Section 6 Federal Aid to Endangered Species
E-1-36
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Endangered & Threatened Wildlife Conservation

Final Report, Project Year
September 1, 2013 – August 31, 2014

NJ Department of Environmental Protection

DIVISION OF FISH AND WILDLIFE
ENDANGERED AND NONGAME SPECIES PROGRAM
P.O. BOX 420
TRENTON, NJ 08625

NEW JERSEY DIVISION OF
Fish and Wildlife

Conserve Wildlife

PERFORMANCE REPORT

STATE: New Jersey **PROJECT NUMBER:** E-1-36

PROJECT TYPE: Research and/or Management

PROJECT TITLE: Endangered and Threatened Wildlife Conservation

STUDY NUMBER AND TITLE: IV - Vertebrate Wildlife Conservation

JOB NUMBER AND TITLE: 2-B Piping Plover Population Survey

PERIOD COVERED: September 1, 2013 to August 31, 2014

PREPARED BY: Christina Davis and Todd Pover

JOB OBJECTIVE: To determine statewide and site specific piping plover populations, nesting success, and productivity.

SUMMARY: The New Jersey Division of Fish and Wildlife (NJDFW)-Endangered and Nongame Species Program (ENSP) monitored over half (12 or 57%) of the state's 21 active piping plover nesting sites. However, those sites accounted for only about one in five (21%) of the state's overall nesting pairs (92). NJDFW regularly monitored 8 additional sites and several others less regularly, although no nests were found at those sites. Other sites in the state were monitored by cooperators including the National Park Service (Gateway National Recreation Area-Sandy Hook Unit); the U.S. Fish and Wildlife Service-Edwin B. Forsythe National Wildlife Refuge (Holgate and Little Beach) and Cape May National Wildlife Refuge (Two-Mile Beach and Coast Guard LSU); the U.S Coast Guard (Coast Guard LSU and Cape May Training Center); The Nature Conservancy (Cape May Migratory Bird Refuge), and the Conserve Wildlife Foundation of New Jersey (various sites throughout the state in conjunction with ENSP). NJDFW worked closely with those cooperators to establish and ensure standardized monitoring and data collection protocols. The cooperators provided data on population and reproductive success from their sites to NJDFW so that we could compile and analyze nesting data for the entire state.

A total of 92 pairs of piping plovers nested in New Jersey in 2014, a 15% drop from 2013 (108 pairs) and the lowest level recorded since federal listing in 1986. Furthermore, the number of nesting pairs has been below the long-term state average since federal listing (118 pairs) for 8 of the past 10 years, suggesting a sustained population decrease. Sandy Hook remained the stronghold in the state with 47 pairs, representing just over half (51%) of the statewide total. The region consisting of Holgate, Little Beach (both part of Edwin B. Forsythe NWR), and North Brigantine Natural Area accounted for 29 pairs, nearly a third (32%) of the state total. Cape May County has seen a precipitous drop in pairs over the past decade, falling from 43 pairs in 2004 to just 11 pairs in 2014.

The number of active nesting sites statewide was the same in 2014 as 2013 (21 sites), but still well below the peak number of sites recorded in the state (30 sites in 2004 and 2005).

Statewide pair nest success (pairs that hatch at least one chick) was relatively high (75%) in 2014, above last year's rate (67%), which was the same as the average for the years since federal listing.

Statewide productivity increased significantly in 2014 compared to 2013 (1.36 vs. 0.85 fledglings/pair), one of the highest rates on record in New Jersey since federal listing and above the range-wide level (1.245 fledglings/pair) believed necessary to maintain a stationary population (USFWS 1996).

SIGNIFICANT DEVIATIONS: None.

RECOMMENDATIONS: Continue intensive monitoring of populations and reproductive success.

BACKGROUND

The piping plover (*Charadrius melodus)* was listed as endangered by the New Jersey Department of Environmental Protection in 1979. In January 1986, the U.S. Fish and Wildlife Service (USFWS) included the piping plover on the Federal Endangered Species list and classified the Atlantic coast population as "Threatened". ENSP has directed local and statewide assessment of population trends since 1976. Statewide surveys were conducted in 1980 and 1984-2014, with limited surveys in 1976 and 1983.

PROCEDURES

Starting in March, NJDFW began visiting coastal beaches to assess the suitability of nesting habitat. Nesting activity was then monitored at all identified nesting sites (with emphasis on areas where nesting had occurred in recent years) following nesting survey guidelines published in the Atlantic Coast Piping Plover Recovery Plan (USFWS, 1996). Starting in mid-April, NJDFW visited nesting areas at least 3 times a week, and typically more frequently, to search for active nests and pairs on territories. Once located, nests, and then broods, were checked 3 to 5 times a week to monitor breeding progress and outcome. Cooperators throughout the state followed a similar protocol, although the Monmouth County sites, Holgate, Little Beach, Strathmere, Avalon Dunes, and Stone Harbor Point, were monitored near daily in 2014. In addition to regular monitoring, a statewide, date-restricted count was conducted between June 1 and 9. All sites where piping plovers had nested the past 10 years (if suitable habitat still existed), as well as any newly created habitat that could potentially support nesting plovers were checked using methodology established by the USFWS (1996) for the Atlantic coast breeding population. NJDFW-ENSP adjusted the date-restricted count to include pairs discovered after the survey window that, based on nesting phrenology, were present during the survey period. Additionally, because NJDFW-ENSP surveyed individual sites more than once during the census period, identification of pairs at NJDFW surveyed sites was based on breeding and territorial behavior noted during the entire survey period (rather than from one specific visit).

FINDINGS

Ninety-two (92) pairs of piping plovers nested in New Jersey in 2014, a 15% decrease compared to 2013 (108 pairs). Except for moderate spikes in 2007 and 2012, the population trend has been flat over the past 10 years (Figure 1). Furthermore, the number of nesting pairs has been below the long-term average since federal listing (118 pairs) in 8 of the last 10 years and substantially below the peak count of 144 pairs in 2003.

The total number of adults recorded for the entire nesting season (186) was nearly the same as the count during the date-restricted survey conducted June 1-9 (184). The number of pairs tallied during the entire nesting season (92) was just slightly higher than the pairs recorded during the date-restricted census (86). Typically in New Jersey, the date-restricted pair counts are well below the final season count, as well as the total adults to a lesser degree. The change this year is the result of a more intensive and comprehensive survey effort at Holgate and Little Beach during the date-restricted survey and throughout the breeding season – in previous years most of the difference between the two survey results was due to variations in the survey protocols used by the USFWS – Edwin B. Forsythe NWR.

As has been the case in recent years, Northern Monmouth County, as a region, continued to account for the largest percentage of pairs in the state (49 pairs or 53% of the statewide total). Nearly all of those pairs nested at Sandy Hook (47 pairs or 51% of the statewide total). The region comprised of Holgate, Little Beach, and North Brigantine Natural Area accounted for the next highest concentration of nesting pairs (29 pairs or 32% of the statewide total). Cape May County, the southernmost region of the state, consisting of Ocean City to Cape May Point, continued its long-term downward population trend, with just 11 pairs in 2014 compared to 43 in 2004.

Looking at the individual sites, there were mostly minor fluctuations in pairs in 2014 versus 2013. The major exception was Little Beach, which decreased to 14 pairs in 2014 (vs. 23 in 2013). However, it is believed at least some of that drop is the result of increases in survey intensity and quality in 2014 of this relatively remote location, which resulted in more accurate tracking of nests and pairs. Stone Harbor Point and North Brigantine Natural Area continued a long-term downward abundance trend, hosting 4 and 3 active pairs, respectively, in 2014, down from peaks of 17 pairs in 2007 and 2003, respectively.

Pairs nested at 21 sites, the same as in 2013, but well below the peak count of 30 sites recorded in both 2004 and 2005. NJDFW monitored 12 of the active nesting sites (57% of the sites statewide), accounting for 19 nesting pairs (21% of the nesting pairs statewide). NJDFW typically monitors about half of the state's active sites (i.e., sites where nests are located), but the total number of active pairs monitored at NJDFW sites continued to drop dramatically in 2014, down from 70 pairs just over a decade ago in 2003. NJDFW also regularly monitored 8 other potential breeding sites with historic nesting records and/or highly suitable habitat, as well as several other sites; however none of those sites yielded nests.

Statewide pair-nest success (the percentage of pairs that successfully hatch at least one nest) was relatively high this year (75%), above last year's rate (67%) and the average for the period since federal listing (67%). This higher than average rate was driven by the Northern Monmouth County region (49 pairs) and Holgate (12 pairs), which had exceptional success with nearly all of their pairs hatching young (90% and 92%, respectively). Looking at just NJDFW-monitored sites, pair-nest success was notably below last year (47% in 2014 vs. 59% in 2013) and the average for NJDFW-monitored sites for the period since federal listing (66%).

The statewide fledgling rate, which includes data collected and provided by all the state cooperators, was 1.36 fledglings per pair. This represents a significant increase from 2013 (0.85 fledglings/pair) and was one of the highest statewide levels recorded since federal listing (Figure 1). Although still below the 1.50 fledglings per pair federal recovery goal, it was above the 1.245 fledglings per pair range-wide threshold for population maintenance established in the USFWS Recovery Plan for the Atlantic Coast population of piping plovers (USFWS, 1996). Productivity at NJDFW-monitored sites rose slightly in 2014 (0.74 fledglings/pair for 19 pairs) compared to 2013 (0.69 fledglings/pair for 29 pairs), but it

remained low and those sites collectively, which represent some of the more heavily recreated and disturbed sites, continued to be less productive than the state as a whole.

As is typical, productivity varied considerably by individual site and region. The Northern Monmouth County region fledged 1.43 chicks per pair (49 pairs), nearly approaching the federal recovery goal of 1.50 chicks fledged per pair. This strong regional trend is largely the result of robust productivity at Sandy Hook (1.40 fledglings/pair for 47 pairs). Within Sandy Hook, the North Beach site remained particularly productive (1.86 fledglings/pair based on 14 pairs), with adjacent North Gunnison also recording strong results in 2014 (1.63 fledglings/pair based on 8 pairs). The Holgate, Little Beach, and North Brigantine Natural Area region saw the greatest gain in productivity in 2014; its rate of 1.69 fledglings per pair (29 pairs) exceeded the federal recovery goal and nearly tripled the output recorded in 2013 (0.59 fledglings/pair). Of particular note, Holgate fledged 2.33 chicks per pair (12 pairs); to a large degree, it is believed this high rate was the result of pairs shifting their nesting at the site into productive overwash habitat created by Superstorm Sandy. The combined Edwin B. Forsythe NWR sites of Holgate and Little Beach produced 1.73 fledglings per pair (26 pairs). The Cape May County region continued its recent trend of very low productivity; in 2014 no chicks fledged across the entire region from Ocean City to Cape May Point (11 pairs), the first time since federal listing that the entire region failed to successfully fledge chicks.

DISCUSSION AND CONCLUSIONS

New Jersey's statewide piping plover breeding population reached a historic low of 92 pairs in 2014, as viewed over the period since federal listing. Furthermore, it has been below average in 8 of the last 10 years after reaching a peak of 144 pairs in 2003. Those declines are largely the result of persistent poor productivity at a number of the state's sites, especially the municipal beaches and state park sites, where recreational activities and disturbance are highest. Without strong productivity at Sandy Hook, which has accounted for 40-50% of the state's total pairs in the past five years, the population decline might be even greater. Continued strong productivity at Sandy Hook is critical overall, but will not lead to statewide recovery alone.

Of particular concern, NJDFW-monitored sites, again those municipal and state sites that are most heavily impacted by human disturbance and proximity to predator activity, have shown dramatic declines over the past decade or so, from 70 pairs (and 49% of the statewide total) in 2003 to just 19 pairs (and 21% of the statewide total) in 2014. Although these sites will continue to remain the greatest challenge in the state in terms of site management and achieving high productivity, reversing this decline is essential to recovering the statewide population. Increasing pairs and productivity at the state-owned sites, notably North Brigantine Natural Area and Cape May Point State Park (in conjunction with The Nature Conservancy's Cape May Meadows), should be an especially high priority. Finally, Holgate and Little Beach, the units of the Edwin B. Forsythe NWR where little to no human disturbance occurs and some of the most highly suitable habitat conditions exist, should also be a high priority to maximize productivity and increase pair totals. A robust recovery would ideally be geographically distributed across the state, but given the challenges at the recreational beaches, significant resources need to be directed to those sites with the highest potential to increase our state's population.

Despite the alarming drop in breeding pairs in 2014, New Jersey recorded one of its highest levels of piping plover productivity (1.36 fledglings/pair) on record since federal listing and it was above the level believed necessary to increase the population. The high productivity was driven by strong fledgling

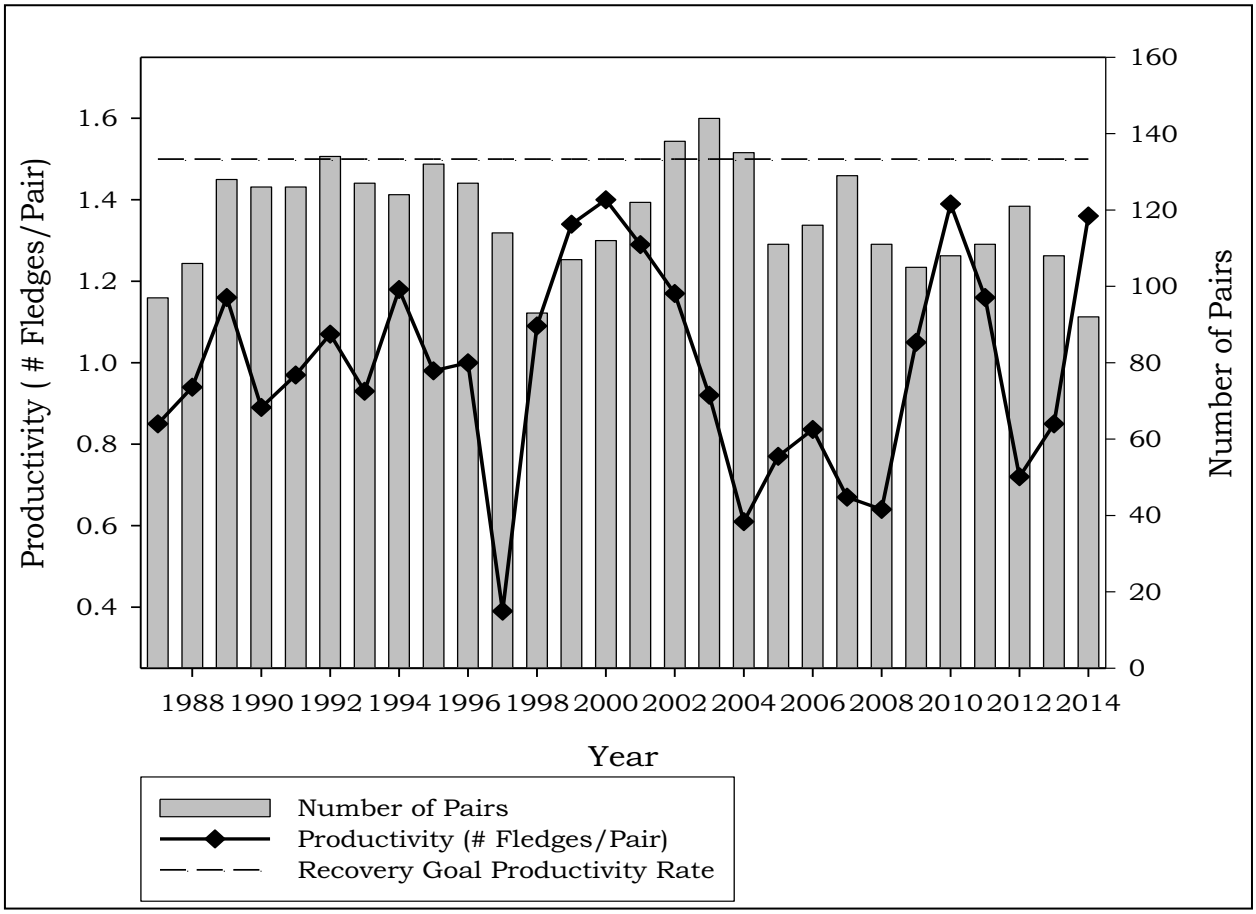
output at Sandy Hook, which accounted for 51% of the state's pairs, but also at the Edwin B. Forsythe NWR sites, especially Holgate. Increases in productivity at the Forsythe sites, which resulted, in part, due to enhanced habitat suitability as a result of Superstorm Sandy, are especially encouraging. If previous trends hold, the statewide increase in productivity this year should result in an increase in the New Jersey's piping plover breeding population next year. However, any long-term increase or recovery will depend on maintaining higher productivity over a sustained period.

FAIRS ACTIVITY CODES: 1450, 1460.

LITERATURE CITED

U.S. Fish & Wildlife Service. 1996. Piping Plover *(Charadrius melodus)*, Atlantic Coast Population, Revised Recovery Plan. Hadley, MA. 258 pp.

Figure 1. New Jersey piping plover population: 1987-2014.



PERFORMANCE REPORT

STATE: New Jersey **PROJECT NUMBER**: E-1-36

PROJECT TYPE: Research and/or Management

PROJECT TITLE: Endangered and Threatened Wildlife Conservation

STUDY NUMBER AND TITLE: IV - Vertebrate Wildlife Conservation

JOB NUMBER AND TITLE: 2-C Piping Plover Threat Assessment and Management

PERIOD COVERED: September 1, 2013 to August 31, 2014

PREPARED BY: Christina Davis and Todd Pover

JOB OBJECTIVES: To determine the nature and level of threats to piping plover populations and reproductive success and to reduce threats through management.

SUMMARY: The New Jersey Division of Fish and Wildlife (NJDFW)-Endangered and Nongame Species Program (ENSP) tracked the nest outcome and causes of nest failure, as well as brood loss (where possible), for 19 pairs of piping plovers nesting at 12 active breeding sites. This accounted for one in five (21%) of the state's nesting population at just over half (57%) of the active nesting sites.

NJDFW staff was able to determine nest outcome for all of the known nests (26) at the sites we monitored. Nearly two-thirds (65%) of the nests failed and just over one-third of the nests (35%) hatched. NJDFW was able to determine the cause of failure for all (100%) of the failed nests. Predation was, by far, the leading cause of nest failure at NJDFW-monitored sites, accounting 71% of the failed nests, with abandonment being the cause of failure for the remaining (29%) failed nests. Flooding was not the cause of failure of any known NJDFW-monitored nests this year. Furthermore, human disturbance was not a direct factor in any nest failures. As is typical, causes of chick loss are difficult to determine, so no systematic assessment of those factors could be made.

Fencing and signage were erected at all NJDFW-monitored nesting sites to minimize human disturbance. As chicks hatched, foraging areas were posted with signage alerting beachgoers that chicks were present, in order to limit disturbance, and, where possible, totally restrict human access into favored foraging areas (i.e., Barnegat Light, North Brigantine Natural Area, Malibu WMA, Stone Harbor Point, and Cape May Point State Park). Nesting areas were patrolled on a regular basis, most intensively on weekends and holidays.

All NJDFW-monitored sites where active breeding occurred were managed, to some degree, to reduce predation of nests. Use of predator exclosures, the primary tool used in past years, was scaled back over concerns of adult mortality associated with their use and evidence of reduced effectiveness over time. As a result, exclosures were used on only about one-third (35%) of NJDFW-monitored nests in 2014. Nest hatch success was higher for the exclosed nests, as would be expected, but not significantly so this year (44% vs. 29% for unexclosed nests). Abandonment associated with nest exclosures remained an issue in 2014 and NJDFW strongly believes adult mortality occurred with two of those abandoned nests (based

on tracking of banded individuals), possibly more. As a result, the jury is still out on the best way to utilize exclosures and New Jersey hopes to continue its participation in a USGS/USFWS led project, including field research, to further explore the cost/benefit ratio of exclosure use.

NJDFW continued its work with the U.S. Fish and Wildlife Service (USFWS)-New Jersey Field Office (NJFO) to assist municipalities and other landowners in developing comprehensive management plans for the protection of federally and state-listed beach dependent species, in particular piping plovers, although efforts were scaled back this year in initiating new plans, as most municipalities where nesting occurs now have plans. A round of revisions for those plans is set to begin next year. NJDFW continues to have the lead role in on-the-ground implementation of those plans as part of its routine management activities.

SIGNIFICANT DEVIATIONS: None.

RECOMMENDATIONS: Maintain current monitoring frequency to ascertain causes of nest failure and brood loss. Continue use of predator exclosures (and electric fence) where they are likely to reduce predation without leading to adult mortality. Continue to monitor the effectiveness of predator exclosures, especially as it relates to the rate of nest abandonment and possible adult mortality, including additional participation with USGS/USFWS and other range-wide partners to study whether and in what situations use of exclosures continues to be warranted. Increase the use of targeted predator removal measures where exclosures and/or electric fence are not effective or feasible and where use will benefit other beach nesting species. Continue to assess the methods and effectiveness of crow management, in order to increase breeding success at impacted sites. Continue to closely coordinate management efforts with municipalities, as well as county, state, and federal landowners. Continue working with the USFWS-NJFO to develop, revise, and implement beach management plans. Explore opportunities for habitat enhancement to increase reproductive success and ultimately breeding pairs.

BACKGROUND: NJDFW has actively managed nesting piping plovers in the state for 29 years using the basic techniques described in "Procedures" below. Funding provided through the B. T. Nautilus oil spill natural resource damage settlement from 1995-2000 and the M.T. Anitra oil spill settlement from 2006-2011, as well as ongoing funding provided by the U.S. Army Corps of Engineers and/or the NJDEP Office of Engineering and Construction has resulted in increased monitoring and management intensity throughout the state since 1995. An intern project initiated with Monmouth University in 2001 has provided students to assist NJDFW with stewardship and management programs in the Monmouth County region. Through a partnership with the Conserve Wildlife Foundation of New Jersey, in part through funding provided by the National Fish and Wildlife Foundation since 2007, monitoring and stewardship was increased at sites all along the coast, especially within Hereford Inlet.

PROCEDURES:

Nest/brood checks: Through regular (3-5 times/week) monitoring, NJDFW attempted to examine the relationship between adverse factors and nest outcome (i.e. nest success and fledging rates). Observers attempted to determine the cause of all nest failures (destruction and abandonment), including evidence of predator activity, weather factors and human disturbance. Brood monitoring included assessing factors that might be involved in chick loss, but rarely resulted in direct observations of chick mortality.

Field management techniques: Specific methods NJDFW applied to protect nesting piping plovers and increase breeding success vary from site to site, although certain basic measures are used at most

locations. Signs and fencing, most commonly string-and-post "symbolic" fencing, restrict public access to nesting areas. Site managers erect fencing either prior to the nesting season -- in areas with a well-established nesting history -- or as nesting activity is discovered. NJDFW staff regularly patrols all major sites on weekends and holidays to monitor human and predator activities, to help reduce human disturbance and to perform on-site education and outreach. Predator exclosures are the primary technique used to reduce nest predation by large avian and mammalian predators. Exclosures are constructed and erected as outlined in the USFWS recovery plan (USFWS, 1996). Due to the higher rate of nest abandonment associated with predator exclosures and the elevated risk of human vandalism and predator harassment at "identified" nests, as a general practice NJDFW uses exclosures on a selective basis, only at sites with a recent history of nest losses due to predation or where managers have observed ongoing predator activity. In recent years, predator activity has been identified at nearly all active nesting sites, and as a result NJDFW has used predator exclosures more routinely at most sites. However, in 2013-14, NJDFW participated in a USGS/USFWS initiative to better determine the relationship between exclosures and adult mortality and the resultant impacts on population dynamics. Because of that project and ongoing range-wide concerns with exclosure use, in 2014 NJDFW once again reverted to more careful use of predator exclosures. Other management techniques used on a more limited basis include: the use of electric fence where exclosures alone are not an effective means of deterring mammalian predation; erection of fenced and/or posted "feeding corridors" to protect foraging areas at beaches with high levels of human activity and/or where human activity is not already seasonally restricted; implementation of seasonal public ORV closures (i.e., North Brigantine Natural Area, Corson's Inlet State Park). In addition, although not funded through this or any other federal grant, NJDFW conducted targeted predator removal at some sites with acute predator problems.

Long-term and field-support management: NJDFW, in conjunction with USFWS-NJFO, has developed or is developing comprehensive management agreements with municipalities and other landowners as a means to minimize the detrimental effects of their activities (e.g., beach maintenance, vehicle use, etc.) on nesting success. During the nesting season, NJDFW issued regular management updates or emails - communications to municipalities and other appropriate agencies outlining current nesting activity and applicable management restrictions. NJDFW also met directly with individuals or departments (including public works, beach patrol, administrative staff, law enforcement, etc.) within municipalities or other agencies to review management issues. More generalized public outreach has included the distribution of informational brochures, placement of interpretive signs at nesting sites, informal on-site contact with the pubic, formal group presentations, and informational booths at local civic events and festivals.

FINDINGS

NJDFW monitored nest outcomes and cause of nest failure, as well as brood loss, where possible, at 12 sites, just over half (57%) of the active piping plover nesting sites in the state. Data were collected for 19 pairs at those sites, representing 21% of the state's pairs.

NJDFW was able to determine nest outcome for all (100%) of the known nesting attempts at the sites it monitored. Of the 26 known nesting attempts, 17 (65%) failed and 9 (35%) hatched. NJDFW determined the likely cause of 100% of the failed nests (17). Predation was the leading cause of nest failure at NJDFW-monitored sites, accounting for 12 nests (46% of nesting attempts, 71% of failures). Abandonment (5 nests) was the next highest cause of nest failure (19% of nesting attempts, 29% of failures). Flooding was not the cause of any known NJDFW-monitored nests. Of the 12 nests lost to

predators, six (50%) were believed to be destroyed by mammalian species and one (8%) by avian species. The species that caused nest destruction was undetermined for five (42%) depredated nests.

The degree of the causes of nest failure at NJDFW-monitored sites varied over the past five years, as is typical. However, predation was, by far, the primary cause of nest failures the past two years. On the other hand, flooding which had been the leading cause of nest loss in 2011 and 2012, was at its lowest level the past two years: flooding has virtually been a non-factor since Superstorm Sandy as it pertains to nest loss. Nest abandonment spiked in 2014, although only when associated with exclosed nests. Causes of brood loss were difficult to determine, although brood loss itself was at its lowest level in five years in 2014 as a factor influencing the reproductive potential at NJDFW-monitored sites. Looking closer at the relationship between nest and brood loss, nest loss has steadily risen over the past five years at NJDFW-monitored sites, so to some degree, as less chicks hatch, one would expect brood loss proportionally as a factor to drop.

NJDFW employed predator exclosures on about one-third (9 or 35%) of the 26 nests it managed in 2014, significantly lower than the rate in recent years. Nearly two-thirds (17or 65%) of the nests were not exclosed. The majority (12 or 71%) of the unexclosed nests failed, all (100%) of them to predation. The hatch success rate of the exclosed nests, which is typically much higher than unexclosed nests, was lower than normal this year, with just 4 of the 9 (44%) of the exclosed nests successfully hatching. Of the failed exclosed nests, all 5 (100%) failed due to abandonment.

DISCUSSION AND CONCLUSIONS:

Although productivity for New Jersey's piping plovers reached one of its highest levels since federal listing in 2014, the breeding population fell to its lowest level over that same period. This year's boost in productivity should jumpstart recovery of the population in the short-term, but much more work is needed to make any sustained correction of the downward population trend. Factors influencing reproductive success vary by site and year, but human disturbance has been minimized at many sites, and flooding has not been a significant factor since Superstorm Sandy. This leaves predators as the primary threat to be addressed; it was, by far, the leading cause of nest failure over the past two years. In the past, predators have been addressed primarily through a combination of predator exclosures and targeted predator control (as needed). With the use of predator exclosures now in question, as they lead to higher levels of nest abandonment (which is likely caused by adult mortality associated with the exclosure), the task of addressing predators becomes more difficult. NJDFW participated in a USGS/USFWS led study of this issue in 2013-14, and used some of the results to more carefully assess where to utilize exclosures during the 2014 breeding season. Unfortunately, the decision making process was still difficult and a number of nests where use of exclosures appeared to still be warranted resulted in abandonment (and likely adults mortality). NJDFW will continue to work with USGS/USFWS and other range-wide partners to assess the benefits vs. risks of exclosures, with hopes of refining a decision tree. However, more emphasis likely needs to be placed on predator control to boost reproductive success. As it is, predator exclosure are only a "band-aid" approach; they do not address the underlying causes, and only help boost nest success, not necessarily brood survival. Predator management is a difficult task on a number levels, but increased application of direct predator control will be necessary if we are going to achieve recovery of piping plovers in New Jersey

FAIRS ACTIVITY CODES: 1450, 1460.

LITERATURE CITED

U.S. Fish & Wildlife Service, 1996. Piping Plover (*Charadrius melodus*), Atlantic Coast Population, Revised Recovery Plan. Hadley, MA. 258 pp.

PERFORMANCE REPORT

STATE: New Jersey **PROJECT NUMBER:** E-1-36

PROJECT TYPE: Research and/or Management

PROJECT TITLE: Endangered and Threatened Wildlife Conservation

STUDY NUMBER AND TITLE: IV - Vertebrate Wildlife Conservation

JOB NUMBER AND TITLE: 2-D Piping Plover Wind Power Threat Assessment

PERIOD COVERED: September 1, 2011 to August 31, 2014

PREPARED BY: Christina Davis, Senior Environmental Specialist

JOB OBJECTIVES:

1) To estimate movement frequency and height of flying piping plovers commuting and displaying during the breeding season, under a range of environmental conditions, and the proportion of birds of different sexes and ages that fly through potential rotor-swept zones or tower locations.
2) To assess whether piping plover flight paths during the breeding season are predictable.
3) To determine response of flying piping plovers to novel and existing human objects in their path.
4) To determine the relationship between habitat configuration (area, proximity, and arrangement of nesting and foraging habitat) and habitat use and movements by adults and young.
5) To estimate baseline survival rates of adults and fledglings during the breeding season, for use in future risk assessments.

SUMMARY:

The piping plover flight behavior study was conducted 15 March – 15 August during the 2012 and 2013 breeding seasons. Field work was conducted at three locations within the state: Stone Harbor Point, Avalon, and Strathmere. During the two field seasons, a total of 42 piping plovers, including adults and juveniles, were color-banded and 26 of the banded females were fitted with radio transmitters. At Stone Harbor Point, 20 individuals were color banded and 15 females were fitted with radio transmitters; at Avalon, 14 piping plovers were banded and eight females were fitted with radio transmitters. Strathmere was added as a study site in 2013 to supplement the small sample size; eight individuals from that site were banded and three females received transmitters. Researchers made daily behavior observations while tracking plover movements across habitats for all the marked individuals. Flight speed, flight height and object avoidance were measured using a variety of methods. A total of 445 individual flights were observed in 2012 and 492 flights in 2013. The same study was replicated at Cape Cod, MA, by another project crew. The final report for this study is pending from the contractor, and once completed we can provide a more detailed analysis and assessment.

SIGNIFICANT DEVIATIONS: None.

RECOMMENDATIONS:

There are no recommendations to report at this interim stage.

COST: $22,222.22 ($20,000 federal share, $2,222.22 state share)

BACKGROUND:

The piping plover (*Charadrius melodus)* was listed as endangered by the New Jersey Department of Environmental Protection in 1979. In January, 1986, the U.S. Fish and Wildlife Service (USFWS) included the piping plover on the Federal Endangered Species list and classified the Atlantic coast population as "Threatened." In the decades since listing, development of wind turbines along the Atlantic Coast has become a reality and in order to best understand the potential impacts of these machines, this project was proposed by Dr. Jonathan Cohen from the State University of New York–Syracuse (SUNY) and primarily funded by USFWS. The increased Section 6 funding in this segment allowed NJDFW to contribute to this project, which fills a critical knowledge gap for this species.

PROCEDURES: All work and procedures were pre-approved by USFWS, and were conducted in NJ and MA by the same contractor.

Habitat use and baseline survival
The technicians estimated the proportion of time color marked piping plovers spent in different cover types (e.g., sand flats, foreshore, backshore, wrack line, dune, blowout, washover fan) and different areas within their breeding sites using marked birds. They estimated weekly survival rates using mark-resight methods. They resighted all banded adults and chicks at least 2 survey days per week, once per survey day, by surveying transects through all known nesting, roosting, and foraging areas. For each banded bird observed alone or in a group, technicians recorded band combination, initial cover type used and initial behavior observed (e.g., foraging, resting, preening, incubating, brooding), breeding status (territorial, scraping/courting, laying, incubating, brood tending), and used a GPS unit to record the location of the bird. Cormack-Jolly-Seber models were used to estimate weekly survival rates from band resightings.

Flight paths and heights
Prior to the nesting period (i.e., March to late April), unmarked birds were studied to record flight heights and frequency for courtship displays and non-courtship flight distances and pathways. Once the nesting period commenced, radio-tracking of a subsample of birds was used to estimate flight paths (Hull et al. 2001) and heights of female piping plovers. Rangefinders with height functions were used for height estimation exercises. Radio-tagged birds were observed with a 60x spotting scope for two hours at a time. Position and height of the path, and distance and height of nearest human structures, if any, were recorded.

Object avoidance and flight speed experiments
During daytime follows SUNY field technicians identified places where piping plovers flew or might fly across dune fields or other landscapes that have been proposed for wind turbine or other human structures, or where such structures have been built in other places. Two potential crossing sites (A and B) separated by at least 100 m were selected for 2-hour behavioral observations. Stakes were placed at two points in the field of view, so that an observer with a stopwatch could record the time flying and walking birds take to pass between them, and hence calculate passage speed. Two observers set up portable chair blinds in positions that gave a clear field of view. Flight height was visually estimated, and flight or walking path was marked with a GPS unit once birds left the area. Orientation, location,

and heights of flight paths relative to the reference point were calculated later using GIS. After three days of such measurements taken at the same time relative to tidal stage, a 6-foot diameter helium balloon attached to a set of 120-foot flagged tethers was placed in one of sites (either A or B, chosen at random), anchored to the reference point. Flagging was bright and obvious, to prevent collisions by birds with the tethers. Flight paths and heights of birds were recorded, and position and orientation and height relative to the balloon were calculated. Behavior of walking and flying piping plovers entering within 10 m of the balloon was recorded, including changes in flight behavior (Savereno et al. 1996). Balloons were taken down at the end of each observation period. SUNY will use a generalized linear model in a before-after control-impact framework to examine the effect of the balloon presence on passage probability, and passage distance, orientation, and height relative to the reference point (i.e., balloon anchor point). Disturbance responses by piping plovers or other beach nesting species to the balloon was monitored, and although the experiment could be modified or if need be discontinued where problems were noted, no changes were necessary. SUNY field technicians also placed stakes at fixed points at least 20 m apart, along the length of typical flight paths. During pre-treatment phases of the avoidance experiment, they used video cameras to record flights of piping plovers past the observation positions. Videos will be analyzed frame by frame to determine passage time between the stakes, and hence flight speed (Hilton et al. 1999).

FINDINGS:

- In 2012 and 2013 SUNY field technicians individually marked 34 adults in NJ (with two Darvic color bands on each upper leg) on their nests as soon after clutch completion as possible, using walk-in funnel traps (Cairns 1977). Adults were weighed and measurements of culmen, tarsus, and wing chord were taken. The eight marked juveniles were captured by hand after they reached a minimum weight requirement and individually marked using the same scheme and colors as the adults. Six (6) adult female piping plovers and one fledgling were radio-tagged in each state and followed until the tags fell off. In one instance, a female adult kept her transmitter through arrival in the Bahamas, where she was photographed with it still attached. A total of 61 adult birds were color marked in both states.
- SUNY field technicians made 1,017.11 hours' worth of diurnal behavioral observation, and 1,689 flights were observed.
- Of 61 candidate models of diurnal flight frequency, the best-fitting model contained an interaction between breeding status and tidal stage, and an interaction between site and temperature (Negative Binomial Regression, AIC_c weight = 0.821).
- Flight frequency was greater at Dead Neck/Sampson's Island, MA than at Spring Hill, MA, Stone Harbor, NJ, and Avalon, NJ.
- The number of flights/hour that occurred during a low-falling tidal stage was greater than the number of flights/hour during high-falling and high-rising tidal stages. Flight frequency during high-rising tides was lower than during any other tide cycle.
- Piping plover adults tending a brood made more than twice as many daytime flights as nesting adults and those without a nest.
- Flight frequency was highest among adults tending a brood across all tidal stages.
- Flight frequency increased with temperature; however, the magnitude of this increase varied among study sites and no correlation was apparent at Stone Harbor, NJ.
- One hundred eighty-nine non-courtship flights were mapped in 2012 at New Jersey study sites, and 516 non-courtship flights at MA study sites. Three hundred ninety-two non-courtship flights were mapped in 2013 at NJ study sites, and 182 non-courtship flights at MA study sites. The center points of flight paths were clustered by territory, indicating that birds tended to commute to foraging areas using pair-specific routes.

- Nineteen flights were captured using the rifle scope videography, and flight heights ranged from 0.65 m to 8.13 m. Visual estimates for piping plovers passing through the reticle ranged from 0.25 m to 10.0 m.
- Average visually-estimated flight height of piping plovers from 1,066 observed flights during 2012 behavioral observations was 2.63 m, and average visually-estimated flight height of piping plovers from 608 observed flights during 2013 was 2.51 m.
- Of the 1,066 flights in 2012, 49.9 percent were less than 1.5 m high, and of the 608 flights observed in 2013, 52.6 percent were less than 1.5 m high.
- Seventeen flight paths were video-recorded and analyzed to determine flight speed. The average flight speed was 9.30 m/s ±1.02 SE.

DISCUSSION AND CONCLUSIONS:

Using the flight parameters determined in this study and assuming no transits of the rotor-swept zone at night, the Scottish Natural Heritage model predicted that when a single, small turbine was placed at a study site, less than 0.25 collisions/year would occur at all sites; however, when 10 small turbines were placed at a study site, the number of collisions/year ranged from 0.08 to 2.15. This was less than for a single large turbine (40 m radius) where the collisions/year ranged from 0.13 to 3.17. The potential number of birds killed/year was highest at Spring Hill Beach, MA and lowest at Avalon, NJ, regardless of the number or type of turbine placed at the beach.

Assuming 2.4 times as many night flights as day flights (Sherfy et al. 2012), the number of collisions per year showed a marked increase across all study sites. When a single, small turbine (9 m radius) was positioned at a study site, as many as 1.48 collisions/year were predicted to occur at Spring Hill Beach, MA; furthermore, when 10 small turbines were placed at a study site, the number of collisions/year ranged from 0.22 to 14.8, and this was less than for a single large turbine (40 m radius) where the collisions/year ranged from 0.32 to 21.91.

Turbines with a smaller diameter, smaller percent chord width, and slower rotation period yielded a lower probability of collision for a piping plover passing through the rotor swept zone than turbines with a larger diameter, larger percent chord width, and faster rotation period.

Note: A more detailed account of this study will be available in December 2014 in the form of a master's thesis. NJ Division of Fish and Wildlife links to this thesis on our website at http://njfishandwildlife.com/ensp/pdf/plover-turbine_stantialthesis14.pdf

FAIRS ACTIVITY CODES: 1450, 1460.

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PERFORMANCE REPORT

STATE: New Jersey PROJECT NO.: E-1-36

PROJECT TITLE: Endangered & Threatened Wildlife Conservation

STUDY TITLE: IV. Vertebrate Wildlife Conservation

JOB NUMBER AND TITLE: 10A. Red Knot Conservation on Delaware Bay

PERIOD COVERED: September 1, 2011 to August 31, 2014

PREPARED BY: Amanda Dey, Principal Zoologist

OBJECTIVE 1: Protect critical habitats and resources on the Delaware Bay stopover for migratory shorebirds: continue regional collaboration with state and federal agencies to recover horseshoe crab and shorebird populations, reduce anthropogenic disturbance to shorebirds enhance/create coastal habitat and impoundments for crab spawning/shorebird foraging and roosting.

OBJECTIVE 2: Assess recovery of red knot and other shorebird species: monitor mass gain and adult survival through resightings of marked individuals; monitor stopover population size through baywide aerial survey and mark-and-resighting methods. ***(Covered in grant NJ T-1-7 report 2013-2014.)***

OBJECTIVE 3: Assess recovery of the horseshoe crab egg resource: monitor horseshoe crab egg densities on Delaware Bay beaches.

SUMMARY: In 2014 NJ continued seasonal beach closures on Delaware Bay (13 sites) and the Atlantic coast (1 site) to protect shorebird foraging and roosting areas from human disturbance during the May migration stopover. Beach closures, staffed by Shorebird Steward Volunteers, and backed by NJDFW Conservation Officers, have played a critical role in aiding a larger proportion of red knots to gain adequate weight (≥180 grams) prior to Arctic breeding. Inadequate weight gain has been statistically linked to reduced adult survival (Baker et al. 2004) and loss of productivity. While improvement in the number of birds reaching 180g is hopeful, it must be tempered by the fact that the red knot stopover population is now 26% of its former size (>94,000 in 1989; < 25,000 in 2014), and the horseshoe crab population has shown no sign of significant improvement despite 14 years of harvest reductions. Positive steps have been made to develop biologically-based methods to manage horseshoe crabs harvests (i.e., Adaptive Resource Management, or ARM, Model); however, the trawl survey that underpins this model (Atlantic Coast Benthic Trawl Survey, conducted by Virginia Tech [Hata and Hallerman 2013]) was defunded in 2013 jeopardizing continued use of this method to set quotas. Without a targeted crab survey, harvest quotas may be set without adequate population data.

Baywide egg surveys (NJ & DE) were conducted from 2005 to 2013; Delaware discontinued its participation in this survey in 2014. New Jersey continued horseshoe crab egg surveys to assess foraging conditions for red knots and other shorebirds. While the mean surface egg density (top 5 cm) continues to remain low (2,332 eggs/m^2 in 2014), several beaches are seeing some improvement in egg

densities. Low egg densities are due to a much-reduced horseshoe crab population and to egg depletion by the larger number of red knots and other shorebirds that consistently use protected NJ beaches (confirmed by baywide ground and aerial surveys). Delaware's bayshore beaches have significant egg resources (roughly 10,000 - 30,000 eggs/ m^2 during 2005 to 2013), but human disturbance limits and/or precludes shorebird use of available eggs on many beaches outside of Mispillion Harbor.

SIGNIFICANT DEVIATIONS: None

RECOMMENDATIONS: The volunteer Shorebird Steward program, with conservation officer support, is one of our most effective conservation actions which, we believe, has helped stabilize the red knot stopover population. Continued/increased funding would help expand protection efforts and community engagement.

Likewise, the horseshoe crab egg survey is key to assessing recovery of red knot foraging conditions. Delaware discontinued its participation in the egg survey for lack of funding. A renewed baywide egg survey would benefit recovery assessment efforts.

COSTS: 100,000 over 3 years (75,000 Federal, $25,000 state/in-kind)

BACKGROUND: NJ Endangered and Nongame Species Program has carried out intensive shorebirds studies on Delaware Bay since 1997, when unregulated harvests of horseshoe crabs peaked and the Delaware Bay states (NJ & DE) began to quantify the impact of crab harvests on shorebird migrants.

The work centers on capture and individually marking shorebirds (survival and population estimation using mark-and-resightings methods), measuring weight gain through the stopover period (assess number of birds reaching adequate departure weight), aerial survey (trend in shorebird abundance and distribution), and egg density survey (assess foraging conditions for red knots and other shorebird migrants). This work, and the work of others in Canada and South America, led to the red knot status assessment in 2007, and helped underpin the red knot listing proposal.

Now with 18 years of data, the metrics above are useful to assess recovery of red knots and horseshoe crab egg resources in Delaware Bay.

Over the 11 years of the Shorebird Steward volunteer program, the incidence of disturbance has been greatly reduced, shorebirds optimize foraging free from human disturbance, and the program enjoys overwhelming community support.

PROCEDURES

Seasonal Beach Closures:

- Seasonal closures have been in place since 2003. All or part of 13 bayshore beaches and one Atlantic coast site (http://www.njfishandwildlife.com/ensp/beachclozmap.htm) were closed from May 7 to June 7 annually.
- Public viewing areas were present at each site; three viewing platforms were established in the south, middle and northern Delaware Bay (at Norbury's Landing, Reeds Beach, and Fortescue) for up-close public viewing of shorebirds and horseshoe crabs.
- Shorebird Steward volunteers staffed all closed beaches; they educated the public on the importance of beach habitat for crabs and shorebirds and prevention of disturbance to foraging shorebirds.

- Conservation officers assisted with closure efforts. Weekend shifts of two officers, on two shifts per day, covered Cape May and Cumberland counties when visitation and recreational use is greatest. Officers educated the public and assisted Stewards in dealing with disturbance problems. Annual cost for officer support was $10,000 from non-federal funds provided by the NJ Natural Lands Trust.

Baywide Horseshoe Crab Egg Surveys:
The baywide egg survey methodology was developed in 2005 by the USGS, Leetown Aquatic Research Center, WV (Hernandez 2014), and is known as the USGS method. Briefly, 20 core samples are collected at 1 m intervals along three, 20-m transects located in the intertidal zone. Eight to ten beaches are sampled each year. Live eggs and larvae are counted and mean density per beach and by state are calculated. As noted earlier, Delaware ceased participation in 2014 due to a lack of funding.

Beach Selection
- In New Jersey, twelve beaches were identified as potential horseshoe crab spawning sites. Seven permanent beaches and three alternate beaches were selected and sampled each year. Permanent beach selection in NJ was based on shorebird use and maintaining continuity with previous horseshoe crab egg sampling projects. NJ carried out crab egg surveys with a pit sample method (Botton et al. 1994) in 2000-2005. Three of the four remaining beaches are selected at random each year.
- In Delaware, 17 beaches were identified as potential horseshoe crab spawning sites. Beaches were stratified based on known shorebird use. Seven beaches with consistently high shorebird use and centered within the current distribution of the horseshoe crab spawning were permanently sampled each year. Six of the remaining nine beaches were categorized to have minimal shorebird use and the remaining three as unlikely shorebird use. The minimal use beaches were assigned probabilities random selection based on shorebird survey data and three were chosen each year. The unlikely shorebird use beaches were added to the minimal shorebird use beaches for random sampling every third year. The intent was to accommodate changes in horseshoe crab spawning and shorebird foraging distribution over the long term.

Segment Selection
- In New Jersey, at each beach, a 20 m sampling segment of open beach was randomly selected. If a beach contained additional habitat types shorebirds are likely to use (e.g., tidal deltas, sandbars, tidal creek mouths), an additional (up to) 20 m sampling segment was selected in that habitat type when feasible. Once selected, the open beach sampling segments were marked (physically and by GPS) and used for the duration of the project. Segments located in other habitats were also marked (by GPS and physically, if possible) and used for the duration of the stopover, though they were re-evaluated yearly, (Fishery Management Report No. 32 of the Atlantic States Marine Fisheries Commission, Interstate Fishery Management Plan for Horseshoe Crab, December 1998. Pgs. 57, http://www.asmfc.org/uploads/file/hscFMP.pdf)
- In Delaware, each beach has at least one segment selected for permanent sampling. Additional segments may be selected in unique habitat types to assess potential variations in horseshoe crab spawning and shorebird foraging. Sample segments for each beach were randomly located from the beach access points and serve as the permanent sampling locations. The coordinates of each segment were recorded using a GPS receiver. Pictures of the segments in relation to permanent landmarks were also taken to help guide sampling in future years.

Sample Timing

- Sampling occurred from the first week in May through the first or second week in June at the first low tide of the day. Sampling was timed to begin prior to the arrival of the majority of shorebirds and extended until the peak spawning activity for horseshoe crabs had likely passed. Each selected beach was sampled once per week and sampling was conducted within two hours of low tide.

Sediment Sampling

- Sample segments were 20 m in length along the beach. Each beach segment was stratified across the beach by elevation / habitat zones (Figure 1a). The number of strata depended on the width of the beach and habitat complexity. Strata were three m wide and extended from the maximum high tide line to the toe of the beach or approximately 80% of the beach width. The middle transect was centered at the mid-beach elevation, such that the entire sampling segment was also centered (Figure 1b). If the beach segment included complex habitat types, such as tidal deltas or intertidal sand bars, then strata included all accessible habitat types. For example, if there were intertidal sand bars where spawning was taking place and these sand bars were accessible to surveyors, then strata were added to include the sand bars. Additionally, if the transect was shorter than 20 m, 1 core per linear meter was taken in each transect (e.g., 7 cores in a 7 m transect).
- Sediment was collected by taking 20 five-cm core samples (5.7 cm in diameter and 5 cm deep) systematically throughout each stratum. Occasions where the number of cores differed from 20 were noted and the appropriate number of cores was used in all egg density calculations. Core samples were placed at regular intervals within strata (e.g., Figure 1b). Collecting samples systematically ensures sufficient spatial coverage, meets statistical analysis requirements, and allows for rapid field implementation. Sediments from all cores taken within a stratum were pooled and combined into a bucket and processed together.

Sediment Processing and Egg Enumeration

- In New Jersey, separation of sediment from eggs was done shortly after sample collection by rinsing sediment and eggs through a series of sieves. The final sieve screen mesh size was 1 mm, a mesh size that did not allow eggs to pass through. The reduced samples were refrigerated until enumeration. Eggs were enumerated manually. This method entails placing the eggs in a shallow white tray, with a light source over tray. Sediment was placed in one end of the tray and sifted to the other end of the tray using curved forceps. Eggs were individually counted using tally counters. Sample separation and egg enumeration were conducted at The Wetlands Institute in Stone Harbor, New Jersey to ensure consistency and quality control (Hernandez 2014).

- All samples from the Delaware study were processed at the St. Jones Center, of the Delaware National Estuarine Research Reserve by DE Division of Fish and Wildlife following a method that used direct counts of eggs and volumetric estimation (where egg quantities were large) (D. Weber, K. Kalasz, pers. comm.).

Analysis

- Egg density (number of eggs/m2) was calculated for each sample stratum. Average egg density was then calculated for each beach and summarized by week and year. Horseshoe crab egg density, particularly in the top five cm of sand, is highly variable both within and between beaches. Horseshoe crab spawning is concentrated along the mid-section of beach. The region of spawning can vary across the width of the beach depending on variations in the height of high tide, which is affected predictably by lunar phase and unpredictably by wind. In addition, eggs tend to be patchily distributed along the beach length. A reasonable approach to decrease variances would be to examine just the middle three

strata where spawning is concentrated. However, this might provide an inflated average density. Therefore, all strata sampled were included. The resulting average densities will have high variances but best represent the availability of horseshoe crab eggs to shorebirds. Differences in egg densities between years was tested using ANOVA at p=0.05.

FINDINGS

- The distribution of four shorebirds species from 2013 and 2014 ground survey show the majority of birds used NJ beaches. This is not the distribution that would be expected given Delaware beaches have significant available egg resources (Figure 3).
- New Jersey horseshoe crab egg densities remained low; the mean density for all beaches in 2014 was 2,332 eggs/m^2 (Figure 3). Low surface egg densities may be due to a reduced horseshoe crab population and depletion of egg resources on NJ beaches.
- The disparity between mean egg densities in DE and NJ have been the subject of discussion focused on differences in egg enumeration methods (volumetric estimation in DE, versus hand counts in NJ). However, over time it is apparent that other factors can be attributed to observed differences: 1) Delaware generally has higher egg densities but the disparity is not consistent in all years (i.e., egg counting methods are not entirely responsible); 2) New Jersey beaches receive greater shorebird use which may result in depletion of surface eggs; 3) New Jersey beaches are subject to persistent westerly winds and wave action that can reduce crab spawning activity, dislodge egg clusters and wash surface eggs into a surface swash zone.
- Egg densities are highly correlated with red knot weight gains (Figure 4), and a greater proportion of red knots have achieved threshold departure weight (≥180 g) in the last three years (Figure 5).
- The relatively flat levels of egg densities over the years are consistent with trends observed in long-term horseshoe crab surveys, which show no significant improvement; data sources include the Atlantic Coast Benthic Trawl Survey (1999-2012, non-breeding crab population); the spawning crab survey (1999 to present), the Delaware 30-foot trawl survey (1999–present; relative abundance of breeding adults in Delaware Bay). *A summary of these trends is provided in the New Jersey T-1-6 (see Table 5.)*

Figure 1. Peak abundance of shorebirds from ground surveys, May 27, 2013. Source: NJ & DE Divisions of Fish and Wildlife (from: Niles et al. 2013).

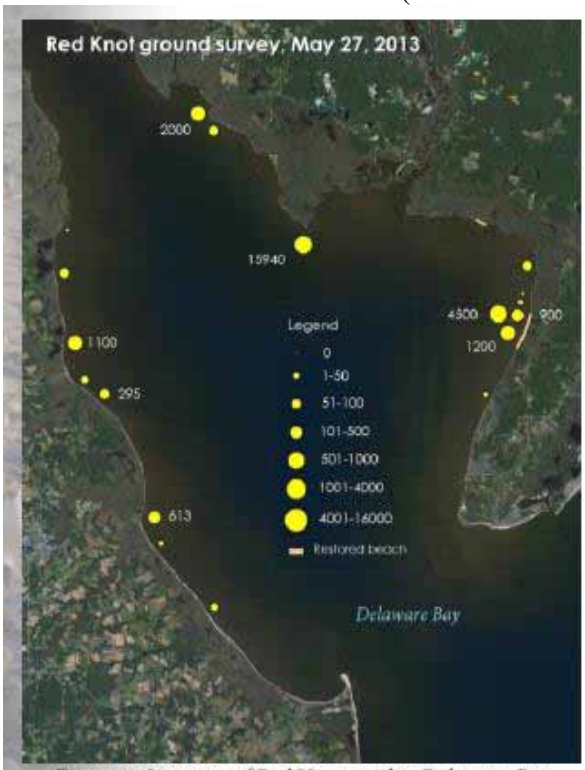


Figure 11. Location of Red Knots within Delaware Bay during peak abundance, 2013

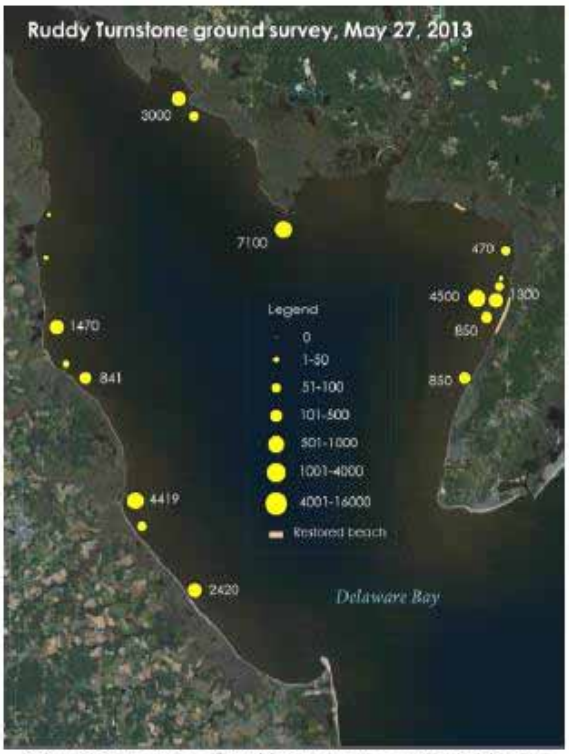


Figure 12. Location of Ruddy Turnstones within Delaware Bay during peak abundance, 2013

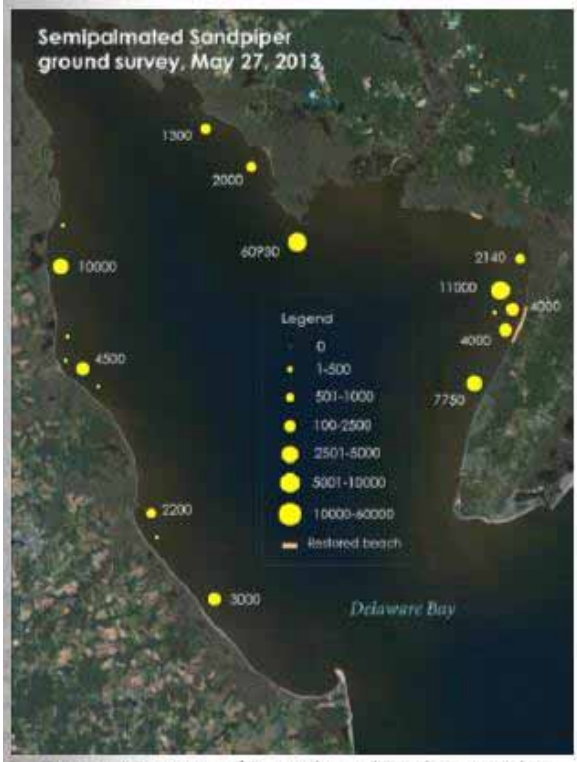
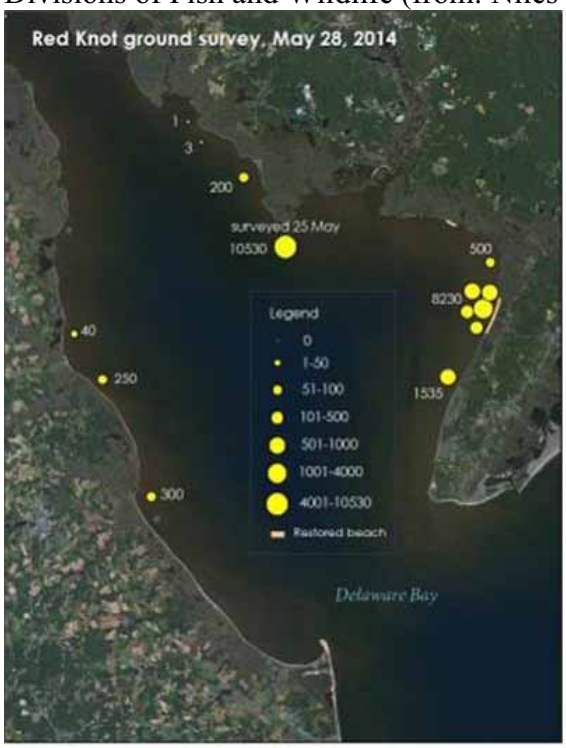
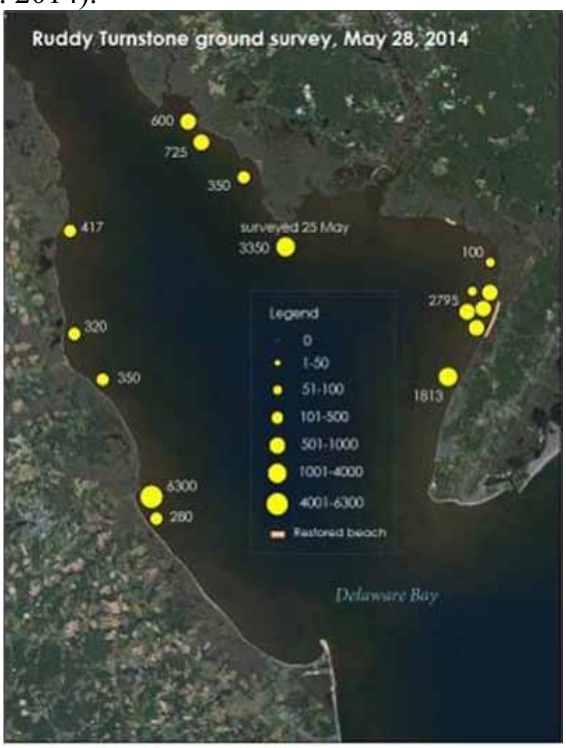


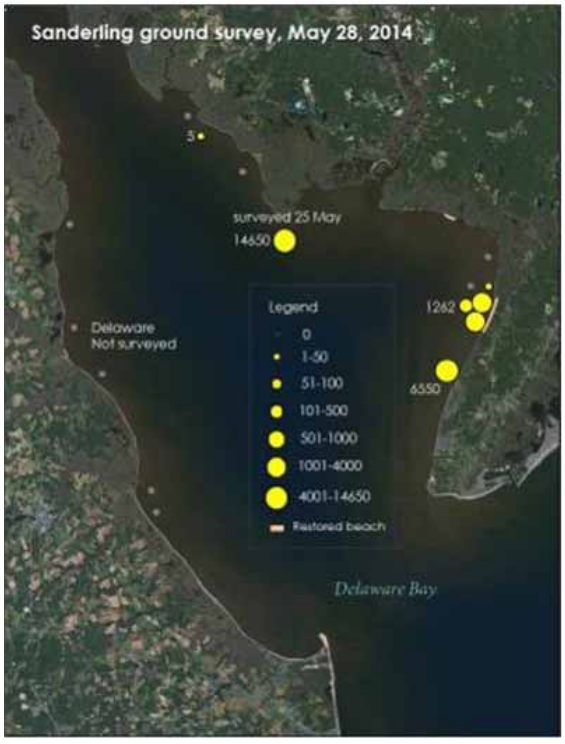
Figure 13. Location of Semipalmated Sandpipers within Delaware Bay during peak abundance, 2013.

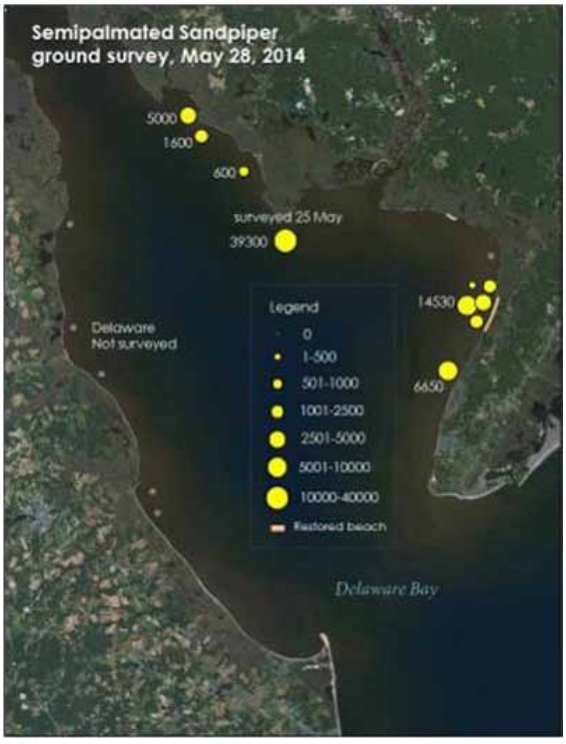
Figure 14. Location of Sanderlings within Delaware Bay during peak abundance, 2013.

Figure 2. Peak abundance of shorebirds from ground survey, May 28, 2014. Source: NJ & DE Divisions of Fish and Wildlife (from: Niles et al. 2014).









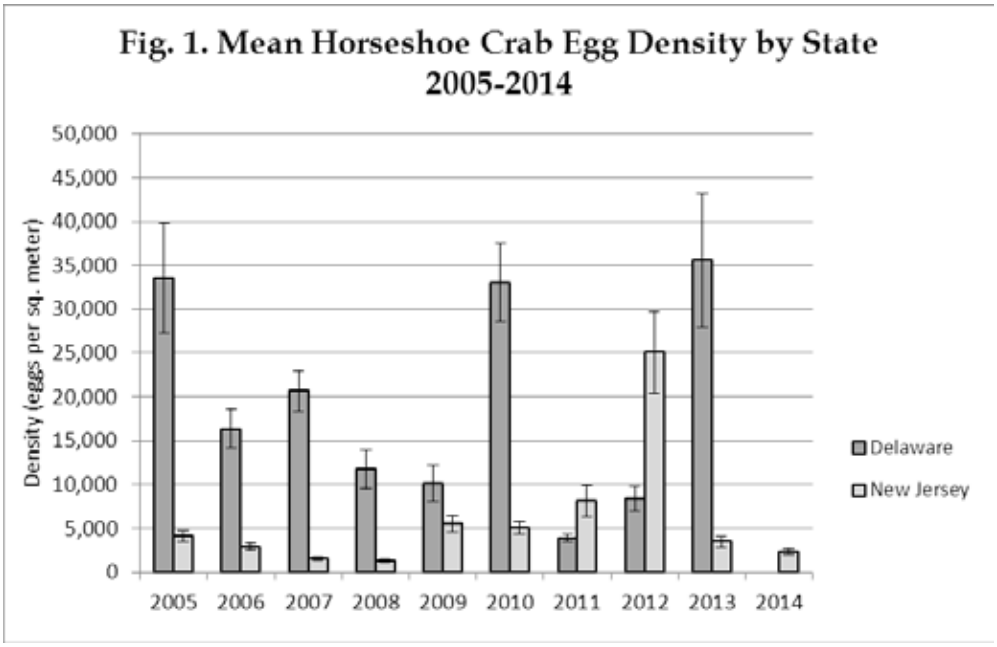


Figure 3. Density of horseshoe crab eggs in the top 5 cm of sand of Delaware Bay beaches during May and early June 2005-2014. Note Delaware discontinued egg surveys in 2014 (Source: Delaware Division of Fish and Wildlife and the New Jersey Division of Fish and Wildlife).

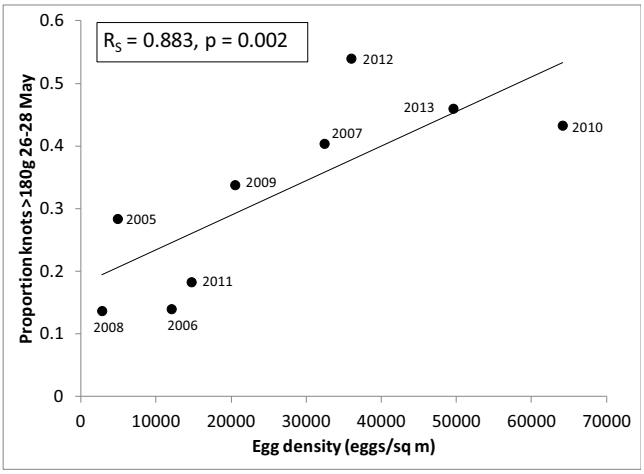


Figure 4. Proportion of Red Knots in the >180 g body-mass category in Delaware Bay during 26-28 May plotted against the median horseshoe crab egg density during 14-27 May 2005-2013 for Delaware and New Jersey (R^2 = 0.883, p = 0.002). DE ceased egg surveys in 2014.

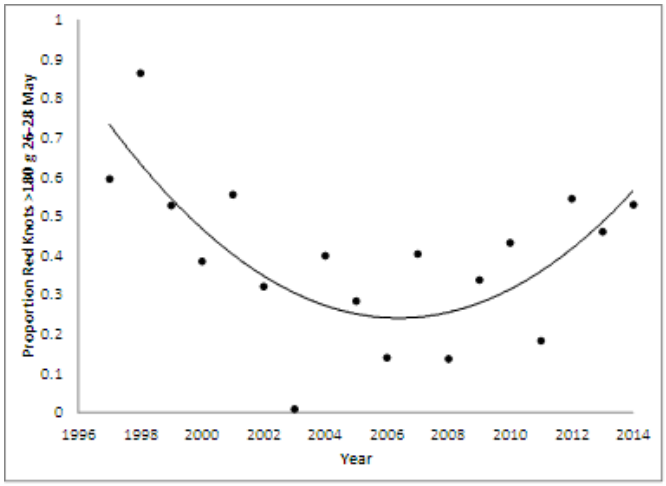


Figure 5. Proportion of Red Knots in the >180 g body-mass category in Delaware Bay near the usual departure time each year (26-28 May) over 1997–2014. The line shows a significant quadratic trend over 1997-2014 (the trend line ±95% confidence intervals in respect of the line, not the variation in the data) was fitted using binary logistic regression of body mass >180g (1 = yes, 0 = no) on year (negative, $p<0.001$) and year2 (positive, $p<0.001$). The strength of the quadratic trend owes much to the very low proportion recorded in 2003, but it is still significant if the 2003 data are omitted.

DISCUSSION

- Delaware Bay is a critical stopover for Arctic-nesting shorebirds because it is the last stopover before Arctic breeding. Fat reserves from Delaware Bay help birds survive and successfully reproduce in years when Arctic conditions are favorable.
- While it appears declines of red knots and horseshoe crabs may have been stemmed, their populations are now at a much lower level than historic numbers. This leaves red knots and other declining shorebirds vulnerable to any perturbation in Delaware Bay or elsewhere in the flyway.
- The lack of substantial recovery of horseshoe crab egg density in Delaware Bay, despite 16 years of harvest reductions, suggests that too many breeding crabs are still being lost from the Delaware Bay population by mortality of known and known-but-unquantified sources (i.e., harvest for bait, mortality from lysate production, loss by sale to non-local states for Lysate bleeding and entry into the bait stream [e.g., Massachusetts], harvest and use of crabs at sea in interstate waters [i.e., without landing], and illegal harvest).
- The best strategy for red knot recovery is a coast-wide moratorium on bait harvest of horseshoe crab to quickly increase breeding crabs, crab eggs, and jump-start restoration of red knots. Reductions in other sources of crab mortality (as above) would help reduce significant annual losses of breeding-age crabs.
- Continued seasonal beach closures, and other collaborative methods, to help protect shorebirds from disturbance is a critical conservation job that should take place equally on both sides of Delaware Bay, and on Atlantic Coast stopovers and wintering areas Massachusetts to Florida. Beach protection would benefit both migrant and post-breeding/wintering beachnesting shorebirds.

CONCLUSIONS

- Without significant and swift recovery of horseshoe crabs, red knot numbers will remain low and the population vulnerable.
- Red knots are not the only Arctic-nesting species affected by loss of horseshoe crabs and crab eggs. Similar trends in the loss of ability to gain adequate weight and declining abundance have been observed for ruddy turnstone and semipalmated sandpiper on the Delaware Bay stopover and precipitous declines have been reported in their wintering populations (D. Mizrahi and R.I.G. Morrison pers. comm.).
- Therefore, the recovery of the Delaware Bay migration stopover is a key area where conservation efforts could have major positive impacts for up to five shorebird species (red knot, ruddy turnstone, semipalmated sandpiper, sanderling and short-billed dowitcher). In the meantime, spawning beach restoration and seasonal beach closures can help augment horseshoe crab egg resources for red knots and other shorebird migrants that rely on Delaware Bay.

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PERFORMANCE REPORT

STATE: New Jersey PROJECT NO.: E-1-36

PROJECT TITLE: Endangered & Threatened Wildlife Conservation

STUDY TITLE: IV. Vertebrate Wildlife Conservation

JOB TITLE: 1. Indiana Bat Status, Survey and Protection

DATES: September 1, 2011 - August 31, 2014

PREPARED BY: Michael Valent , Principal Zoologist

OBJECTIVE 1: To identify, characterize, monitor and protect summer Indiana bat colonies on state-owned lands within a 25-mile radius of the Hibernia and Mt. Hope Mines.
OBJECTIVE 2: To identify, characterize, monitor and protect Indiana bat winter habitats within New Jersey and provide winter population counts to the USFWS.

SUMMARY: Indiana bat numbers at Hibernia Mine have declined precipitously since WNS was confirmed at the mine in January, 2009. During the pre-emergence banding/band reading effort conducted on 3/24/14, not a single Indiana bat was observed. Conversely, the Indiana bat population at Mt. Hope Mine appears to be significantly less affected by WNS. Pre-hibernation sampling during the fall of 2012 and 2013 resulted in the capture of 448 and 351 Indiana bats, respectively. As a follow-up to Phase 2 acoustic sampling conducted at Weldon Brook Wildlife Management Area (WMA) in 2013, biologists conducted Phase 3 mist netting during 2014. Mist net sampling was conducted at 4 of the 8 acoustic monitoring sites where *Myotis spp.* were recorded in 2013. The total number of captures was 40 bats of three species, including 31 big brown, 1 little brown and 8 red bats. No Indiana bats were captured. ENSP continued to work with the landowner at Mt. Hope Mine to protect the site from illegal trespass.

SIGNIFICANT DEVIATIONS: None.

RECOMMENDATIONS: Continue to conduct biennial hibernacula surveys, protect known hibernacula and identify and sample potential Indiana bat summer habitat on public lands within 25 mile radii of Mt. Hope and Hibernia mines.

COST: $33,333.33 over 2 years ($30,000.00 federal share, $3,333.33 state share)

BACKGROUND

Very limited data exist regarding documented Indiana bat summer roost and foraging habitat within NJ. Most of this work has occurred on or in the immediate vicinity of the Great Swamp and Wallkill River National Wildlife Refuges and Picatinny Arsenal, all of which have documented Indiana bat occurrences. Additional summer mist-netting to document Indiana bat habitat has occurred sporadically across northern NJ as required for various development projects such as gas and electric rights-of-ways.

None of these efforts have specifically targeted the best potential habitats on publically-owned lands within northern NJ.

The NJ Division of Fish and Wildlife (NJDFW) is proposing to conduct forest management/harvesting activities on several wildlife management areas within a 25 mi. radius of the two known Indiana bat hibernacula in NJ. The management activities are being proposed to provide/improve habitat for the state-listed golden-winged warbler and other SGCN species such as ruffed grouse and American woodcock. However, due to the presence of suitable Indiana bat summer roosting/foraging habitat on the wildlife management areas, the ENSP and the USFWS's NJ Field Office recommended that surveys be conducted prior to the commencement of any forestry activity.

NJ has two known Indiana bat hibernacula, both located in Morris County in the northern third of the state. Both hibernacula have bat-friendly gates protecting the entrances from unauthorized access. ENSP has conducted winter Indiana bat surveys at Hibernia Mine since 1995. The highest count (148) occurred in January, 2009, the same year that White-nose Syndrome (WNS) was confirmed in NJ. The Mt. Hope Mine has only been surveyed (partial internal survey) once due to safety and property ownership issues that limit access. The only internal survey occurred in February of 2004 when 537 Indiana bats were tallied. WNS has been confirmed at both Hibernia and Mt. Hope mines. Since then, Indiana bat numbers have declined precipitously at Hibernia Mine but numbers at Mt. Hope Mine suggest that Indiana bats are persisting at relatively high numbers despite WNS. In 2011, Chris Sanders (Sanders Environmental, Inc.) applied for, and was granted, a permit to conduct a long-term monitoring program at the Mount Hope West shaft.

PROCEDURES

Following an approved Indiana bat survey plan, ENSP conducted Phase 3 mist net surveys at 4 of the 8 points where acoustic monitoring was conducted in 2013. Two triple high mist nets were set up at each survey point for two nights. The nets were opened 30 minutes after sunset and remained open for 5 hours each night. Sampling was conducted between July 25 and August 11, 2014. All nets were monitored constantly and captured bats were removed from the net immediately. All captured cave bats were banded with Porzana bat bands and released immediately at the site of capture.

Internal mine surveys are restricted at Mt. Hope Mine due to safety and ownership issues. Therefore, pre-hibernation sampling has been determined to be the best method for monitoring the site. Three fall sampling periods were selected to gather data across the period of fall activity at the site. The three sampling periods were: 8/30/13 – 9/1/13, 9/13/13 – 9/15/13 and 10/4/13 – 10/6/13. Three net sets and two harp traps were used during each sampling period. The two harp traps were set up at the bat-friendly gate to capture bats entering and exiting the mine. The three net sets were positioned across an old mine road, at the entrance of a shallow surface excavation and the third near the mine gate. Captured bats were measured for forearm length, aged, sexed, evaluated for reproductive condition, assigned a wing damage index and banded. Unbanded Indiana bats were banded using Porzana 2.4 mm, narrow bat bands. Band numbers of previously banded bats were also recorded. During periods of high volume capture rates, some nets/traps were closed in an effort to reduce holding time for bats waiting to be processed. No bats were held for more than 30 minutes following capture. All USFWS WNS decontamination protocols were followed throughout the survey. Sampling was conducted under NJ Scientific Collecting Permit #SC2012114.

FINDINGS

A Phase 3 mist net sampling plan for the Weldon Brook WMA was submitted to, and approved by, the USFWS's NJ Field Office. The mist net sampling plan was developed based on the results of the Phase 2 acoustic monitoring conducted during 2013. Mist net sampling was conducted at each of the points where high frequency or Myotid calls were detected. No Indiana bats were captured during the surveys.

Table 1. Summary of 2014 bat captures at Weldon Brook WMA.

Survey Point Number	Number of bat captures		
	Myotis lucifugus	*Eptesicus fuscus*	*Lasiurus borealis*
1	0	1	0
2	0	0	0
7	1	17	7
8	0	13	1
Total	1	31	8

Pre-hibernation sampling was conducted at the Mt. Hope Mine-West Shaft on August 30- September 1, September 13-15 and October 4-6, 2013. A total of 351 Indiana bats were captured, including 122 first-time captures (unbanded) and 229 previously banded bats. Seven species were captured during the sampling effort including 42 little brown bats (*Myotis lucifugus*), 4 northern Myotis (*M. septentrionalis*), 20 small-footed Myotis (*M. leibii*), 5 tri-colored bat (*Perimyotis subflavus*), 5 big brown bats (*Eptesicus fuscus*) and 5 red bats (*Lasiurus borealis*).

An internal survey conducted at Hibernia Mine on March 24, 2013 failed to tally a single Indiana bat. However, several large clusters of Myotid bats were located inside approximately 6-in. diameter drill holes near the ceiling of the tunnel making it impossible to identify all bats to species. The last documented occurrence of an Indiana bat in Hibernia Mine was March 15, 2012.

DISCUSSION AND CONCLUSIONS

Since members of the *Myotis* (and often *Perimyotis*) genera are difficult to distinguish acoustically, all likely bat call data from this "high-frequency" group were combined and considered to be potential Myotid/Indiana bat calls. However, despite the presence of suitable roosting and foraging habitat, no Indiana bats were captured at Weldon Brook WMA. Despite the failure to capture any Indiana bats at Weldon Brook WMA, all forestry activities will remain subject to timing restrictions that would protect roost trees from being cut when bats are present. In addition, ENSP recommends that all suitable roost trees be retained during any forest management activity.

ENSP plans to conduct additional bat sampling at each of the wildlife management areas where the NJDFW is proposing to conduct forestry/habitat management activities that involve tree harvesting within a 10 mi. radius of the two known Indiana bat hibernacula. All sampling will follow the current USFWS guidelines for Indiana bat summer surveys.

FAIRS ACTIVITY CODES: 1450.

LITERATURE CITED

Sanders, C. 2013. Report on Indiana bat (*Myotis sodalis*) sampling at the Mount Hope Mine shaft west. Unpublished report to the NJ Division of Fish and Wildlife, Endangered and Nongame Species Program. January 30, 2014. 13 pp.

PERFORMANCE REPORT

STATE: New Jersey **PROJECT NUMBER**: E-1-36

PROJECT TYPE: Research and/or Management

PROJECT TITLE: Endangered and Threatened Wildlife Conservation

STUDY NUMBER AND TITLE: IV Invertebrate Wildlife Conservation

JOB NUMBER AND TITLE: V-1 Status, Survey and Protection of the Dwarf Wedgemussel

PERIOD COVERED: September 1, 2011 to August 31, 2014

JOB OBJECTIVES: To maintain, monitor and protect Dwarf wedgemussel (*Alasmidonta heterodon*) populations in New Jersey.

SUMMARY

We surveyed two Dwarf wedgemussel locations in the Pequest River, and conducted visual inspections throughout the area to document impacts of recent extreme weather events on known populations and habitats. Searches of the Pequest River at the lower boundary population boundary revealed no Dwarf wedgemussels or shells. Although some scouring of the substrate was apparent, the site may be more affected by the presence of a small dam, water quality issues, or some other unknown factor, than by recent weather events. Despite finding Dwarf wedgemussel shells at the second survey site, visual assessments showed significant habitat changes had occurred, especially in proximity to the road crossing. We believe that habitat changes were most likely due to the combined effects of Hurricane Irene and Tropical Storm Lee in 2011. The 2013 field season was dominated by poor weather conditions which severely hampered survey efforts.

STATUS

Completed. This report repeats the 2013-14 report as no additional work was funded in 203-14.

SIGNIFICANT DEVIATIONS

None.

RECOMMENDATIONS

1. Continue surveys for Dwarf wedgemussels in the Pequest River to determine population boundaries and distributions; focus quantitative survey efforts on occupied stretches of the river.
2. Continue assessing habitat in all Dwarf wedgemussel locations (Pequest River, Paulins Kill and Flatbrook River) to determine if recent hurricanes and other extreme weather events have impacted available habitat.
3. Conduct surveys in previously unsurveyed, suitable habitat with known populations of host fishes present.
4. Continue to work with the DEP's Division of Water Monitoring and Standards to upgrade stream classifications in areas that support Dwarf wedgemussel populations.

5. Identify areas in the Pequest River where stream bank restoration may benefit Dwarf wedgemussel populations.

COST
Federal share: $10,000; State share $1,000.00

BACKGROUND
The Dwarf wedgemussel once existed in 70 localities within 15 major Atlantic slope drainage basins from New Brunswick, Canada to North Carolina (Moser 1993). Today, however, this species is thought to be extirpated from all but approximately 32 small sites within 12 states. In New Jersey, the Dwarf wedgemussel occurs in the Paulins Kill (Sussex Co.), Pequest River (Warren Co.) and the Flatbrook (Sussex Co.) (Bowers-Altman 1997, Bowers-Altman 2000, Lellis 2002). In addition, there is one individual reported in the upper Delaware River, Sussex County (Lellis 2002).

Primary threats to freshwater mussel populations include degradation of water quality due to pollutants from industrial discharges, wastewater effluents, agricultural and residential chemical runoff, and siltation (Bogan 1993, Williams et al. 1993). Other threats to mussel populations include habitat degradation and disruption due to channelization and dredging, the introduction of exotic mollusks such as zebra mussels and Asian clams, and dams that disrupt the reproductive cycle by eliminating host fishes (Bogan 1993, Williams et al. 1993). Dwarf wedgemussels are also susceptible to overcollecting and loss of genetic diversity due to geographic isolation (Moser 1993).

Dwarf wedgemussel habitat ranges from muddy sand, to sand and gravel/pebble bottoms in rivers and creeks with slow to moderate currents (Moser 1993). Michaelson and Neves (1995) found that the species prefers fine over coarse substrate. It is often associated with submerged aquatic vegetation and can sometimes be found near stream banks underneath overhanging limbs (Master 1986). The species is known to co-occur with other freshwater mussels such as the Eastern elliptio (*Elliptio complanata*), Triangle floater (*Alasmidonta undulata*), Creeper (*Strophitus undulatus*), Eastern floater (*Pyganodon cataracta*) and Eastern lampmussel (*Lampsilis radiata*)(Master 1986).

Like most freshwater mussels, the Dwarf wedgemussel requires a host fish to support a parasitic life stage known as a glochidium. Michaelson and Neves (1995) identified three fish: the Mottled sculpin (*Cottus bairdi*), Johnny darter (*Etheostoma nigrum*) and Tessellated darter (*Etheostoma olmstedi*), that serve as Dwarf wedgemussel hosts. Schulz and Marbain (1998), citing work performed by B. Wicklow, Saint Anslem College, NH, reported the Slimy sculpin (*Cottus cognathus*) as another potential host fish for the species. Juvenile Atlantic salmon (*Salmo salar*) also serve as effective hosts for Dwarf wedgemussel larvae (Wicklow 2001).

PROCEDURES
We surveyed for Dwarf wedgemussels using a two phase sampling approach modeled after Smith *et al*. (1995) and Smith *et al.* (2001). Mussels were surveyed in wadeable water using bathyscopes and/or direct visual inspections, depending on depth and water quality conditions. We performed two hour timed searches in riffles, run, and pool habitats within a 500 meter stretch of the target stream. If two people were searching a segment, each individual searched one hour, three people searched 40 minutes, etc. If there was only one habitat type at a survey site, ideally two person-hour searches were performed in 125 meter stream sections. Although quantitative surveys were to be completed only if live Dwarf wedgemussels were found, we randomly sifted substrate during all searches. The ENSP-designed "sampling rake" was also used at one site in order to supplement visual searches. Preliminary findings

when comparing the rake to .25 m quadrats suggest that the rake is actually more effective at finding early life stage and smaller mussels, like the Dwarf wedgemussel (see NJ T-1-6, Sept. 2010-Aug 2011).

We surveyed each site by starting at the most downstream segment and worked our way upstream so that turbidity from movement did not obscure the view of the substrate. We examined substrate for exposed mussels, siphons and mussel trails and inspected shorelines for shells and relicts (old shells) at all survey sites. We recorded bivalve species present at each survey segment, along with the lengths and widths (mm) of all live listed mussels, shells and valves. Live specimens were carefully returned to the water in a normal life position, whereas vouchers of shells were taken from selected locations and placed in the ENSP freshwater mussel reference collection.

The following habitat information was recorded at each survey segment: habitat type (riffle, pool or run), substrate type, water temperature (^{o}C), depth (m), pH, segment length and width (m), dissolved oxygen (mg/L), and boundary coordinates (lat/long). In addition, an EPA Habitat Assessment Data Field Sheet following Barbour et al. (1999) was completed for each segment surveyed. Taxonomic nomenclature for freshwater mussels used in this report follows Turgeon *et al.* (1998).

FINDINGS

- We surveyed two separate locations in the Pequest River where live Dwarf wedgemussels have been documented; 1) just below the known lower population boundary of the at Furnace Brook Road, in Oxford Township, Warren County and 2) at Long Bridge Road, Allamuchy Township, Warren County (two separate trips).
- We examined habitat in two other areas of the Pequest River to determine if extreme weather events had significantly altered habitat; 1) Pequest Hatchery near train bridge and 2) another Long Bridge Road crossing, about one mile upstream from the above-mentioned survey site.

Furnace Brook Road, Oxford Township

- We surveyed three segments (one run, one run/riffle – 3.2 hour search time) at the Furnace Brook Road site, with one segment just below a small dam. Habitat was comprised of a sand/cobble/boulder mix, with more sand and fewer boulders in the segments upstream of the dam. Habitat score totaled 134 out of a possible 200. Despite large patches of suitable habitat, adequate flow, relatively stable substrate, and host fish present, only relict Eastern elliptio valves were found. There appeared to be some evidence of scouring, but not enough to severely impact mussels.
- At the uppermost upstream segment, we encountered a small, discolored tributary that gave off an odor resembling a volatile organic substance. The water trickled into the main stem where we were surveying, and quickly turned a white shirt sleeve orange. Despite efforts, we could not determine what was responsible for discoloring the water.

Long Bridge Road, Allamuchy Township

- We surveyed the Long Bridge Road site on two separate occasions, comprising six segments (five run, one pool) and ten hours search time. Habitat scores averaged 133.5. Although we did not find live Dwarf wedgemussels, we found two Dwarf wedgemussel shells (one relict, one fresh), one live Triangle floater (T) and two Triangle floater shells, one very fresh juvenile Creeper shell (SC), and 187+ live Eastern elliptio and 27 shells. We documented significant habitat changes since our last survey in 2008, both upstream and downstream of the road crossing. Substrate closer to the bridge had change from primarily gravel/sand mix to silt, and there were few live mussels found here. There appeared to be fairly significant scouring, especially downstream of the bridge. Habitat was

much more suitable in the upper reaches of the stretch, where most of the live mussels and shells were found.

CONCLUSIONS AND RECOMMENDATIONS

- The 2013 field season was dominated by poor weather conditions and staffing shortages. A late, cold spring was followed by precipitation throughout June, raining on 17 out of 30 days. A rainy June was followed by one of the hottest Julys on record. Rain and high water of June, and then unprecedented (and unsafe) high temperatures severely impacted survey efforts. As a result, we were unable to conduct surveys at the uppermost Pequest River boundary.
- It is unknown whether the site's water quality, the small dam near Furnace Brook Road and Rt. 46, or unknown factors are limiting expansion of Dwarf wedgemussels downstream. Although there was evidence of minimal scouring, there was still ample suitable habitat present. It does not appear that there were lasting effects from earlier extreme weather events.
- As we found during last year's survey in the Pequest River, Great Meadows, we believe that habitat change at the Long Bridge Road, Allamuchy Township site occurred during Hurricane Irene and/or Tropical Storm Lee event. Hurricane Irene hit the east coast in NJ during late August 2011, whereas Tropical Storm Lee severely impacted northern NJ counties September 6-11, 2011. The high, turbulent flows in the river during the hurricane are believed to have carried fine grained sediment into the Great Meadows survey area and significantly changed the habitat. Local residents and fishermen discussed habitat changes with the field crew during the 2012 Dwarf wedgemussel survey. They confirmed that the river had changed substantially after the hurricane, stating that during and immediately after the severe weather events, Cemetery Road was under water and substantially more sand and silt substrates were observed in the area of previous sightings.
- Similarly, there is anecdotal information that the Long Bridge Road site experienced the same unprecedented flooding as did the Cemetery Road site. Further, evidence of a significant flooding event is apparent, especially downstream of the road crossing, where substantial scouring has occurred. There appears to have been much erosion as well as bank undercutting in downstream sections. Habitat just upstream of the road crossing has changed from primarily sand/cobble to silt. In 2008, habitat scores averaged 163, compared to 133.5 in 2013, a fairly dramatic drop in a five year span.
- Unlike Hurricane Irene and Tropical Storm Lee, Superstorm Sandy (October 30, 2012) presented as more of a wind event in the northwestern parts of the state. Although there were many downed trees in the area, there was minimal flooding associated with the storm in Warren County. It is unlikely that the impacts to the Long Bridge Road site were caused by the storm
- Although we cannot conclude that the absence of live Dwarf wedgemussels at the Long Bridge Road site is due to impacts of Hurricane Irene and/or Tropical Storm Lee, we cannot rule out the possibility. There is still suitable habitat upstream where live individuals occurred in 2008. More surveys, especially upstream and adjacent to private property, should be conducted.
- Although there was evidence of minimal scouring at the Furnace Brook site, there was still ample suitable habitat present. It does not appear that there were lasting effects from earlier extreme weather events. Most likely, the small dam and prevalence of boulder/cobble/rocky substrate may limit Dwarf wedgemussels from establishing populations downstream. Just upstream at the Pequest River hatchery, there is evidence of scouring above the hatchery outfall near the train bridge.
- The increased frequency of extreme weather events poses a serious threat to Dwarf wedgemussel populations in NJ and elsewhere. Information from biologists at the National Park Service indicated that Dwarf wedgemussel areas in the Flatbrook, Sussex County, were severely impacted by flooding due to Hurricane Irene and Tropical Storm Sandy. Surveys conducted in 2012 by Biodrawversity

revealed that Dwarf wedgemussels had recently been found in a formerly unoccupied area of the Flatbrook. It may be that these individuals may have been carried in from occupied areas with the flooding. Also, flooding in the Paulins Kill was reported to have caused much erosion, sedimentation, and scouring; surveys in the Paulins Kill and Flatbrook should be conducted in impacted areas to update distributions.

- Continue surveys for Dwarf wedgemussels in the Pequest River upstream of Long Bridge Road to determine if population and distributions have changed; focus quantitative survey efforts on occupied stretches. Survey upper population boundary in Sussex County.
- Assess habitat in all NJ Dwarf wedgemussel locations to determine if recent hurricanes and other extreme weather events have impacted available habitat.
- Determine whether tributary encountered at the Furnace Bridge Road site is still discolored; measure pH and DO at outfall, and attempt to identify source.
- Identify Pequest River areas where stream bank and riparian restoration may benefit Dwarf wedgemussel populations and enhance resilience during flooding/extreme weather events.
- Continue to refine Category site selection process based on the presence of aquatic obligate species. Work with DEP's Bureau of Standards to recommend stream classification upgrades in areas with Dwarf wedgemussels and other listed freshwater mussels using the new methodology.

FAIRS

Activity code 1460.

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