


Figure 83. Common/Mantled Baskettail flight season at Cape Cod National Seashore.

Prince Baskettail (*Epitheca princeps*) (Hagen, 1861)

- Range: New Mexico, South Dakota, Manitoba and Nova Scotia south to Tamaulipas and Florida
- Habitat: Rivers and large streams; lakes
- Number of CACO Sites: 4 (plus 6 historical—2 of them upland)
- Number of Surveys: 17
- Average Number/Survey: 2
- High Count: 3

The darner-like Prince Baskettail is a fairly common resident within CACO. Like many of the emeralds, it is more often seen away from potential wetland breeding sites, this species frequently encountered foraging at tree-top level, often in swarms, early on warm summer mornings or late in the day. The preferred wetland habitat locally is large, sandy bottomed ponds (Figure 84). No

evidence of breeding was noted during the surveys, but breeding activity occurs mostly early and late in the day and is thus easily missed; in 2019, following completion of the surveys, several exuviae were found at Gull Pond, Wellfleet, confirming successful breeding at that large, sparsely vegetated pond. The flight season extends from mid-June through early September (Figure 85).

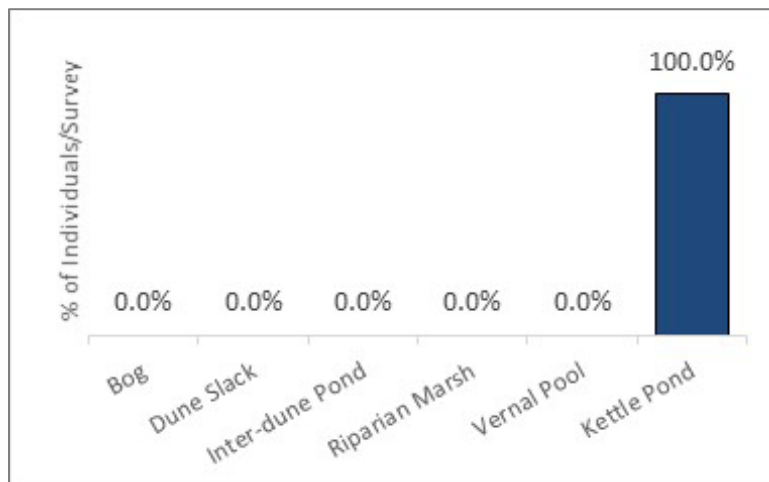


Figure 84. Prince Baskettail distribution by habitats at Cape Cod National Seashore.

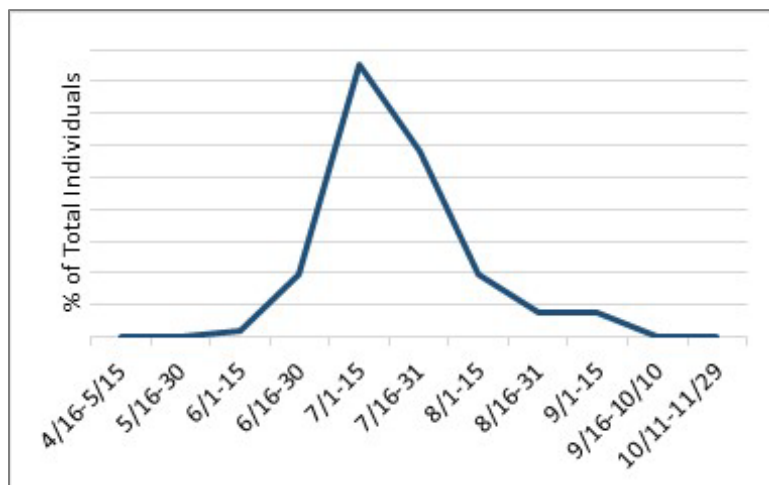


Figure 85. Prince Baskettail flight season at Cape Cod National Seashore.

Skimmers (Libellulidae)

Calico Pennant (*Celithemis elisa*) (Hagen, 1861)

- Range: Colorado, Manitoba and Nova Scotia south to Texas and Florida
- Habitat: Vegetated ponds
- Number of CACO Sites: 19 (plus 13 historical—5 of them upland sites)
- Number of Surveys: 132
- Average Number/Survey: 10

- High Count: 111

The Calico Pennant is the most common and widespread member of its genus within CACO and elsewhere on Cape Cod; it was recorded on 34% of the surveys. However, it occurs almost exclusively at kettle ponds with emergent vegetation (Figure 86). Curiously, it is rather rare in Provincetown, despite the presence of seemingly suitable habitat. Where present, it is one of the most conspicuous dragonflies, despite its small size. Ovipositing females and pairs frequently are seen in flight over open water. The flight season extends from early June into early September (Figure 87).

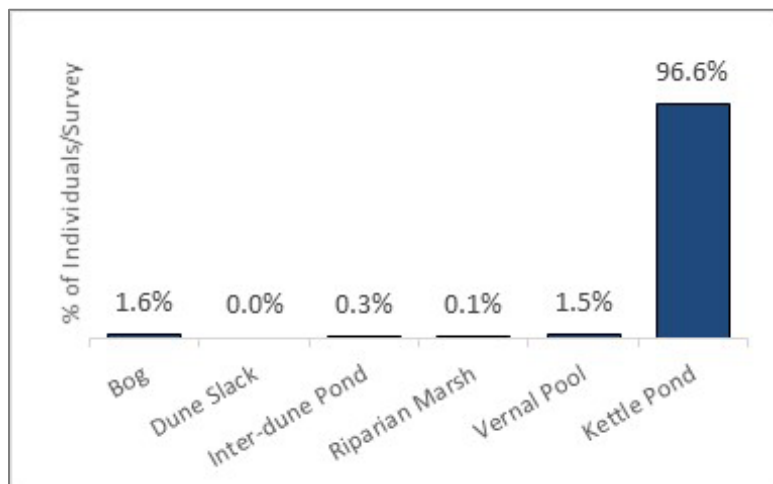


Figure 86. Calico Pennant distribution by habitats at Cape Cod National Seashore.

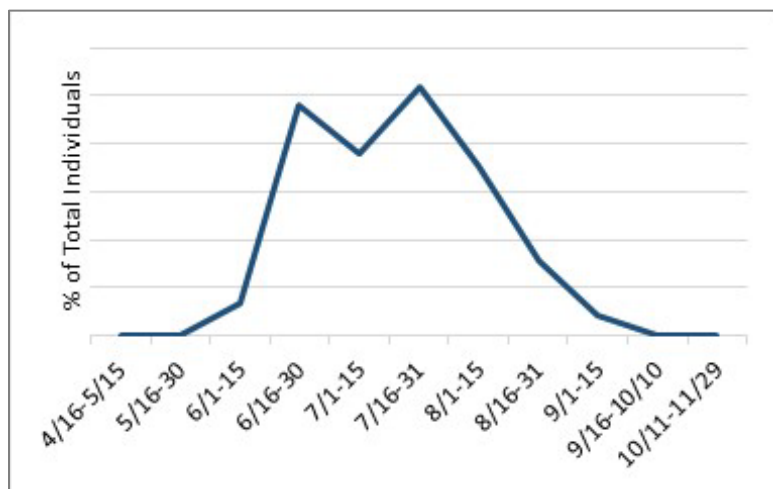


Figure 87. Calico Pennant flight season at Cape Cod National Seashore.

Halloween Pennant (*Celithemis eponina*) (Drury, 1773)

- Range: Colorado, Minnesota, Ontario and Maine south to Coahuila and Florida, west to southeastern Arizona; also, Bahamas and Cuba
- Habitat: Lakes, ponds, and marshes

- Number of CACO Sites: 10 (plus 3 historical)
- Number of Surveys: 22
- Average Number/Survey: 4
- High Count: 24

The Halloween Pennant is an uncommon species within CACO, recorded from 10 sites, but on only 22 (5%) surveys. However, unlike its congeners, this is a species that spends little time at its wetland breeding sites, more often encountered in upland fields and clearings. When at wetlands, it showed a strong preference for kettle ponds (77% of individuals), in particular Herring Pond in Wellfleet, where 62% of the individuals and the three highest counts were recorded (Figure 88). It was not recorded in Provincetown during the surveys, though there is one historical record from that town. The flight season extends from mid-June through mid-August (Figure 89).

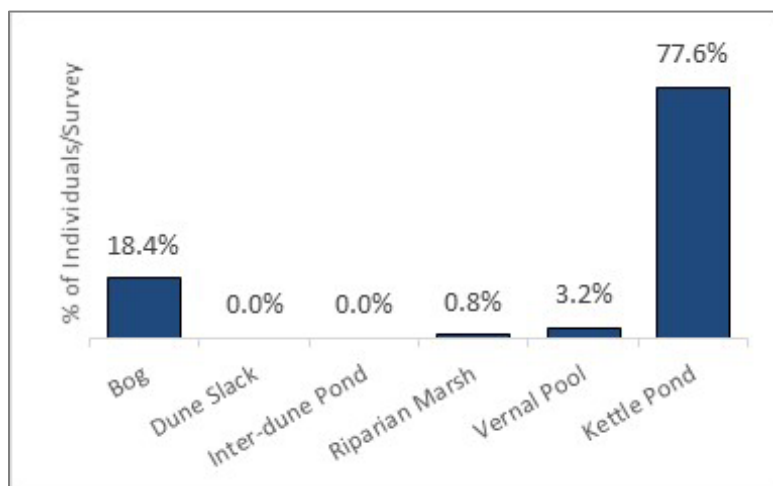


Figure 88. Halloween Pennant distribution by habitats at Cape Cod National Seashore.

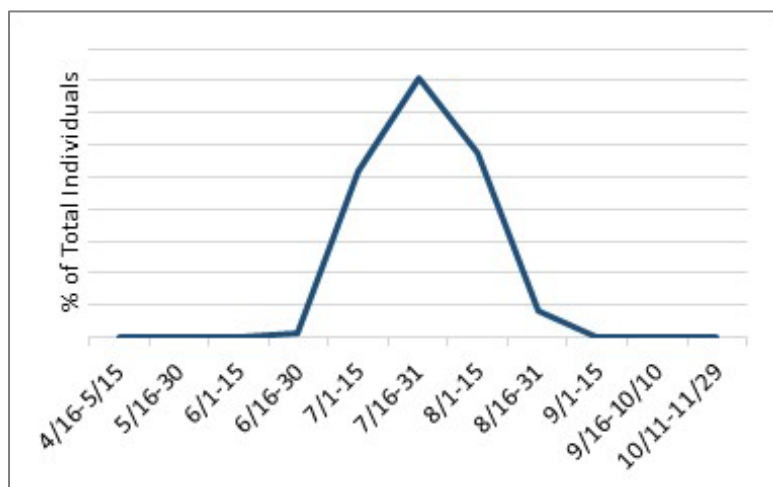


Figure 89. Halloween Pennant flight season at Cape Cod National Seashore.

Banded Pennant (*Celithemis fasciata*) (Kirby, 1889)

- Range: Southeastern New Mexico, Kansas, Michigan, Ontario and Massachusetts south to Texas and Florida
- Habitat: Vegetated, generally sandy bottomed ponds and lakes
- Number of CACO Sites: 9 (plus one historical)
- Number of Surveys: 22
- Average Number/Survey: 2
- High Count: 9

The Banded Pennant is an uncommon and local species, recorded at just nine sites and on only 5% of the surveys. It was found exclusively at kettle ponds (Figure 90) and was never recorded in large numbers. It has not been recorded north of south Truro (Great Pond). Although recorded at nine sites, over 60% of the individuals were found at just one: Turtle Pond in Wellfleet. Like its congeners, it is a summer flier, on the wing from mid-June through mid-August (Figure 91).

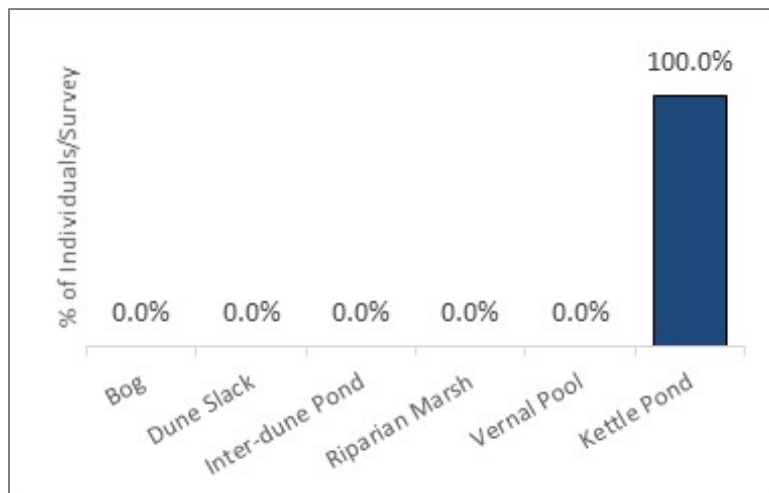


Figure 90. Banded Pennant distribution by habitats at Cape Cod National Seashore.

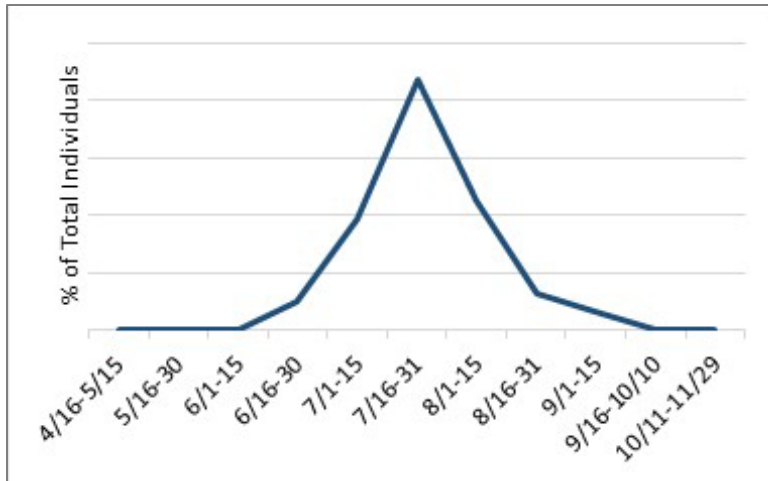


Figure 91. Banded Pennant flight season at Cape Cod National Seashore.

Martha's Pennant (*Celithemis martha*) (Williamson, 1922)

- Range: Maine and Nova Scotia south to Virginia
- Habitat: Vegetated, usually sandy bottomed lakes and ponds
- Number of CACO Sites: 11 (plus 2 historical)
- Number of Surveys: 67
- Average Number/Survey: 9
- High Count: 64

Martha's Pennant is a fairly common but local species within CACO, recorded exclusively at kettle ponds (Figure 92). Although present at 11 sites, just four, Great Pond Truro, Horseleeche Pond, Snow Pond, and Turtle Pond, accounted for 83% of the individuals on the surveys. The flight season extends a bit later into the season than the other pennants, running from mid-June into mid-September (Figure 93).

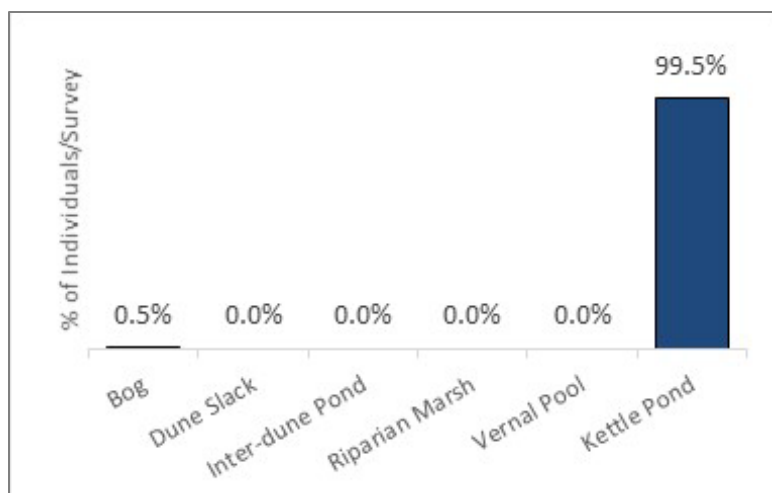


Figure 92. Martha's Pennant distribution by habitats at Cape Cod National Seashore.

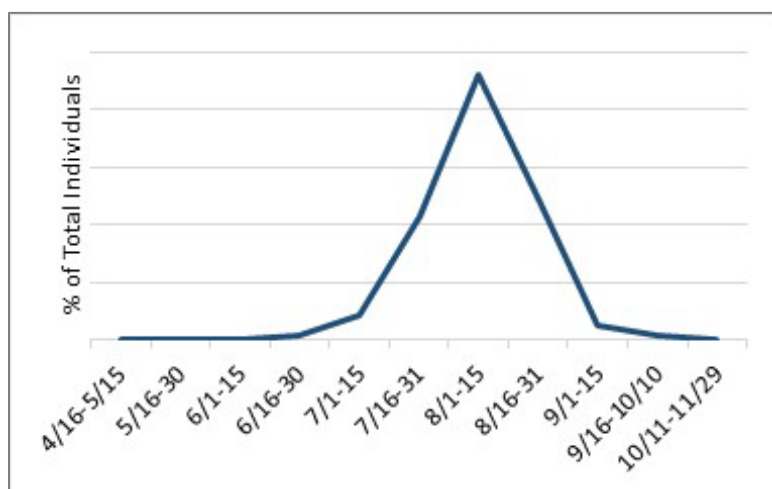


Figure 93. Martha's Pennant flight season at Cape Cod National Seashore.

Eastern Pondhawk (*Erythemis simplicicollis*) (Say, 1839)

- Range: Southeastern Montana, North Dakota, Ontario and Maine south to Costa Rica; also, Bahamas and Greater Antilles
- Habitat: A wide variety of well-vegetated wetlands, especially ponds and large vernal pools, but also sluggish streams and man-made wetlands
- Number of CACO Sites: 40 (plus 12 historical)
- Number of Surveys: 218
- Average Number/Survey: 9
- High Count: 150

The Eastern Pondhawk is one of the most common and widespread odonates within CACO, recorded at all but one site and on 56% of the surveys. Females and immature males are frequently

encountered well away from water, in fields or along dirt roads and power line clearings, most often perching on the ground, logs, or rocks. Although recorded in every wetland habitat, it has a strong preference for vernal pools, where two-thirds of the individuals were found (Figure 94). The flight season is quite long, running from late May through mid-September (Figure 95).

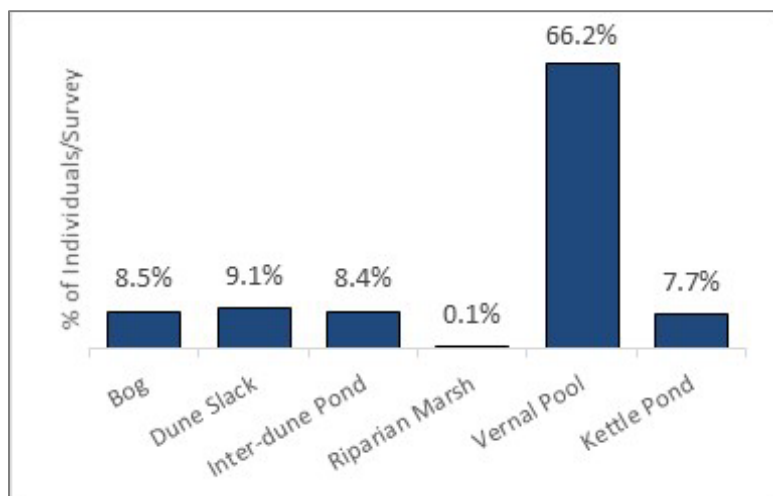


Figure 94. Eastern Pondhawk distribution by habitats at Cape Cod National Seashore.

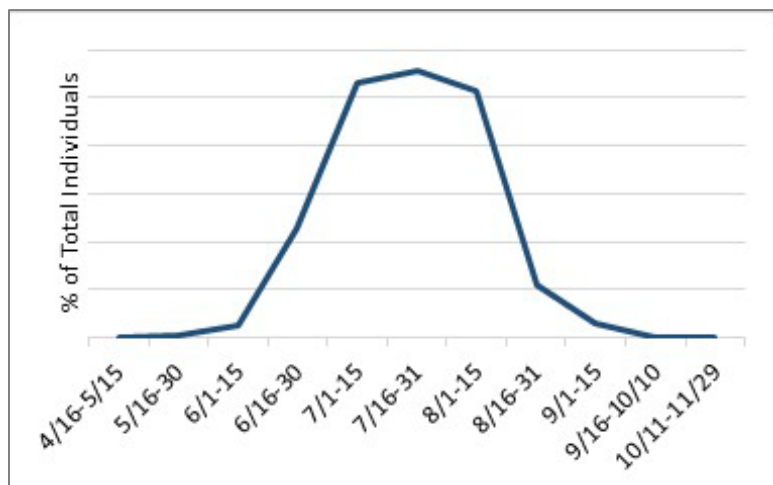


Figure 95. Eastern Pondhawk flight season at Cape Cod National Seashore.

Seaside Dragonlet (*Erythrodiplox berenice*) (Drury, 1773)

- Range: Nova Scotia to Venezuela and Trinidad along Atlantic, Gulf and Caribbean coasts, inland to Oklahoma and New Mexico; also, Pacific coast of Mexico, Bahamas, Greater Antilles and some Lesser Antillean islands; isolated records in interior Georgia, New York and Quebec
- Habitat: Salt marshes—
- Number of CACO Sites: 1 (plus 2 historical sites)
- Number of Surveys: 1

- Average Number/Survey: 1
- High Count: 1

Along the Atlantic Seaboard, the diminutive Seaside Dragonlet breeds exclusively in salt marshes, a habitat not surveyed during this project. Thus, the one record—a single, wandering individual at a small pond in Eastham (E23), just a quarter mile from the Nauset marsh—is not indicative of the species status within CACO. In the 1990s it was a common to abundant resident in Nauset marsh, but its current status there is uncertain, as is its status in suitable habitat elsewhere within the seashore. It is a summer flier, though there are too few records to define the flight season with greater precision.

Blue Corporal (*Ladona deplanata*) (Rambur, 1842)

- Range: Kansas, Iowa, Illinois, Pennsylvania and New Hampshire south to Texas and Florida
- Habitat: Ponds and lakes, with varying amounts of vegetation
- Number of CACO Sites: 9 (plus one historical)
- Number of Surveys: 16
- Average Number/Survey: 2
- High Count: 8

The Blue Corporal is an uncommon and local species within CACO, recorded at only 9 sites and on just 4% of the surveys. It is distinctly less common here than through the mid and upper Cape. It is a coastal plain pond specialist: 97% of the individuals recorded were at kettle ponds (Figure 96). Males typically perch flat on floating vegetation or logs. Like other coastal plain pond specialists, it has not been recorded north of south Truro. The flight season is early, extending from late May through mid-July (Figure 97).

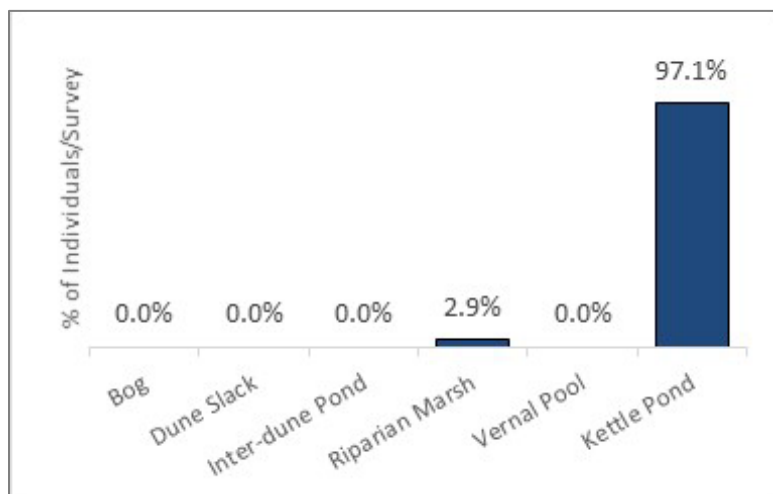


Figure 96. Blue Corporal distribution by habitats at Cape Cod National Seashore.

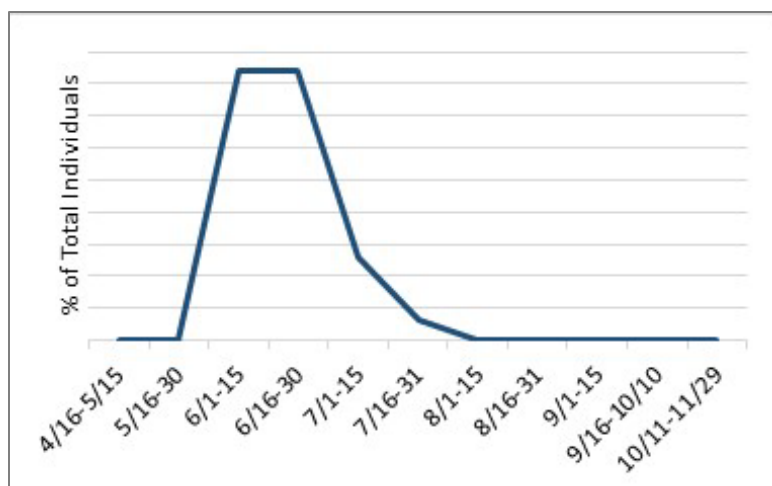


Figure 97. Blue Corporal flight season at Cape Cod National Seashore.

White Corporal (*Ladona exusta*) (Say, 1839)

- Range: New York, New Brunswick and Nova Scotia south to Maryland
- Habitat: Ponds, lakes, and bog pools
- Number of CACO Sites: 15 (plus 5 historical)
- Number of Surveys: 38
- Average Number/Survey: 4
- High Count: 15

The White Corporal is less of a habitat specialist than its congener, the Blue Corporal, and was recorded from 15 sites and on 10% of the surveys (Figure 98). It is common at inter-dune ponds in Provincetown where the Blue Corporal is absent. Although the two species occasionally occur at the same sites, invariably one species predominates. Males of both species generally perch flat on floating vegetation or logs. The flight seasons are similar, though the White Corporal has been recorded emerging as early as late April—the first locally reared odonate species to appear in the spring (Figure 99); only migrant Common Green Darners occasionally appear earlier in the season.

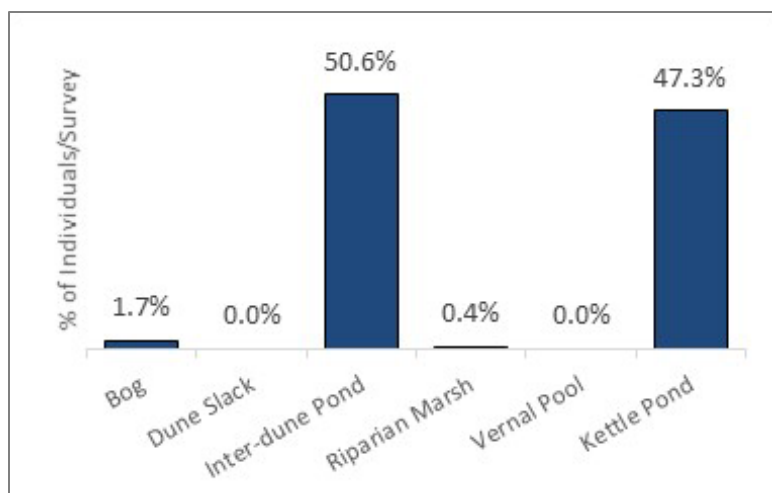


Figure 98. White Corporal distribution by habitats at Cape Cod National Seashore.

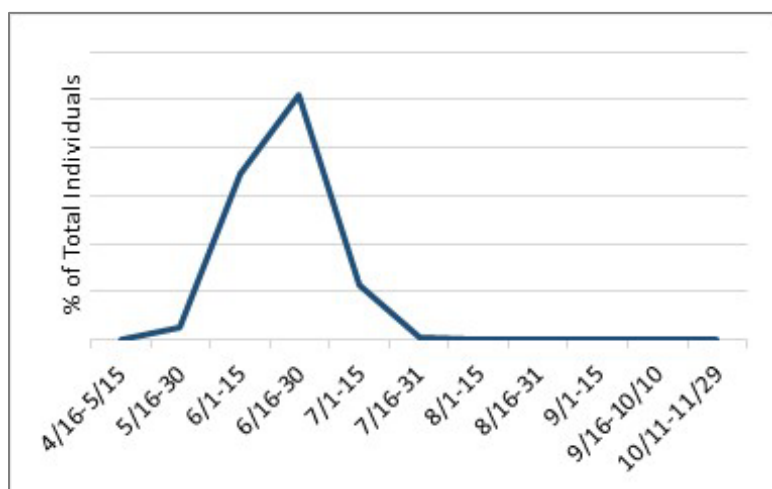


Figure 99. White Corporal flight season at Cape Cod National Seashore.

Frosted Whiteface (*Leucorrhinia frigida*) (Hagen, 1890)

- Range: Manitoba and New Brunswick south to Minnesota, Indiana and West Virginia
- Habitat: Boggy pools, well-vegetated muddy-bottomed ponds
- Number of CACO Sites: 2
- Number of Surveys: 2
- Average Number/Survey: 1
- High Count: 1

The Frosted Whiteface is a rare and erratic species within CACO as well as throughout Cape Cod. It has been recorded at only four sites on Cape Cod, two of them large vernal pools in Eastham (E09 and E10). And despite these two sites being among the most frequently surveyed within the seashore (20 times each during this project, plus numerous additional times dating back to the early 1990s),

the species has been recorded only once at E09 (2016) and three times at E10 (once each in 1997, 1998, and 2016). Thus, whether it is resident within CACO or merely a vagrant is uncertain, though the presence of three individuals on one visit in 1997 argues against the latter. Whichever the case, its presence is clearly sporadic and unpredictable. It is a “spring” flier, on the wing from late May through mid-July.

Dot-tailed Whiteface (*Leucorrhinia intacta*) (Hagen, 1861)

- Range: British Columbia, Manitoba and New Brunswick south to California, New Mexico, Iowa, Kentucky and Virginia
- Habitat: Vegetated ponds and large vernal pools
- Number of CACO Sites: 22 (plus 10 historical)
- Number of Surveys: 51
- Average Number/Survey: 9
- High Count: 151

The Dot-tailed Whiteface is a fairly common early season species, recorded at 22 sites and on 13% of the surveys. It occurs in a variety of habitats, though with a strong preference for large vernal pools (Figure 100); over half of the individuals were recorded at just one such site, E09 in Eastham. Males typically perch on water lilies or other floating vegetation. Like others in its genus, it emerges early, with a flight season extending from early May through mid-July (Figure 101).

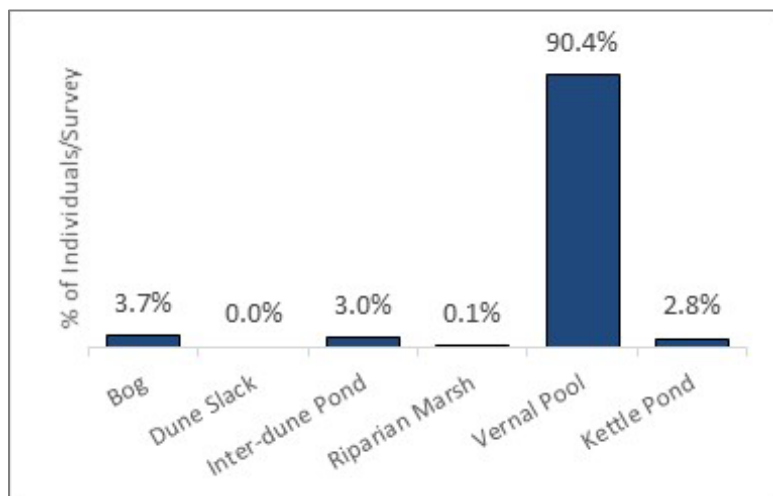


Figure 100. Dot-tailed Whiteface distribution by habitats at Cape Cod National Seashore.

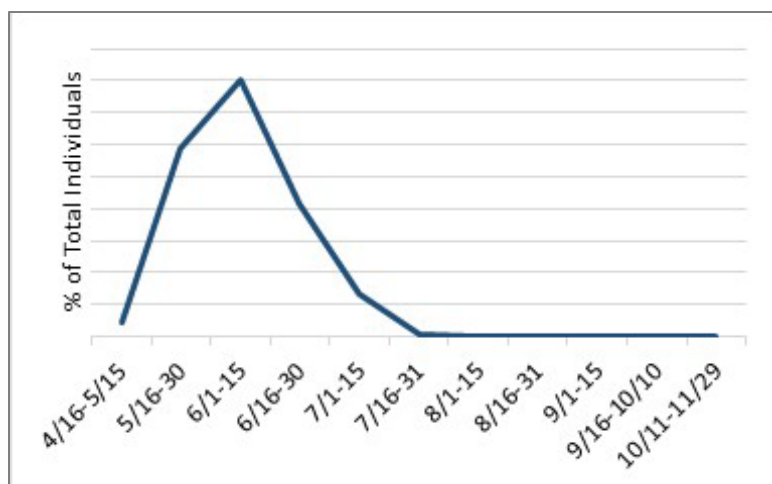


Figure 101. Dot-tailed Whiteface flight season at Cape Cod National Seashore.

Golden-winged Skimmer (*Libellula auripennis*) (Burmeister, 1839)

- Range: Oklahoma, Arkansas, Tennessee, New York and Massachusetts south to Texas and Florida; vagrant farther north to Nebraska, Iowa, Illinois and Michigan
- Habitat: Coastal plain ponds
- Number of CACO Sites: 1 (plus 2 historical)
- Number of Surveys: 1
- Average Number/Survey: 1
- High Count: 1

This large, orange skimmer is a southeastern species at the northern edge of its range in southeastern Massachusetts. It is an uncommon and local resident through the mid and upper Cape, confined to coastal plain ponds, but is a rare vagrant on the outer Cape. It was recorded just once during the formal surveys, at Great Pond in Truro; there are also a couple of historical records. This species and Needham's Skimmer are very similar in appearance, and there are several records of individuals that were not seen well enough to identify to species. The two species typically segregate by habitat, but wandering individuals can appear almost anywhere. The peak flight season runs from early July through late August.

Bar-winged Skimmer (*Libellula axilena*) (Westwood, 1837)

- Range: Arkansas, Kentucky, Pennsylvania and Massachusetts south to Texas and Florida
- Habitat: Wooded and boggy pools; slow, wooded streams
- Number of CACO Sites: 7 (plus one historical)
- Number of Surveys: 9
- Average Number/Survey: 1
- High Count: 3

The first CACO (and Massachusetts) record for this southeastern species was of an individual collected at a small vernal pool (E01) in Eastham in early July 1996 (Nikula et al. 2001). There were no further Cape Cod records for two decades until these surveys, during which it was recorded at seven sites and on nine surveys. An ovipositing female, guarded by a male, was seen at E04 in Eastham in 2017, apparently the first confirmation of breeding in the state. This species has occurred with increasing frequency in southern New England over the past decade or so, presumably in response to climate change, a trend that seems likely to continue. The majority of CACO records are from vernal pools and the one dune slack (Figure 102). The recorded flight season extends from mid-June through mid-August (Figure 103).

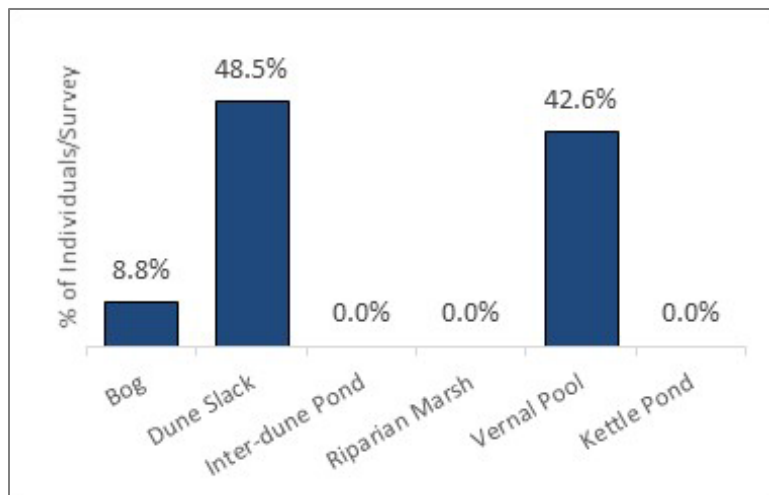


Figure 102. Bar-winged Skimmer distribution by habitat at Cape Cod National Seashore.

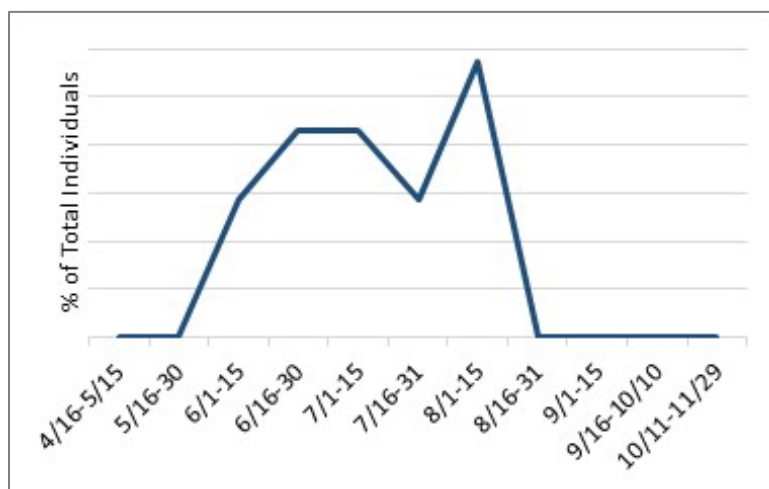


Figure 103. Bar-winged Skimmer flight season at Cape Cod National Seashore.

Spangled Skimmer (*Libellula cyanea*) (Fabricius, 1775)

- Range: Kansas, Michigan and Maine south to Texas and Georgia
- Habitat: Variety of vegetated lakes, ponds, and pools

- Number of CACO Sites: 17 (plus 9 historical)
- Number of Surveys: 51
- Average Number/Survey: 2
- High Count: 7

The distinctive Spangled Skimmer is a widespread, though somewhat uncommon, inhabitant of a variety of wetlands within CACO. It was recorded most frequently in bogs (though not generally considered a bog species) and vernal pools, but also occurred with some frequency at kettle ponds and inter-dune ponds (Figure 104). It was never recorded in large numbers. Breeding activity was noted only rarely, but occurred at one inter-dune pond, one kettle pond, and two vernal pools. The flight season extends from late May through mid-August, with a peak in July (Figure 105).

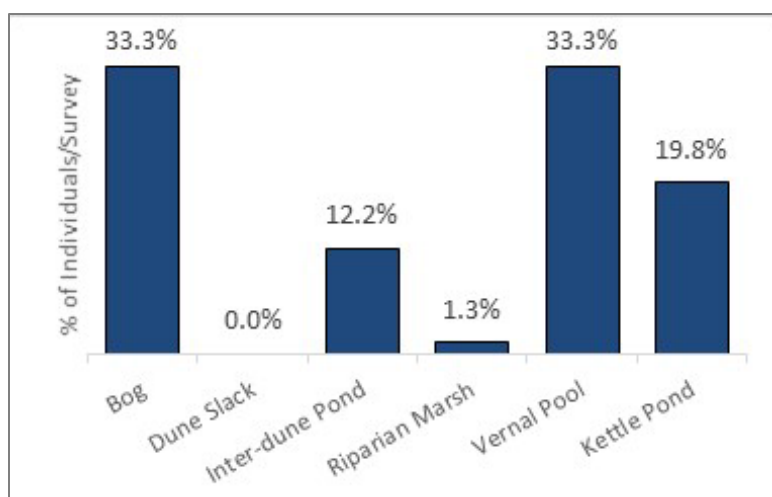


Figure 104. Spangled Skimmer distribution by habitats at Cape Cod National Seashore.

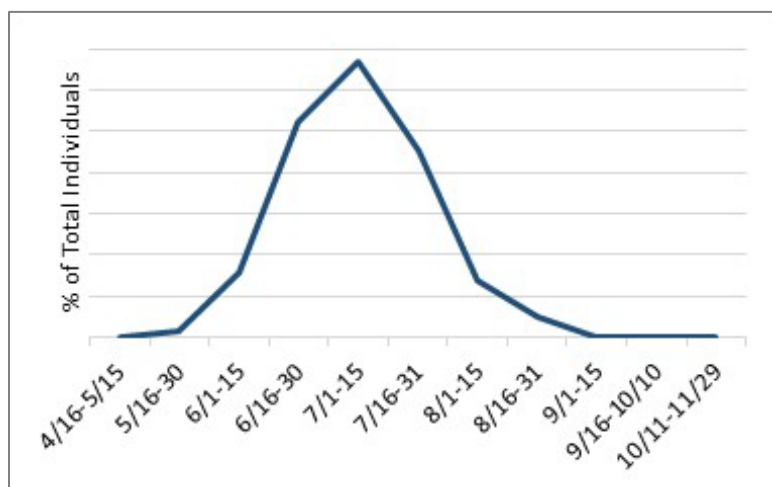


Figure 105. Spangled Skimmer flight season at Cape Cod National Seashore.

Slaty Skimmer (*Libellula incesta*) (Hagen, 1861)

- Range: Kansas, Wisconsin, Ontario and New Brunswick south to Texas and Florida
- Habitat: Wide variety of lakes, ponds, and pools, as well as sluggish streams
- Number of CACO Sites: 39 (plus 10 historical)
- Number of Surveys: 265
- Average Number/Survey: 12
- High Count: 114

This large, dark skimmer is one of the most common and widespread odonates within CACO (and southern New England generally), recorded at all but three of the survey sites. Although recorded in a variety of habitats, over half were at kettle ponds (Figure 106). The lengthy flight season extends from early June through mid-September with a peak in July (Figure 107).

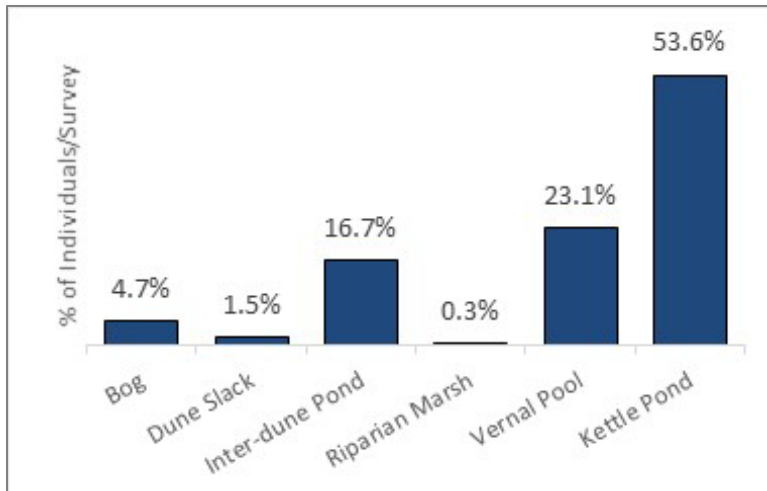


Figure 106. Slaty Skimmer distribution by habitats at Cape Cod National Seashore.

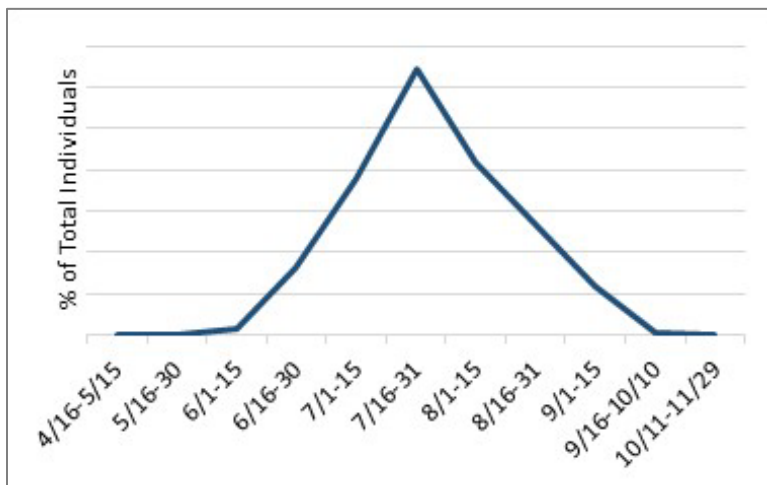


Figure107. Slaty Skimmer flight season at Cape Cod National Seashore.

Needham's Skimmer (*Libellula needhami*) (Westfall, 1943)

- Range: Maine south along Atlantic coastal plain to Florida, then to Coahuila and Quintana Roo; also, Jalisco, Bahamas and Cuba
- Habitat: Variety of wetlands, including brackish and artificial sites
- Number of CACO Sites: 3 (plus 3 historical)
- Number of Surveys: 10
- Average Number/Survey: 1
- High Count: 2

This large, reddish-orange skimmer was seen only rarely on these surveys, though to some extent this is a reflection of its preferred habitat of brackish and disturbed wetlands not being surveyed. Adult males are very similar to Golden-winged Skimmers, lending a degree of uncertainty to sight only reports. Most of the handful of records were from Salt Meadow Big Pool in Truro. Occasional records from other habitats probably represent wandering individuals. It likely occurs at low density in brackish wetlands and the upper reaches of salt marshes elsewhere within the seashore. The flight season is primarily from early July through late August.

Twelve-spotted Skimmer (*Libellula pulchella*) (Drury, 1773)

- Range: Southern British Columbia, Saskatchewan, Ontario and New Brunswick south to California, Sonora, Coahuila and northern Florida
- Habitat: Vegetated lakes and ponds
- Number of CACO Sites: 7 (plus 16 historical)
- Number of Surveys: 10
- Average Number/Survey: 2
- High Count: 3

The large, distinctive Twelve-spotted Skimmer is a scarce species within CACO (and throughout Cape Cod generally). It is somewhat migratory and it is not clear to what extent local records represent only wandering individuals; no evidence of breeding was noted during the surveys. It was recorded primarily at large vernal pools and shallow ponds (both kettle and inter-dune) (Figure 108). The flight season runs from late May through mid-September (Figure 109).

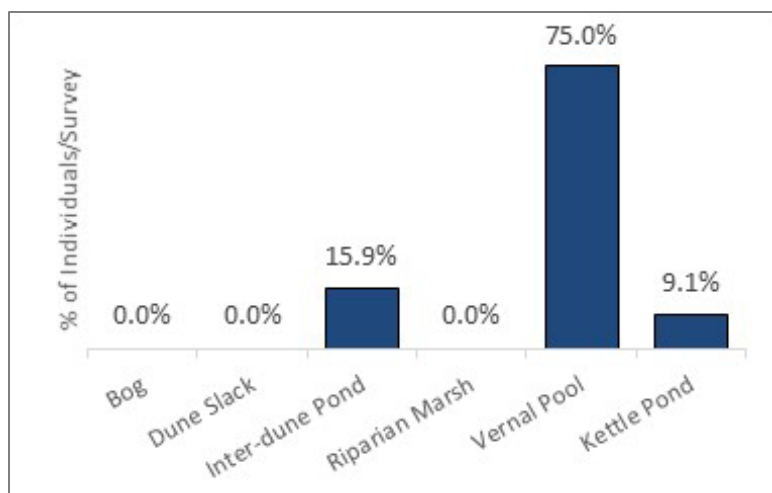


Figure 108. Twelve-spotted Skimmer distribution by habitat at Cape Cod National Seashore.

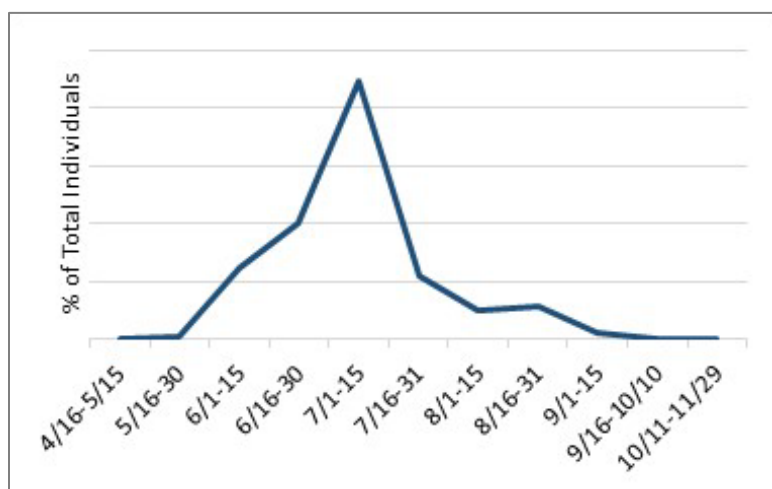


Figure 109. Twelve-spotted Skimmer flight season at Cape Cod National Seashore.

Four-spotted Skimmer (*Libellula quadrimaculata*) (Linnaeus, 1758)

- Range: Alaska, Northwest Territories and Labrador south to California, New Mexico, Nebraska, Illinois and West Virginia; also, widely in Eurasia
- Habitat: Boggy and muddy-bottomed ponds and pools
- Number of CACO Sites: 2 (plus 8 historical)
- Number of Surveys: 2
- Average Number/Survey: 3
- High Count: 4

The Four-spotted Skimmer, formerly an uncommon resident within CACO, was recorded only twice during the surveys, and appears to be on the verge of extirpation not only within the seashore, but throughout Cape Cod. During the 1990a, it was fairly common at the Eastham vernal pools, but was

not found at all there during these surveys, despite numerous visits. It is a northern species near the southern edge of its range here, and its decline may be a consequence of climate warming. It inhabits bogs and boggy vernal pools, usually where sphagnum is present. The flight season is early, extending from mid-May through early July.

Painted Skimmer (*Libellula semifasciata*) (Burmeister, 1839)

- Range: Kansas, Michigan, Ontario and New Brunswick south to Texas and Florida
- Habitat: Vegetated ponds and pools; bogs
- Number of CACO Sites: 27 (plus 13 historical)
- Number of Surveys: 84
- Average Number/Survey: 4
- High Count: 20

The Painted Skimmer is a common and conspicuous inhabitant of a variety of wetland habitats within CACO, though a substantial percentage were at vernal pools, dune slacks, and bog pools (Figure 110). It is a southern migratory species that has colonized this area over the past 30-40 years. The flight season runs from early June through mid-August (Figure 111); a steep peak in the flight data in mid-June may represent an influx of migrants.

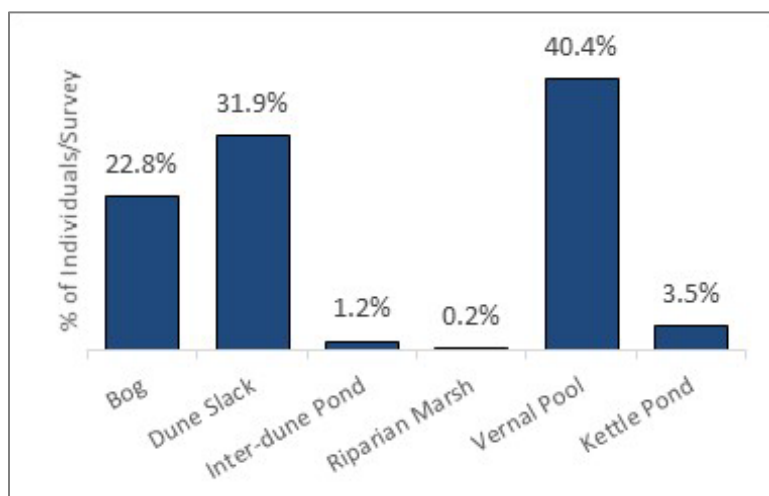


Figure 110. Painted Skimmer distribution by habitats at Cape Cod National Seashore.

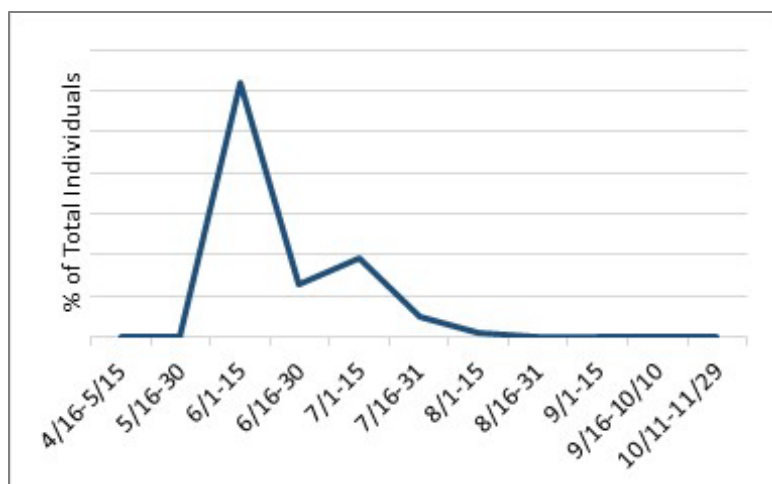


Figure 111. Painted Skimmer flight season at Cape Cod National Seashore.

Great Blue Skimmer (*Libellula vibrans*) (Fabricius, 1793)

- Range: Kansas, Wisconsin, Ontario and New Hampshire south to Texas and Florida; isolated records in northern Colorado, Minnesota and Michigan
- Habitat: Woodland pools, swamps, and sluggish, mucky streams
- Number of CACO Sites: 1 (plus one historical)
- Number of Surveys: 2
- Average Number/Survey: 2
- High Count: 2

The Great Blue Skimmer is another southern species that has moved into the area over the past couple of decades, though it is still scarce with no evidence yet of breeding here. It was recorded only twice on the surveys, but is most often encountered at atypical habitats, such as puddles along dirt roads or even ornamental backyard pools. The survey records were both in June, but elsewhere on Cape Cod it has been recorded into early September.

Elfin Skimmer (*Nannothemis bella*) (Uhler, 1857)

- Range: Minnesota, southern Ontario and Nova Scotia south to Mississippi and northwestern Florida
- Habitat: Bogs and boggy pools and ponds
- Number of CACO Sites: 1
- Number of Surveys: 2
- Average Number/Survey: 3
- High Count: 5

This diminutive dragonfly, the smallest in North America, was found at just one site on this survey, representing the first record within the seashore. However, it is known historically from Shank Painter Pond in Provincetown, just a half mile or so from the CACO site, so its presence within appropriate habitat nearby is not surprising. It is a rare species on Cape Cod, known from just one other site about 30 miles distant in Osterville. This easily overlooked species is closely tied to wetlands with extensive sphagnum, and suitable habitat seems to be present elsewhere within the seashore, so it may well occur at other sites within, or to the south of, Provincetown. Three teneral individuals were noted at Clapps Pond Bog, confirming breeding at this site. The bog is large and difficult to access, so it may well support a substantial population of Elfin Skimmers, though none were found at another bog site (P14) on the eastern edge of the Clapps Pond complex.

Blue Dasher (*Pachydiplax longipennis*) (Burmeister, 1839)

- Range: Southern British Columbia, Colorado, southern Manitoba and New Brunswick south to Baja California Sur, Michoacan and Yucatan; also, Bermuda and Bahamas
- Habitat: Wide variety of vegetated ponds and pools
- Number of CACO Sites: 41 (plus 18 historical)
- Number of Surveys: 229
- Average Number/Survey: 21
- High Count: 254

The Blue Dasher is the most widespread odonate within CACO, recorded at every site surveyed, as well as the most numerous dragonfly, averaging 21 individuals/survey. Although found in every habitat, a substantial majority was at large vernal pools (Figure 112). Evidence of breeding was noted at 14 sites. The lengthy flight season extends from late May through mid-September (Figure 113).

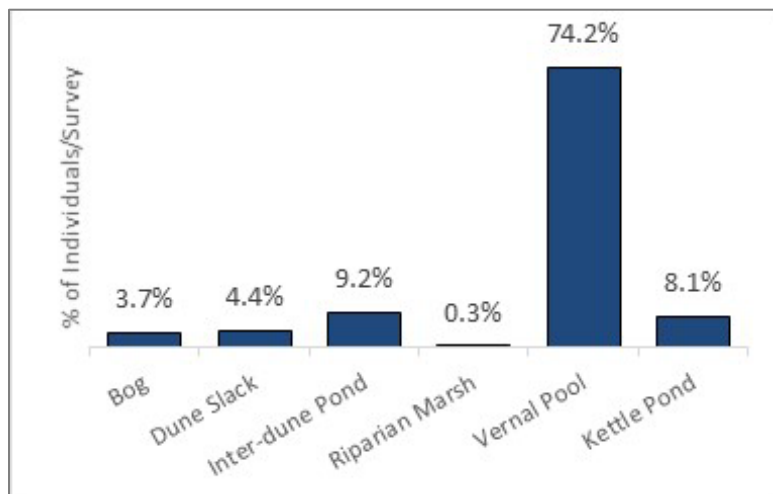


Figure 112. Blue Dasher distribution by habitats at Cape Cod National Seashore.

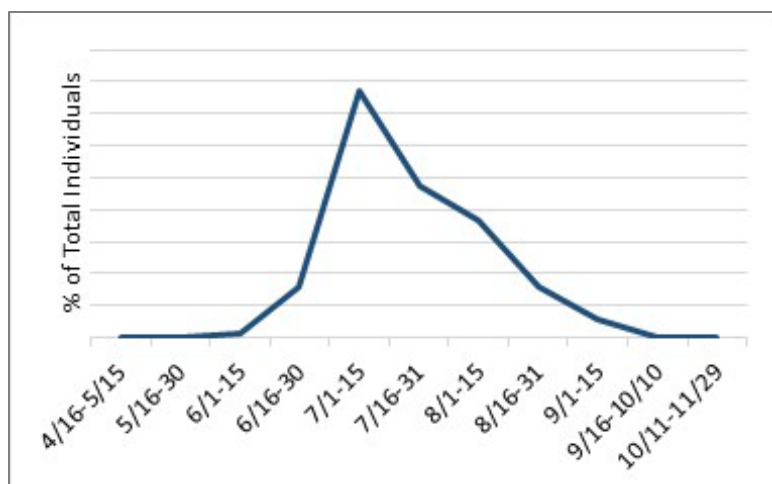


Figure 113. Blue Dasher flight season at Cape Cod National Seashore.

Wandering Glider (*Pantala flavescens*) (Fabricius, 1798)

- Range: Oregon, Nebraska, Manitoba, Ontario and Nova Scotia (vagrant farther north to Washington, Alberta, Quebec and Newfoundland) south to Argentina, Galapagos and West Indies, also Old World tropics and subtropics
- Habitat: Breeds in small, temporary, fishless pools and puddles, but most often encountered over upland areas
- Number of CACO Sites: 2 (plus 9 historical)
- Number of Surveys: 3
- Average Number/Survey: 1
- High Count: 1

Although the strong-flying Wandering Glider is a fairly common migrant through CACO, it was recorded on only three surveys at two sites. This species is most frequently encountered in upland areas and along the coast where other migrant species congregate. Both species of glider (genus *Pantala*) breed in very small, temporary wetlands, including puddles in dirt roads, and are seen only rarely at permanent wetlands, accounting for the few records during this survey. Unlike the vast majority of odonates, glider eggs and nymphs develop very rapidly—in a matter of weeks; thus, the breeding cycle is completed in just one season. Flight season data for this species is rather sparse but extends from mid-June through mid-September; it is considerably more numerous during the southbound migration period from late July through September. The Wandering Glider is the only cosmopolitan odonate, having been recorded on every continent except Antarctica, and often has been encountered, occasionally in large numbers, far offshore.

Spot-winged Glider (*Pantala hymenaea*) (Say, 1839)

- Range: Washington, Colorado, South Dakota, Michigan, Ontario and New Brunswick (vagrant farther north to Alaska, Manitoba and Newfoundland) south to Argentina; also, Bermuda, West Indies and Galapagos
- Habitat: Breeds in small, temporary, fishless pools and puddles, but most often seen over upland areas
- Number of CACO Sites: 4 (plus 11 historical)
- Number of Surveys: 4
- Average Number/Survey: 7
- High Count: 25

The Spot-winged Glider is the more common of the two gliders within CACO, occasionally numbering into the thousands during northbound migratory movements along the coast in late June and July. It generally is much less numerous during southbound migrations in August and September when it is often outnumbered by the Wandering Glider. Despite its abundance as a migrant, it is not often seen at freshwater wetlands and was recorded on only four surveys during this project. Additionally, no evidence of breeding was noted, though it undoubtedly breeds with some regularity within the seashore. It breeds in very small, temporary wetlands, resulting in it being poorly sampled. The flight season extends from mid-May through early September, with a strong peak during the first half of July.

Eastern Amberwing (*Perithemis tenera*) (Say, 1839)

- Range: Southeastern Arizona, Minnesota, Ontario and Maine south to Durango
- Habitat: Vegetated lakes and ponds, especially where Pickerel Weed is present
- Number of CACO Sites: 10 (plus 7 historical)
- Number of Surveys: 48
- Average Number/Survey: 14
- High Count: 60

The diminutive Eastern Amberwing is a fairly common, though local, resident of well-vegetated kettle ponds within the seashore (Figure 114). Over 84% of the individuals recorded on the surveys were at just two sites in Wellfleet: Herring Pond and Turtle Pond. This species seems to have a particular affinity for sites where pickerel weed (*Pontederia cordata*) is present, though there is no obvious obligate relationship between the two species. The flight season is from late June through early September (Figure 115).

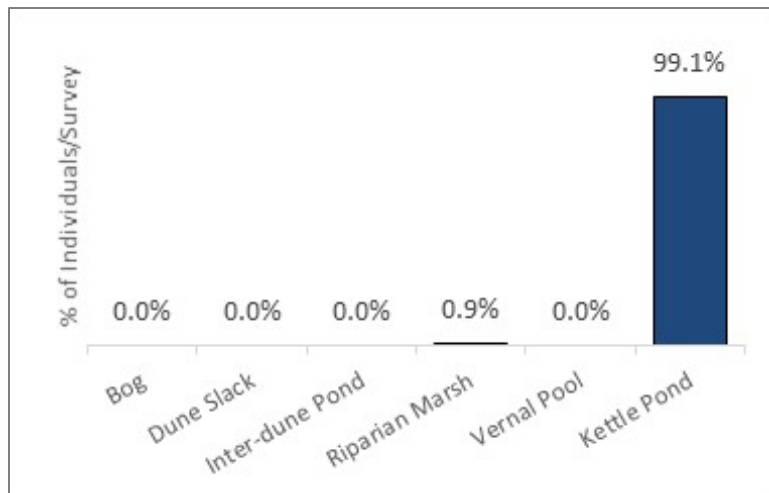


Figure 114. Eastern Amberwing distribution by habitats at Cape Cod National Seashore.

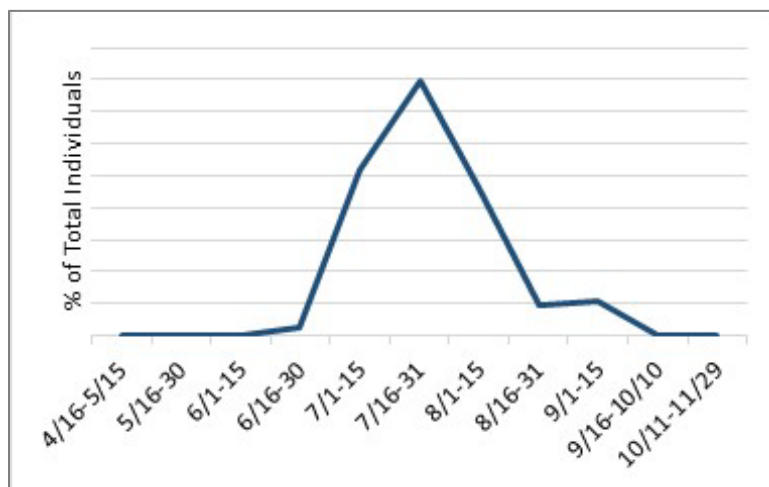


Figure 115. Eastern Amberwing flight season at Cape Cod National Seashore.

Common Whitetail (*Plathemis lydia*) (Drury, 1773)

- Range: Southern edge of Canada from British Columbia to Nova Scotia and south to California, Sonora, Nuevo León and northern Florida
- Habitat: Ponds and slow, vegetated streams; quite tolerant of degraded conditions
- Number of CACO Sites: 2 (plus 18 historical)
- Number of Surveys: 3
- Average Number/Survey: 1
- High Count: 2

Though a common and widespread species throughout much of southern New England, the Common Whitetail is surprisingly scarce within CACO and on the outer Cape in general, though it historically was more numerous. During these surveys it was recorded at only two sites (Figure 116), but

formerly was recorded at an additional 18 sites, suggesting a significant decline. In particular, it was recorded frequently at the large vernal pool E09 in Eastham from 1994–2005 but was not found there on 20 surveys over the three years of this project. Common Whitetails are generalists and seem quite tolerant of degraded wetlands, so their apparent decline is puzzling. The recorded flight season runs from mid-June through mid-August (Figure 117).

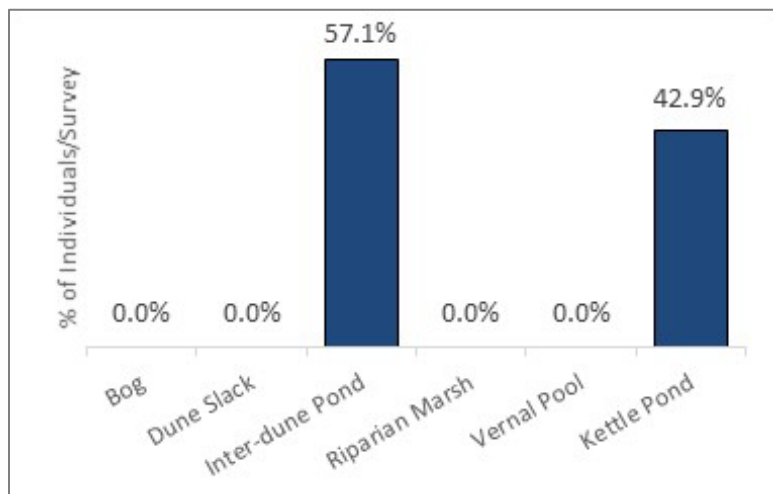


Figure 116. Common Whitetail distribution by habitats at Cape Cod National Seashore.

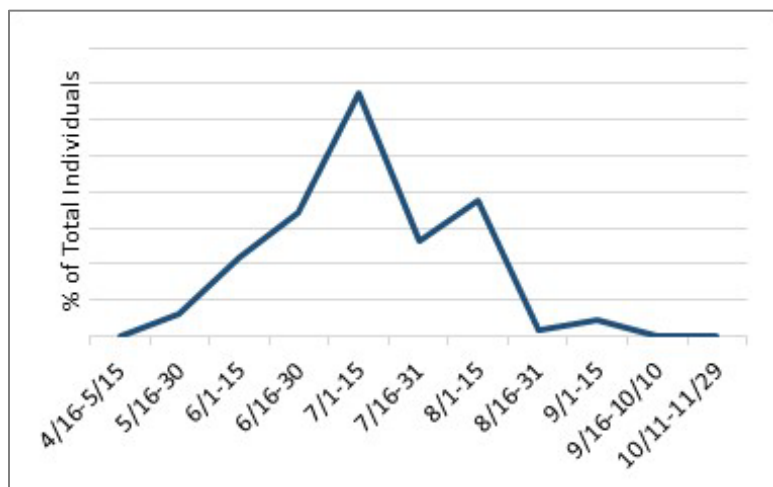


Figure 117. Common Whitetail flight season at Cape Cod National Seashore.

Saffron-winged Meadowhawk (*Sympetrum costiferum*) (Hagen, 1861)

- Range: British Columbia, Northwest Territories, Quebec and Newfoundland south to California, Colorado, Oklahoma, Missouri, Ohio and New Jersey
- Habitat: Sparsely vegetated, sandy-bottomed lakes and ponds
- Number of CACO Sites: 2 (plus 4 historical)
- Number of Surveys: 6

- Average Number/Survey: 7
- High Count: 12

The Saffron-winged Meadowhawk is a scarce and very local inhabitant within CACO, as it is elsewhere on Cape Cod, recorded at only two sites during these surveys: Horseleeche Pond in Truro and Great Pond in Wellfleet (Figure 118). It is also known historically from Duck and Gull ponds in Wellfleet. All of these sites are very clear, sandy-bottomed ponds. Like others in its genus, it has a rather late flight season, on the wing from late July through late September (Figure 119).

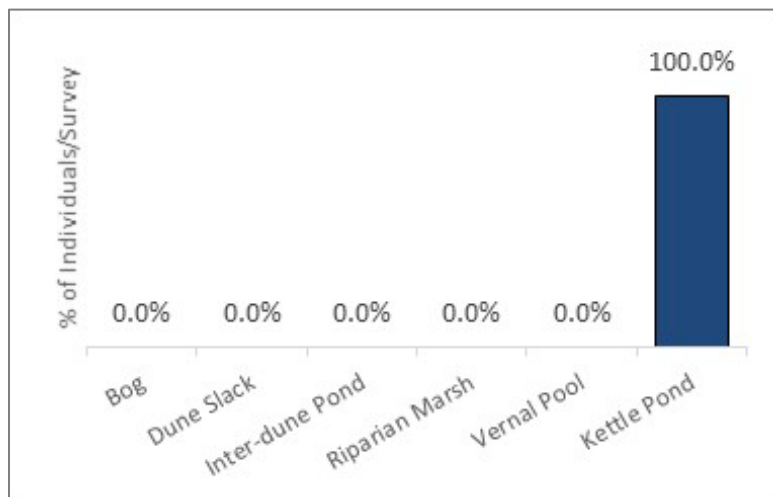


Figure 118. Saffron-winged Meadowhawk distribution by habitat at Cape Cod National Seashore.

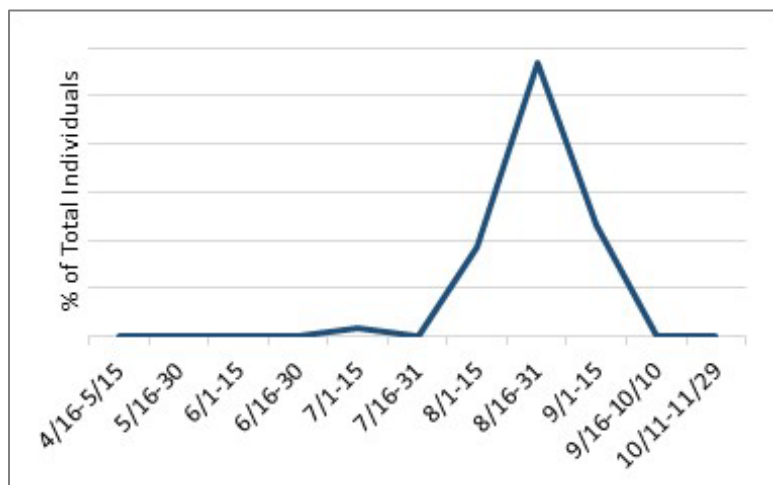


Figure 119. Saffron-winged Meadowhawk flight season at Cape Cod National Seashore.

Ruby Meadowhawk (*Sympetrum rubicundulum*) (Say, 1839)

- Range: Manitoba, Ontario and Quebec south to Colorado, Missouri and Georgia; isolated records in Montana and western Wyoming

- Habitat: Variety of well-vegetated ponds and pools
- Number of CACO Sites: 39 (plus 14 historical)
- Number of Surveys: 150
- Average Number/Survey: 23
- High Count: 240

The Ruby Meadowhawk is one of the most common and widespread odonates within CACO, recorded at all but two of the 41 sites surveyed. Although recorded in all of the six habitat types, the vast majority of individuals (93%) were at vernal pools, dune slacks, and bogs (Figure 120). It frequently is found in upland areas as well, often some distance from any wetland. It has a rather late, but lengthy flight season, extending from mid-June through late October (Figure 121); it is the first of the meadowhawks to emerge in the early summer.

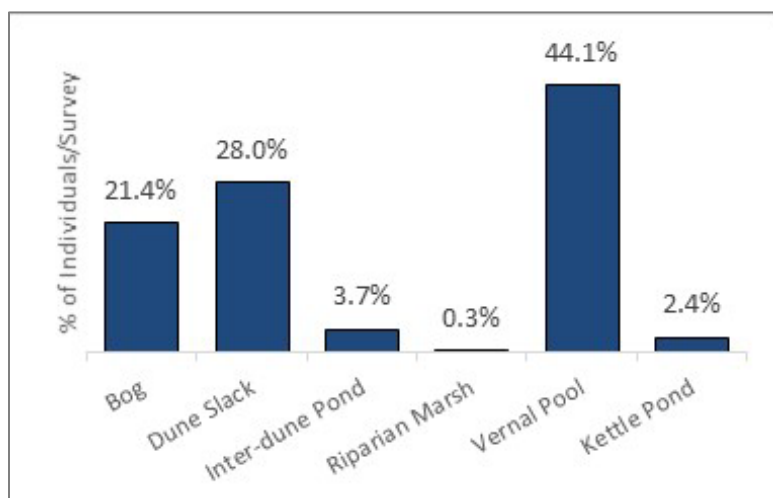


Figure 120. Ruby Meadowhawk distribution by habitats at Cape Cod National Seashore.

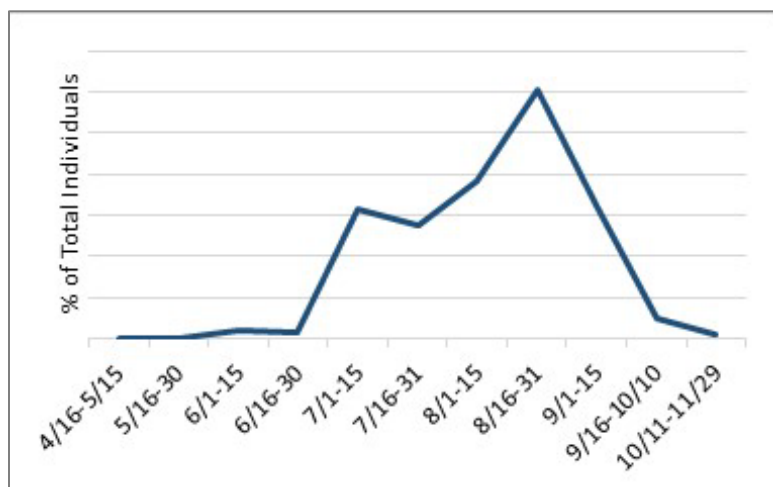


Figure 121. Ruby Meadowhawk flight season at Cape Cod National Seashore.

Band-winged Meadowhawk (*Sympetrum semicinctum*) (Say, 1839)

- Range: Southern British Columbia to Nova Scotia, south to California, New Mexico, Oklahoma, Alabama and North Carolina
- Habitat: Grassy marshes and seepage areas
- Number of CACO Sites: 3
- Number of Surveys: 6
- Average Number/Survey: 6
- High Count: 16

The Band-winged Meadowhawk is a scarce and very local species within CACO, recorded at just three sites; it was unknown within the park prior to this survey, likely due to a lack of effort within the appropriate habitat at the appropriate season (late summer). All but one of the records are from the Herring River in Wellfleet, where freshly emerged individuals were present in seepage areas adjacent to the river. The limited data suggest a flight season from mid-July through early September.

Autumn Meadowhawk (*Sympetrum vicinum*) (Hagen, 1861)

- Range: Southern British Columbia, Manitoba, Ontario and Prince Edward Island south to northern California, Texas and northwestern Florida; scarce in or absent from most of northern Great Plains, Rocky Mountains and Great Basin
- Habitat: Well-vegetated ponds; vernal pools
- Number of CACO Sites: 35 (plus 6 historical)
- Number of Surveys: 94
- Average Number/Survey: 8
- High Count: 75

The appropriately named Autumn Meadowhawk is a common and widespread species, recorded at 35 sites during this survey. The majority of individuals (61%) were at kettle ponds, with lesser numbers at vernal pools (Figure 122). Like the Ruby Meadowhawk, it wanders widely and is frequently seen in upland areas far from water. It has the latest flight season of any local odonate, emerging in late July and on the wing into late November (Figure 123), apparently able to survive exposure, at least briefly, to below freezing temperatures.

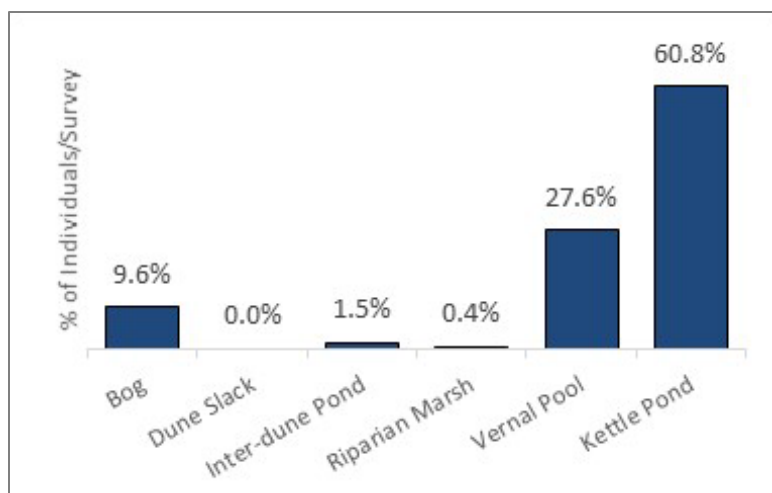


Figure 122. Autumn Meadowhawk distribution by habitats at Cape Cod National Seashore.

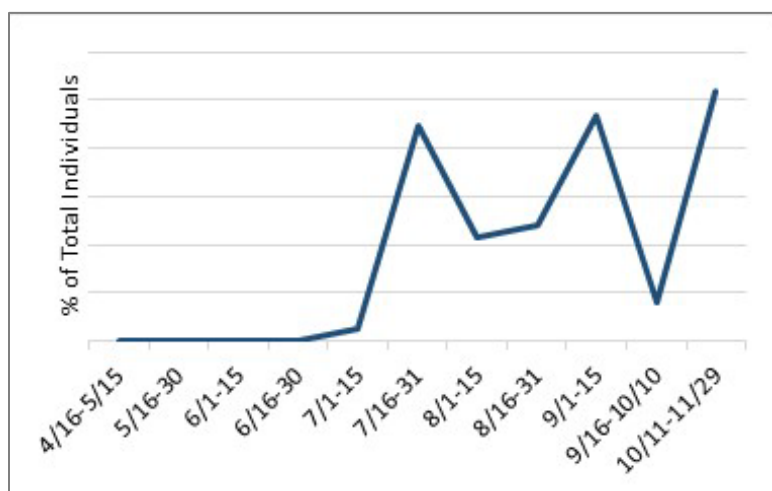


Figure 123. Autumn Meadowhawk flight season at Cape Cod National Seashore.

Striped Glider (*Tamea calverti*) (Muttkowski, 1910)

- Range: Southern California, Arizona, Oklahoma and Florida south to Argentina, also West Indies; records of vagrants scattered across North America north to Nebraska, Iowa, Wisconsin, Michigan, New York and Massachusetts
- Habitat: Tropical ponds and pools
- Number of CACO Sites: 1 historical

The only record of this tropical vagrant within CACO is of a single male seen well, but not captured or photographed, at Fort Hill in Eastham on 12 July 1997. This represented the first record for the state; it has subsequently been found on three additional occasions in the state, once on Cape Cod and twice inland. Like its congeners, it spends a lot of time on the wing, making identification challenging, so it may occur somewhat more frequently than the only record suggests.

Carolina Saddlebags (*Tramea carolina*) (Linnaeus, 1763)

- Range: Kansas, Wisconsin, Ontario and Nova Scotia south to Texas and Florida, also Bermuda
- Habitat: Vegetated, mostly sandy-bottomed ponds
- Number of CACO Sites: 22 (plus 10 historical)
- Number of Surveys: 111
- Average Number/Survey: 2
- High Count: 15

The Carolina Saddlebags is a fairly common resident and migrant in CACO. The majority (78%) were at kettle ponds and vernal pools, though it also was seen frequently at inter-dune ponds (Figure 124). As with all migratory species, distinguishing residents from transients is problematic, though evidence of breeding for this distinctive dragonfly was noted at 13 sites. The flight season is from early June through mid-September (Figure 125).

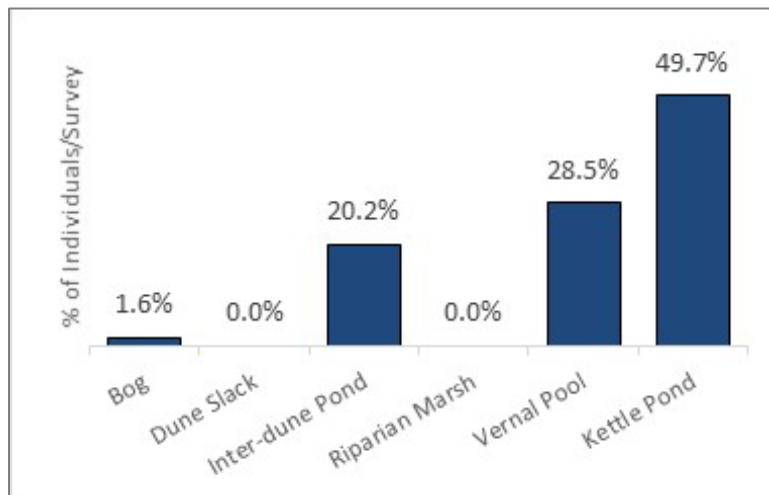


Figure 124. Carolina Saddlebags distribution by habitats at Cape Cod National Seashore.

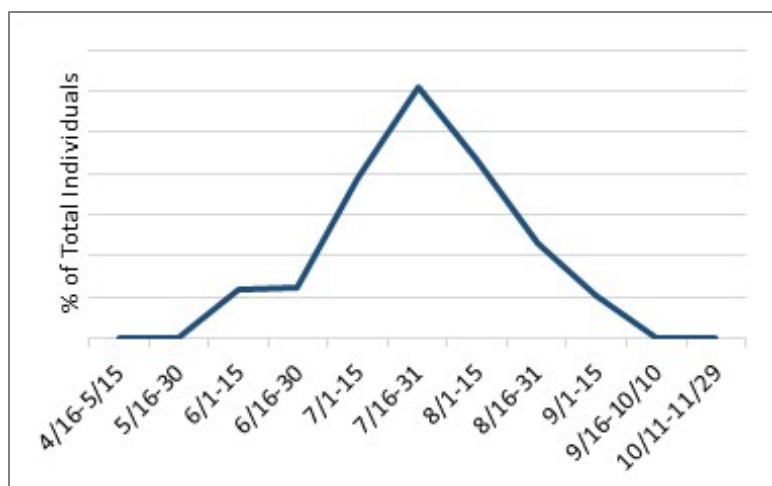


Figure 125. Carolina Saddlebags flight season at Cape Cod National Seashore.

Black Saddlebags (*Tamea lacerata*) (Hagen, 1861)

- Range: Southwestern British Columbia, Idaho, Colorado, South Dakota, Ontario and Nova Scotia south to Baja California Sur, Yucatan and Florida; also, Bermuda, Bahamas, Cuba and Hawaii
- Habitat: Vegetated ponds and pools
- Number of CACO Sites: 4 (plus 8 historical)
- Number of Surveys: 5
- Average Number/Survey: 1
- High Count: 2

The Black Saddlebags is an uncommon migrant, most often encountered among migratory movements along the outer beaches. It was recorded only rarely on the surveys, in several habitats (Figure 126), and the only suggestion of breeding within CACO was a tandem pair observed at a vernal pool (E09) in Eastham. The flight season runs from early June through late August (Figure 127).

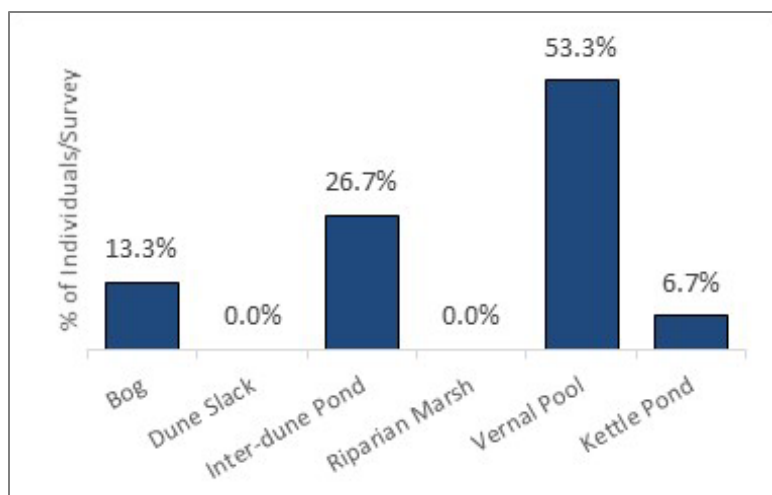


Figure 126. Black Saddlebags distribution by habitats at Cape Cod National Seashore.

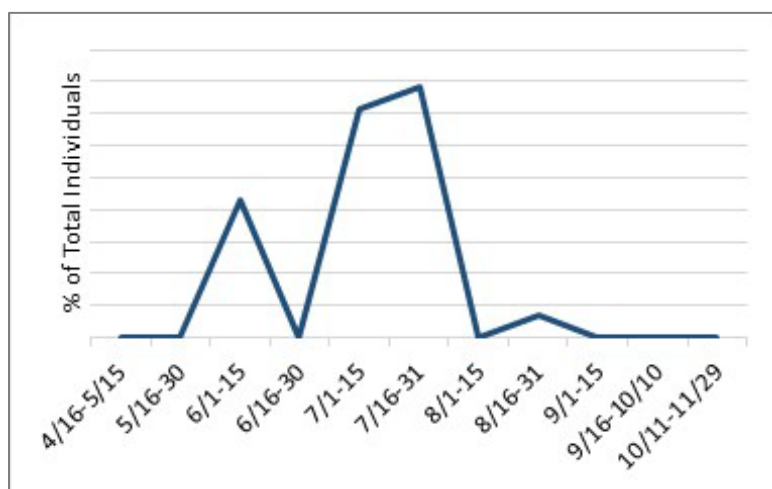


Figure 127. Black Saddlebags flight season at Cape Cod National Seashore.

Other Species

Problematic Species

Spotted darner species (*Boyeria* sp.)

Two tables in Colburn (2005, pages 14 & 22) list unidentified *Boyeria*, but no specifics are provided, though the record(s) presumably are based upon collected nymph(s). The Fawn Darner (*B. vinosa*), one of only two species of *Boyeria* in North America, is the only species recorded (or likely) on Cape Cod, though there are very few records from the peninsula. Both species of spotted darners are primarily lotic species, though the Fawn Darner occasionally occurs on large, wind-swept lakes. If resident within CACO, as the presence of one or more nymphs, if correctly identified, would indicate, Gull Pond is the most likely site (and was included in Colburn's study).

Brush-tipped Emerald (*Somatochlora walshii*) (Scudder, 1866)

Carpenter (1990) reported two sight records of this species in Truro but given the difficulty of identifying this species in the field, the unlikely nature of the species' occurrence here, and the lack of a specimen or photograph, the reports are best considered unconfirmed.

White-faced Meadowhawk (*Sympetrum obtrusum*) (Hagen, 1867)

Colburn (2005) reported numbers of nymphs, and on at least one occasion teneral, of this species from several vernal pools in Eastham during the period 1994 - 2000. This species is otherwise unrecorded on Cape Cod, and the nymphs are nearly identical to those of the very common Ruby Meadowhawk (Needham et al. 2014). Even adults can be extremely difficult to distinguish, often requiring in-hand examination. Additionally, Nikula and others visited some of these vernal pools on numerous occasions during the same time frame but recorded only Ruby Meadowhawks (many examined in the hand). Thus, it seems likely the nymphs reported by Colburn were misidentified.

Appendix 3. Sex Ratios and Breeding Activity

Whenever possible the sex of individuals was recorded. Overall, we were able to sex just over 75% of all the odonates recorded (Table 37). The percentage for dragonflies was 83% and damselflies just under 71%, not surprising given the former's larger size and more conspicuous habits. Female odonates in general spend very little time at the wetland breeding sites (Corbet 1999), appearing only when ready to breed. Our results were very consistent with this tendency, though there was considerable difference between the two suborders, with less than 5% of dragonflies sexed being females, compared with almost 22% of damselflies. Two species of forktails (genus *Ischnura*), Fragile Forktail and Eastern Forktail, stand out for the high percentage of females recorded (54%). However, it is extremely difficult to distinguish between the females of the two species and most were recorded as simply "forktail species," (Table 38). For reasons that are not clear, females of these two species frequently outnumber the males at breeding sites, in sharp contrast to any other odonate taxon in the Northeast.

Table 37 Observed sex ratios by suborder and family at Cape Cod National Seashore.

Families	Total	# of Males	# of Females	Total Sexed	% Sexed	% Female
Calopterygidae	32	25	7	32	100.0%	21.9%
Lestidae	8098	3140	330	3470	42.9%	9.5%
Coenagrionidae	25391	15354	4816	20170	79.4%	23.9%
Zygoptera Totals	33521	18519	5153	23672	70.6%	21.8%
Aeshnidae	850	652	41	693	81.5%	5.9%
Gomphidae	110	108	0	108	98.2%	0.0%
Macromiidae	3	3	0	3	100.0%	0.0%
Corduliidae	78	47	7	54	69.2%	13.0%
Libellulidae	19167	15888	735	16623	86.7%	4.4%
Anisoptera sp.?	12	0	0	0	0.0%	0.0%
Anisoptera Totals	21006	16714	783	17497	83.3%	4.5%
undetermined	786	16	0	16	2.0%	0.0%
Totals	54527	35233	5936	41169	75.5%	14.4%

Table 38. Observed sex ratios by species at Cape Cod National Seashore.

Species	Total	# of Males	# of Females	Total Sexed	% Females
Spotted Spreadwing	16	13	2	15	13.3%
Northern Spreadwing	203	183	2	185	1.1%
Amber-winged Spreadwing	647	522	13	535	2.4%

Table 38 (continued). Observed sex ratios by species at Cape Cod National Seashore.

Species	Total	# of Males	# of Females	Total Sexed	% Females
Sweetflag Spreadwing	4159	1065	129	1194	10.8%
Elegant Spreadwing	63	47	3	50	6.0%
Slender Spreadwing	248	159	68	227	30.0%
Swamp Spreadwing	1263	1028	59	1087	5.4%
Ebony Jewelwing	32	25	7	32	21.9%
Eastern Red Damsel	19	1	3	4	75.0%
Variable Dancer	1633	1101	103	1204	8.6%
Taiga Bluet	2	2	0	2	0.0%
Northern Bluet	667	592	9	601	1.5%
Azure Bluet	1079	902	3	905	0.3%
Familiar Bluet	617	360	12	372	3.2%
Attenuated Bluet	399	194	19	213	8.9%
Atlantic Bluet	5376	4820	8	4828	0.2%
Skimming Bluet	3084	2235	180	2415	7.5%
New England Bluet	118	98	0	98	0.0%
Little Bluet	733	640	1	641	0.2%
Pine Barrens Bluet	308	225	1	226	0.4%
Orange Bluet	158	102	31	133	23.3%
Slender Bluet	67	45	2	47	4.3%
Vesper Bluet	8	2	4	6	66.7%
Citrine Forktail	33	26	6	32	18.8%
Lilypad Forktail	396	285	83	368	22.6%
Fragile Forktail	721	616	85	701	12.1%
Rambur's Forktail	1	1	0	1	0.0%
Eastern Forktail	5194	1550	3149	4699	67.0%
Sphagnum Sprite	2365	1203	84	1287	6.5%
Canada Darner	2	2	0	2	0.0%
Mottled Darner	92	86	1	87	1.1%
Spatterdock Darner	6	6	0	6	0.0%
Black-tipped Darner	58	21	25	46	54.3%
Green-striped Darner	3	3	0	3	0.0%
Common Green Darner	522	448	13	461	2.8%
Comet Darner	19	18	1	19	5.3%
Harlequin Darner	8	8	0	8	0.0%
Lancet Clubtail	30	30	0	30	0.0%

Table 38 (continued). Observed sex ratios by species at Cape Cod National Seashore.

Species	Total	# of Males	# of Females	Total Sexed	% Females
Common Sanddragon	80	78	0	78	0.0%
Swift River Cruiser	3	3	0	3	0.0%
Petite Emerald	8	7	1	8	12.5%
Common Baskettail	44	18	6	24	25.0%
Prince Baskettail	24	21	0	21	0.0%
Pennant Species	4	0	0	0	
Calico Pennant	1309	869	136	1005	13.5%
Halloween Pennant	89	67	17	84	20.2%
Banded Pennant	50	30	3	33	9.1%
Martha's Pennant	581	438	32	470	6.8%
Eastern Pondhawk	1883	1664	104	1768	5.9%
Seaside Dragonlet	1	1	0	1	0.0%
Blue Corporal	28	27	1	28	3.6%
White Corporal	167	155	2	157	1.3%
Frosted Whiteface	2	2	0	2	0.0%
Dot-tailed Whiteface	482	475	1	476	0.2%
Golden-winged Skimmer	1	1	0	1	0.0%
Bar-winged Skimmer	12	11	0	11	0.0%
Spangled Skimmer	119	110	6	116	5.2%
Slaty Skimmer	3197	3088	39	3127	1.2%
Needham's Skimmer	12	10	1	11	9.1%
Twelve-spotted Skimmer	15	15	0	15	0.0%
Four-spotted Skimmer	6	1	0	1	0.0%
Painted Skimmer	358	321	9	330	2.7%
Great Blue Skimmer	3	3	0	3	0.0%
Elfin Skimmer	6	4	1	5	20.0%
Blue Dasher	4760	4596	109	4705	2.3%
Wandering Glider	3	0	0	0	–
Spot-winged Glider	28	0	0	0	–
Eastern Amberwing	665	611	41	652	6.3%
Common Whitetail	4	4	0	4	0.0%
Saffron-winged Meadowhawk	39	29	1	30	3.3%
Ruby Meadowhawk	3476	2505	141	2646	5.3%
Band-winged Meadowhawk	36	6	3	9	33.3%
Autumn Meadowhawk	798	300	78	378	20.6%

Table 38 (continued). Observed sex ratios by species at Cape Cod National Seashore.

Species	Total	# of Males	# of Females	Total Sexed	% Females
Carolina Saddlebags	277	220	3	223	1.3%
Black Saddlebags	6	3	0	3	0.0%

Evidence of breeding was recorded whenever observed during the surveys and was categorized as one of four behaviors: tandem pairs; ovipositing females; ovipositing pair; or tenerals. Only the last category provides proof of successful breeding at a site. Unfortunately, tenerals, especially among damselflies, are often very difficult to identify, so most (70%) were identified only to genus, family, or suborder; of these, 97% were damselflies (Table 39).

Table 39. Observed breeding activity at Cape Cod National Seashore.

Species	Tandem Pairs	Ovipositing Females	Ovipositing Pairs	Tenerals	Sum Of Breeding Evidence
damselfly species	0	0	0	769	769
spreadwing species	30	1	0	1324	1355
Spotted Spreadwing	0	0	0	8	8
Northern Spreadwing	9	0	0	1	10
Amber-winged Spreadwing	45	2	8	14	69
Sweetflag Spreadwing	1271	3	197	66	1537
Elegant Spreadwing	5	2	0	1	8
Slender Spreadwing	5	6	0	31	42
Swamp Spreadwing	70	0	15	7	92
Ebony Jewelwing	0	0	0	0	0
Eastern Red Damselfly	2	0	0	6	8
Variable Dancer	274	0	21	4	299
Taiga Bluet	0	0	0	0	0
bluet species	29	1	1	6	37
Northern Bluet	42	3	0	0	45
Azure Bluet	87	0	0	0	87
Familiar Bluet	123	0	8	3	134
Attenuated Bluet	97	0	0	24	121
Atlantic Bluet	264	0	16	1	281
Skimming Bluet	323	0	4	1	328
New England Bluet	10	0	0	0	10
Little Bluet	62	0	0	0	62
Pine Barrens Bluet	40	0	1	0	41

Table 39 (continued). Observed breeding activity at Cape Cod National Seashore.

Species	Tandem Pairs	Ovipositing Females	Ovipositing Pairs	Tenerals	Sum Of Breeding Evidence
Orange Bluet	14	2	1	1	18
Slender Bluet	8	0	2	0	10
Vesper Bluet	0	0	0	2	2
forktail species	0	45	0	843	888
Citrine Forktail	0	0	0	1	1
Lilypad Forktail	25	0	0	0	25
Fragile Forktail	9	0	1	4	14
Rambur's Forktail	0	0	0	0	0
Eastern Forktail	37	24	7	119	187
sprite species	3	0	0	2	5
Sphagnum Sprite	338	0	6	502	846
dragonfly species	0	0	0	5	5
darner species	0	0	0	4	4
mosaic darner species	1	6	0	0	7
Canada Darner	0	0	0	0	0
Mottled Darner	0	5	0	1	6
Spatterdock Darner	0	0	0	0	0
Black-tipped Darner	0	31	0	0	31
Green-striped Darner	0	0	0	0	0
Common Green Darner	15	4	8	5	32
Comet Darner	0	0	0	0	0
Harlequin Darner	0	0	0	0	0
Lancet Clubtail	0	0	0	0	0
Common Sanddragon	1	0	0	0	1
Swift River Cruiser	0	0	0	0	0
emerald species	0	0	0	0	0
Petite Emerald	0	0	0	0	0
Common Baskettail	0	4	0	0	4
Prince Baskettail	0	0	0	0	0
skimmer species	0	2	0	2	4
Pennant Species	0	2	1	0	3
Calico Pennant	98	17	56	33	204
Halloween Pennant	7	1	3	0	11
Banded Pennant	1	3	4	1	9
Martha's Pennant	22	13	34	5	74

Table 39 (continued). Observed breeding activity at Cape Cod National Seashore.

Species	Tandem Pairs	Ovipositing Females	Ovipositing Pairs	Tenerals	Sum Of Breeding Evidence
Eastern Pondhawk	15	37	5	9	66
Seaside Dragonlet	0	0	0	0	0
Blue Corporal	0	0	0	0	0
White Corporal	0	8	1	0	9
Frosted Whiteface	0	0	0	0	0
Dot-tailed Whiteface	1	2	0	0	3
Golden-winged Skimmer	0	0	0	0	0
Bar-winged Skimmer	0	1	0	0	1
Spangled Skimmer	1	2	1	4	8
Slaty Skimmer	22	31	1	0	54
Needham's Skimmer	0	0	0	0	0
Twelve-spotted Skimmer	0	0	0	0	0
Four-spotted Skimmer	0	0	0	5	5
Painted Skimmer	3	11	0	10	24
Great Blue Skimmer	0	0	0	0	0
Elfin Skimmer	0	0	0	3	3
Blue Dasher	15	19	1	17	52
Wandering Glider	0	0	0	0	0
Spot-winged Glider	2	0	0	0	2
Eastern Amberwing	8	10	1	0	19
Common Whitetail	0	0	0	0	0
meadowhawk species	62	0	12	83	157
Saffron-winged Meadowhawk	1	0	2	3	6
Ruby Meadowhawk	329	2	3	175	509
Band-winged Meadowhawk	3	1	0	20	24
Autumn Meadowhawk	75	0	45	210	330
saddlebag species	1	0	0	0	1
Carolina Saddlebags	20	0	9	0	29
Black Saddlebags	1	0	0	0	1
Totals	3926	301	475	4335	9037

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