# BIOLOGICAL OPINION ON THE EFFECTS OF EXISTING AND EXPANDED STRUCTURAL AQUACULTURE OF NATIVE BIVALVES IN DELAWARE BAY, MIDDLE AND LOWER TOWNSHIPS, CAPE MAY COUNTY, NEW JERSEY ON THE FEDERALLY LISTED RED KNOT (*CALIDRIS CANUTUS RUFA*)

Photo credit: G. Breese, USFWS

Photo credits: E. Schrading, USFWS

Prepared for:
U.S. Army Corps of Engineers
Philadelphia District
Philadelphia, Pennsylvania

Prepared by:
U.S. Fish and Wildlife Service
New Jersey Field Office
Galloway, New Jersey

Preparer:
Wendy L. Walsh

Assistant Project Leader:
Ron Popowski

Project Leader:
Eric Schrading

April 2016

# TABLE OF CONTENTS

## LIST OF FIGURES



## LIST OF TABLES

## ACKNOWLEDGEMENTS

The U.S. Fish and Wildlife Service's New Jersey Field Office appreciates the cooperation and perseverance of our partner agencies in developing the framework of Conservation Measures included in this document. Key agencies include the New Jersey Bureau of Shellfisheries (Russell Babb, Jenny Tomko, Craig Tomlin), the New Jersey Endangered and Nongame Species Program (Dave Jenkins, Amanda Dey), the New Jersey Department of Agriculture (Amanda Wenczel), and the U.S. Army Corps of Engineers, Philadelphia District (Jim Boyer, Sam Reynolds). Supporting agencies include the New Jersey Division of Land Use Regulation (Colleen Keller, Kristen Symanski), and the Natural Resources Conservation Service (Elizabeth McShane) within the U.S. Department of Agriculture.

## INTRODUCTION

This document represents the U.S. Fish and Wildlife Service's (Service) Biological Opinion, in accordance with Section 7 of the Endangered Species Act of 1973, as amended (87 Stat. 884, as amended; 16 U.S.C. 1531 *et seq*.) (ESA), on the effects of U.S. Army Corps of Engineers, Philadelphia District (Corps) authorizations for existing and expanded structural aquaculture in Middle and Lower Townships, Cape May County, New Jersey on the federally listed (threatened) red knot (*Calidris canutus rufa*). The proposed action includes all Corps authorizations for structural aquaculture of native bivalves over a 10-year period along approximately 6.5 miles (10.5 kilometers [km]) of Delaware Bay shoreline on the Cape May peninsula (the "action area," Figure 1). Definitions of selected terminology used in this document are provided in Appendix A, and a list of acronyms is given in Appendix B. Other that the red knot, no federally listed species under Service jurisdiction occur in the action area.

This Programmatic Biological Opinion (PBO) covers structural aquaculture of any native species of bivalve. Currently, the vast majority of commercially farmed bivalves in the action area are eastern oysters (*Crassostrea virginica*), primarily triploid (a genetic variant) oysters that have been developed for disease resistance. Hereafter in this document, we (the Service) frequently refer to the proposed action as "oyster growing" or "oyster farming," but we do not mean to imply exclusion of other native bivalve species that may be proposed for future aquaculture in the action area. Likewise, references to "shellfish" are not meant to imply inclusion of any farmed taxa other than native bivalves; [1] specifically, this PBO does not cover aquaculture of non-native bivalves, non-bivalve mollusks, or any arthropod species. Nor does this PBO cover aquaculture of finfish, algae or marine plants, or any other taxa besides native bivalves.

As evaluated in this PBO, structural aquaculture involves the tending and harvesting of native bivalves in bags, cages, or other structures. Currently, the vast majority of farming operations involve purchased (hatchery-produced, not wild) oyster "seed" grown to market size in bags that are laid on rebar racks on the intertidal flats (a "rack and bag" system). Smaller amounts of seed oysters are currently grown in bags suspended by floats, or in cages placed directly on the bay bottom. However, this PBO evaluates the possibility that the predominant structural methods may change over time, and that new structural gear or methods may be developed. This PBO <u>does not</u> cover non-structural (or "traditional") aquaculture, which typically involves moving "wild" oysters (*i.e.*, naturally occurring oyster populations, not from hatchery-produced seed) to favorable growing locations and/or the placement of shell for wild oyster recruitment ("shell planting"). Hereafter in this document, we use "aquaculture" interchangeably with "structural aquaculture," but we do not mean to imply inclusion of non-structural methods. Any references to non-structural aquaculture will be so specified.

Structural aquaculture may potentially impact red knots both directly and indirectly. In a literature review, Forrest *et al.* (2009) found that effects on birds from elevated oyster culture conceivably arise due to the alteration of food sources, displacement from foraging habitat, and as a result of disturbance related to farm activities. These are the same potential effects identified by the Service, the Corps, and several State agencies in the course of preparing the Biological Assessment (BA) for this consultation (NJDFW 2016). Best available science permits

[1] This usage of the term "shellfish" differs from the definition found in State law at N.J.S.A. Title 50.

a high degree of certainty regarding direct effects of structural aquaculture on red knots. Placement of gear on intertidal flats precludes red knots from foraging in those areas due to the physical presence of the gear because red knots will not or cannot forage under racks, cages, or floats. The presence of exposed gear during falling and low tides also likely precludes red knots from foraging for some distance between and around the gear, as the birds probably display some level of avoidance behavior due to the visual impact of the structures. These effects constitute functional loss of foraging habitat. In addition, structural aquacultural methods require frequent tending by oyster growers, which is likely to disturb red knots attempting to forage or roost in the area, thereby impacting the birds' already tight time and energy budgets. High levels of human activity may also suppress or entirely preclude red knot use (displace them from) an otherwise suitable habitat. In addition to causing disturbance, motor vehicles used in aquaculture can also cause rutting of the beach; can crush horseshoe crab[2] (*Limulus polyphemus*) adults, nests, or larvae; and can crush or disperse the wrack line, which accumulates horseshoe crab eggs and is thus an important component of red knot foraging habitat in Delaware Bay.

Far less certainty is associated with indirect effects. Some environmental benefits associated with structural aquaculture, such as shoreline protection, locally increased species richness from the presence of structure, and improved water quality, may indirectly benefit the red knot, but any linkage of such benefits to red knots is not clear. In addition, aquaculture could potentially impact horseshoe crabs through entanglement or entrapment; by blocking crab movements (especially of crabs moving to and from spawning beaches); and by impacting the quality, quantity or accessibility of horseshoe crab prey. Both the likelihood of these impacts occurring and their possible effects on red knots are uncertain, but are evaluated in this PBO using best available information.

During several reviews and consultations on Corps aquaculture authorizations, the Service and the Corps recognized that many of the endangered species issues encountered were similar from project to project. An initial set of Service recommendations dated December 11, 2014 andintended to avoid adverse effects to red knots proved insufficient to avoid aggregate effects to red knots from multiple aquaculture operations spread along the Cape May peninsula. Moreover, adoption of these recommendations would substantially impact the logistics and/or economics of many oyster farms due to access and other restrictions. Finally, absent a Biological Opinion, even growers following the 2014 recommendations were not authorized for any incidental take that may occur, leaving growers at risk of unintentional violations of the ESA. For these reasons, the Service, the Corps, and the New Jersey Division of Fish and Wildlife (NJDFW), within the New Jersey Department of Environmental Protection (NJDEP), determined that a programmatic approach to the consultation process was appropriate. In addition to addressing the issues listed above, completion of this PBO will also streamline and expedite future consultations on individual Corps authorizations for aquaculture in the action area, which are required under Section 7 of the ESA.

To ensure the protection of federally listed species, the Corps proposes to incorporate Conservation Measures (CMs) for the protection of the red knot into its aquaculture authorizations in the action area. The CMs were developed over six months of discussions by the

[2] Horseshoe crab eggs are the red knot's primary food source during the birds' May stopover in Delaware Bay, a key part of their long northbound migration to Arctic breeding grounds. See Species Status for more details.

Corps, the NJDFW (primarily the Bureau of Shellfisheries (BSF) and the Endangered and Nongame Species Program [ENSP]), the New Jersey Department of Agriculture (NJDA), and the Service. Concurrent with these discussions, the NJDFW and NJDA provided opportunities for feedback from certain outside parties, primarily oyster growers and environmental organizations active in the action area.

For the purposes of this programmatic consultation, the Service has evaluated the proposed action (namely, continued and expanded structural aquaculture) with the CMs as proposed in the BA (NJDFW 2016). These same CMs are listed—with some revisions agreed to by NJDFW—in this PBO. We also considered other information provided by the Corps, NJDFW, and NJDA, and discussions with these same agencies as listed under Consultation History, below. A complete administrative record of this consultation is on file in the Service's Ecological Services, New Jersey Field Office.

Programmatic consultation involves a two-tiered approach. Tier 1 consists of the programmatic consultation on the overall agency program[3] while Tier 2 involves streamlined consultations on individual actions carried out under a program. Individual Corps authorizations must continue to undergo individual (Tier 2) consultation to ensure consistency with the Project Description as given in this PBO (including all CMs), as well as consistency with the Reasonable and Prudent Measures (RPMs) and Terms and Conditions (TCs) of this PBO. Site-specific information for individual authorizations will also be evaluated by the Service to ensure continued consistency with the conclusions in this PBO regarding effects to the red knot, as well as the level of take anticipated in the Incidental Take Statement.[3] Proposed actions conforming with all provisions of this PBO will receive expedited review by the Service. Individual actions or activities that cannot be designed or carried out to conform to the CMs, or actions that will exceed the anticipated level of adverse effects or incidental take[3] described in this PBO, will require individual consultations and Biological Opinions. The Service will re-evaluate this programmatic consultation annually to ensure that its continued application will not result in unacceptable effects on the red knot. This PBO is intended to allow for adaptive management of structural aquaculture as it relates to effects on red knots. The NJDEP, the NJDA, the Corps, and the Service commit to periodic review of the CMs in light of new information (see CM 6). These agencies agree that the CMs may be altered by mutual agreement, so long as the types and levels of adverse effects (including incidental take) described in this PBO, and in any subsequent Tier 2 consultation documents, are not exceeded.

There is currently no critical habitat designated for the red knot. The Service expects to publish a proposed rule to designate red knot critical habitat some time in 2016. If all or part of the action area is proposed or designated critical habitat in the future, the Corps and the Service will need to

[3] Consistent with final regulations published May 11, 2015 (*Federal Register* Vol. 80, No. 90, p. 26845), this PBO evaluates a "mixed programmatic action." As such, the Incidental Take Statement included with this PBO is only for those program actions that are reasonably certain to cause take and are not subject to further Section 7 consultation. Additional incidental take resulting from actions subsequently authorized by the Corps will be assessed in the Tier 2 consultation process.

re-initiate consultation and review this PBO to ensure that the covered activities are not likely to destroy or adversely modify[4] critical habitat.

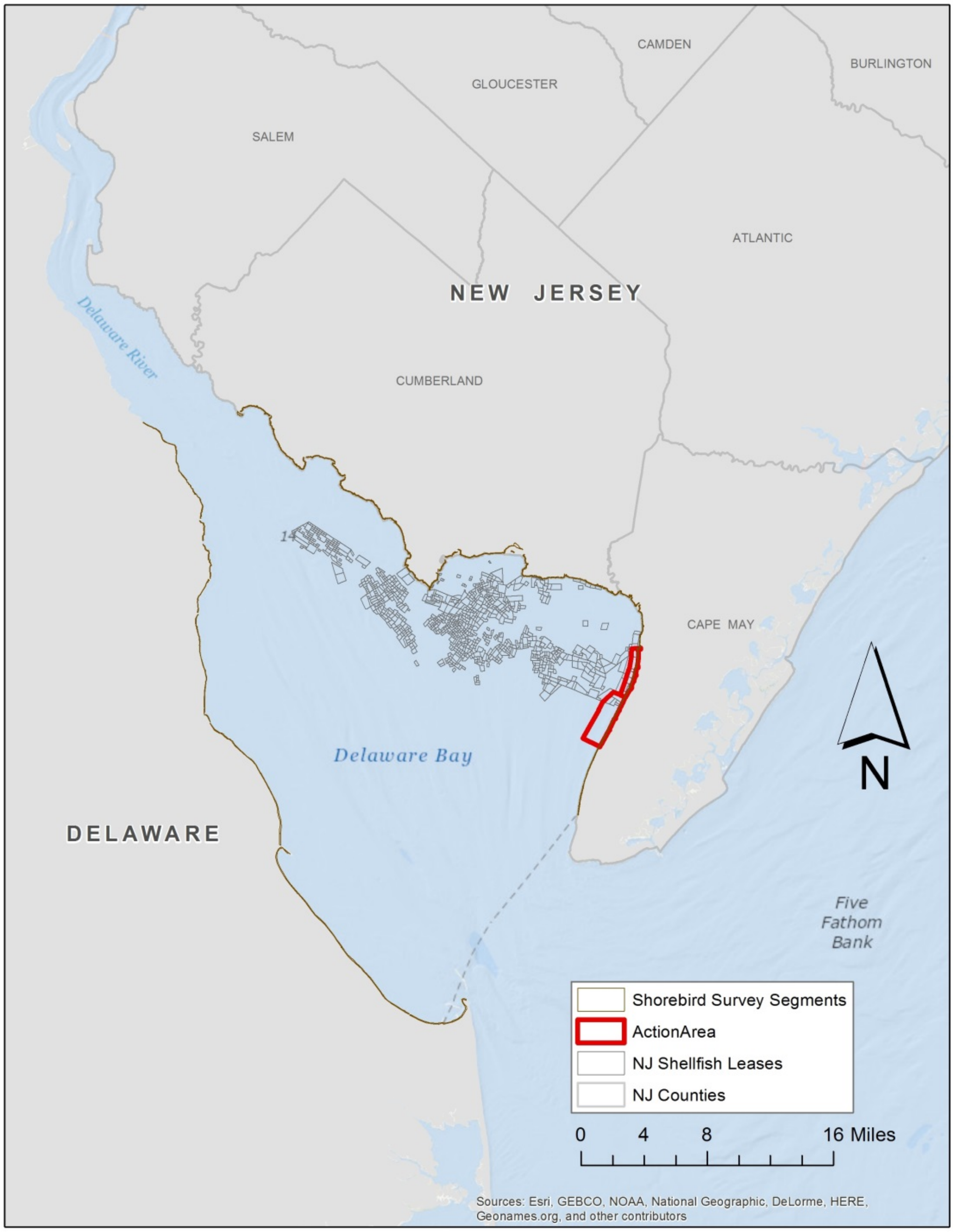


**Figure 1. Action area overview, Cape May Peninsula, Cape May County, New Jersey**

[4] A final regulation published February 11, 2016 (*Federal Register* Vol. 81., No. 28, p. 7214) established the following new definition, "Destruction or adverse modification means a direct or indirect alteration that appreciably diminishes the value of critical habitat for the conservation of a listed species. Such alterations may include, but are not limited to, those that alter the physical or biological features essential to the conservation of a species or that preclude or significantly delay development of such features." Background information on critical habitat is available in this fact sheet: https://www.fws.gov/endangered/esa-library/pdf/critical_habitat.pdf.

## CONSULTATION HISTORY

### BACKGROUND

The action being evaluated in this PBO is the Corps' authorization of existing and expanded structural aquaculture of native bivalves along a roughly 6.5-mile-long (10.5-km-long) section of Delaware Bay shoreline on the Cape May peninsula in New Jersey (the "action area," Figure 1). Service involvement and review of structural aquaculture in this area dates to the late 2000s, when the NJDFW was working on siting for a proposed Aquaculture Development Zone (ADZ). At the time, the red knot was a candidate for Federal listing, meaning the Service had determined listing was warranted but precluded by other high priority listing actions. At the request of the Corps and the ENSP, the Service provided technical assistance regarding the siting and operation of ADZ-4, which is currently the only ADZ section that includes intertidal areas (and thus the only ADZ that directly overlaps with red knot habitat).

With ENSP and Service input, the Corps issued permit CENAP-OP-R-2010-1051-24 to the NJDFW to create three ADZs within Delaware Bay. The permit is dated August 8, 2011, was modified February 28, 2012, and expires December 31, 2021. The authorized project involves sub-leasing portions of the bay bottom to individual growers for the placement of structures to grow native shellfish (*i.e.*, structural aquaculture). The three sites are located offshore from Middle Township, Cape May County, New Jersey. Two of the areas are located approximately 5 miles (8 km) offshore (ADZ-2 and ADZ-3, both outside the action area of this PBO), while a third area (ADZ-4) is located in the nearshore area about 1 mile (1.6 km) south of Pierces Point and within the action area. A fourth area (ADZ-1) was eliminated from the original proposal. The existing ADZ permit includes conditions developed with ENSP and Service input to avoid the most severe adverse effects to red knots. From May 1 to June 7, the permit limits access at ADZ-4 to 2 hours before and 2 hours after low tide, requires shore-parallel vehicle and pedestrian travel to be at least 100 feet (30 meters [m]) waterward of the Mean High Water (MHW) line, and requires that all gear be at least 200 feet (61 m) waterward of the MHW line.

In 2012 and 2013, the Service provided technical assistance review of a proposed oyster farm on Lease A-19 (Figure 2). Via Nationwide Permit 48 (NWP-48), the Corps authorized the Dias Creek Oyster Company to operate on Lease A-19 on October 24, 2012, with a modification on November 19, 2013 (CENAP-OP-R-2012-798-24). As with all the NWPs, this authorization expires on March 18, 2017.

The red knot was proposed for listing as a threatened species on September 30, 2013, triggering certain provisions under Section 7 of the ESA. A final listing rule was published December 11, 2014, with an effective date of January 12, 2015, triggering the full Section 7 consultation requirements.

As mentioned previously, during several reviews and consultations on Corps aquaculture authorizations, the Service and the Corps recognized that many of the endangered species issues encountered were similar from project to project. An initial set of Service recommendations (dated December 11, 2014) intended to avoid adverse effects to red knots proved insufficient to avoid aggregate effects to this species from multiple aquaculture operations spread along the

Cape May peninsula. Moreover, adoption of these recommendations would substantially impact the logistics and/or economics of many oyster farms due to access and other restrictions. Finally, absent a Biological Opinion, even growers following the 2014 recommendations were not authorized for any incidental take that may occur, leaving growers at risk of unintentional violations of the ESA. For these reasons, the Service, the Corps, and the NJDFW determined that a programmatic approach to the consultation process was appropriate. In addition to addressing the issues listed above, completion of this PBO will also streamline and expedite future consultations on individual Corps authorizations for aquaculture in the action area, which are required under Section 7 of the ESA.

## CHRONOLOGY OF KEY CORRESPONDENCE, MEETINGS, AND COMMUNICATIONS

During informal consultation and following initiation of formal consultation, the Corps, NJDFW, NJDA, and the Service have participated in numerous meetings and engaged in regular communications via telephone, email, and webinar to exchange information, delineate the scope of the programmatic consultation, and develop and refine the CMs that will apply to all structural aquaculture in the action area authorized by the Corps under the Tier 2 process. A chronology of key correspondence and meetings is provided below.

| | |
|---|---|
| September 30, 2013 | The red knot was proposed for listing as a threatened species under the ESA. |
| April 8, 2014 | The Corps, the Service, BSF, ENSP, the Division of Land Use Regulation (DLUR), and the National Marine Fisheries Service (NMFS) met to discuss aquaculture permitting and consultation. |
| November 7, 2014 | The Corps, DLUR, BSF, ENSP, and the Service met to discuss aquaculture permitting and consultation. |
| November 25, 2014 | The BSF, ENSP and the Service held an informational meeting with several oyster growers. |
| December 9, 2014 | The Corps, DLUR, BSF, ENSP, Rutgers University (Rutgers), the Service, and several oyster growers met to discuss forthcoming Service recommendations for avoiding adverse effects to red knots. |
| December 11, 2014 | The Service issued a documented entitled *Recommendations for Red Knot Conservation Measures (Permit Conditions for NWP-48) in Delaware Bay Native Shellfish Aquaculture Lease Areas* (hereafter, “2014 recommendations”). |
| January 12, 2015 | The red knot was listed as a threatened species under the ESA. |

| | |
|---|---|
| January 23, 2015 | Service staff attended an Aquaculture Advisory Council (AAC) meeting to update Council members on ESA consultations. The Service informed the AAC that, due to limited staff time, Service staff would not begin work on a consultation for the ADZ for several months and that, in the interim, the existing permit conditions would remain in effect. |
| January 30, 2015 | Service staff met with several growers and representatives from the Rutgers Haskin Shellfish Research Laboratory (Haskin Lab) for a site visit of ADZ-4 and nearby existing and proposed aquaculture operations. |
| February 5, 2015 | Via letter to Atlantic Capes Fisheries, Inc., the Service responded to various questions from several oyster growers. |
| February 6, 2015 | In accordance with the 2014 recommendations, the Service released a Delaware Bay Red Knot Use Classification, as well as red knot habitat mapping for Leases A-19, A-28, and A-29 (Figures 2 and 3). |
| February 18, 2015 | The Service met with the representatives of the Sweet Amalia Oyster Farm regarding an application to the Corps to begin operating on Lease A-28. |
| February 19, 2015 | Via letter, the Corps initiated consultation for its existing permit for the ADZs, due to the listing of the red knot. |
| March 2, 2015 | The Service hosted a meeting to discuss an upcoming Rutgers study to investigate the potential for aquaculture activities to disturb red knots. In attendance were Rutgers, BSF, ENSP, NJDA, American Littoral Society, New Jersey Audubon Society, individual oyster growers, and the Service. A Coordinating Group was established to coordinate study goals, methods, and logistics relative to the information needs of upcoming ESA consultations, and to coordinate with other studies/monitoring taking place in the area. The Coordinating Group includes three Principal Investigators from Rutgers as well as representatives from Rutgers' Haskin Lab, BSF, ENSP, and the Service. Year one of the study was funded by BSF and ENSP, and data collection occurred in May and June 2015. Years two and three are planned for 2016 and 2017, to be funded by New Jersey Sea Grant. |
| March 23, 2015 | The Service met separately with growers operating on Lease A-19 (Dias Creek Oyster Company) and Lease A-29. |
| April 1, 2015 | Service staff attended an Endangered and Nongame Species Advisory Committee (ENSAC) meeting to update Committee members on ESA consultations related to aquaculture. |

| | |
|---|---|
| April 2, 2015 | Via letter, the Service concurred with the Corps' determination that authorization for the Sweet Amalia Oyster Farm on Lease A-28 was "not likely to adversely affect" the red knot. Service concurrence was based on inclusion of the 2014 recommendations as permit conditions. |
| April 6, 2015 | Via Nationwide Permit 48 (NWP-48), the Corps authorized the Sweet Amalia Oyster Farm to operate on Lease A-28 (CENAP-OP-R-2014-970-24). As with all the NWPs, this authorization expires on March 18, 2017. |
| April 6, 2015 | Via letter, the Service informed the Corps that limited staff resources precluded starting work on consultation for the ADZs. |
| April 27, 2015 | Via email, the Service disseminated an Aquaculture Update to a broad distribution list of interested parties. The update covered permitting and the Rutgers study. |
| April 30, 2015 | The Coordinating Group for the Rutgers study conducted a site visit of ADZ-4 and nearby areas. |
| May 5, 2015 | The Coordinating Group for the Rutgers study held a field training for the study team, including many seasonal interns. |
| May 11, 2015 | The Service and NMFS published a rule (*Federal Register* Vol. 80, No. 90, pp. 26832-26845) clarifying that, for a framework programmatic action, an Incidental Take Statement is not required at the programmatic level. Any incidental take resulting from any action subsequently authorized, funded, or carried out under the program will be addressed in subsequent (Tier 2) Section 7 consultation, as appropriate. |
| June 5, 2015 | The Corps, BSF, ENSP, NJDA, DLUR, the Natural Resources Conservation Service (NRCS, within the U.S. Department of Agriculture) and the Service met to discuss consultation for ADZ-4 and the possibility of expanding to a programmatic consultation. The agencies agreed formal consultation was necessary, but did not agree on the scope of the consultation (*i.e.*, ADZ-4 only, or programmatic covering a larger area). |
| June 12, 2015 | Via letter, the Service noted a May 7, 2015 electronic mail informing the Corps that staff resources were now available to start work on consultation for the ADZs. The Service encouraged the Corps to opt for programmatic consultation, rather than limit the consultation to ADZ-4. |
| July 1, 2015 | The Corps, BSF, ENSP, and the Service met and tentatively agreed to pursue programmatic formal consultation for an action area extending from Bidwell Creek in Middle Township to the north end of Villas in Lower Township (Figures 1 to 3). The action area includes ADZ-4 and all |

| | |
|---|---|
| | private leases (A-19, A-28, A-29) and riparian grants for which permitting was in progress or structural aquaculture was in place at the time. |
| July 17, 2015 | Service staff attended an AAC meeting to update Council members on ESA consultations related to aquaculture, including the programmatic consultation. |
| August 11, 2015 | The Corps, BSF, ENSP, NJDA, and the Service met to discuss the programmatic consultation. |
| August 19, 2015 | The BSF, ENSP, NJDA, and the Service met to discuss the programmatic consultation. |
| September 3, 2015 | The BSF, ENSP, NJDA, and the Service met to discuss the programmatic consultation. |
| September 9, 2015 | Service staff attended an ENSAC meeting to update Committee members on ESA consultations related to aquaculture, including the programmatic consultation. |
| September 14, 2015 | Via letter to the New Jersey Bureau of Tidelands Management (BTM), the Service's Cape May National Wildlife Refuge (CMNWR) provided comments as the upland landowner adjacent to proposed or existing oyster farms on Leases A-28 and A-19. The letter stated that CMNWR did not object to aquaculture activities adjacent to the Refuge provided such activities are carried out in accordance with the applicable consultation document(s) as finalized between the Corps and the Service's New Jersey Field Office under Section 7 of the ESA. |
| September 17, 2015 | The BSF, ENSP, NJDA, and the Service met to discuss the programmatic consultation. |
| September 29, 2015 | The BSF, ENSP, NJDA, and the Service met to discuss the programmatic consultation. |
| October 8, 2015 | The BSF, ENSP, NJDA, and the Service met to discuss the programmatic consultation. |
| October 15, 2015 | The Corps, BSF, ENSP, NJDA, and the Service held an informational meeting with growers and lease holders potentially affected by the programmatic consultation. |

| | |
|---|---|
| October 19, 2015 | The Corps, BSF, ENSP, NJDA, and the Service held an informational meeting about the programmatic consultation with environmental organizations active in Delaware Bay shorebird issues. Two growers were also present for part of the meeting to answer questions. |
| October 19, 2015 | The NRCS announced extension of opportunities to the aquaculture industry. The Aquaculture Initiative available through the Environmental Quality Incentives Program (EQIP) will provide technical and financial assistance through Fiscal Year 2016 to address excessive shoreline erosion, fish and wildlife habitat degradation, and inefficient energy use from equipment and facilities, among other issues. |
| October 22, 2015 | The Corps, BSF, ENSP, NJDA, and the Service met to discuss the programmatic consultation. |
| October 28, 2015 | Via email, the Service disseminated an Aquaculture Update to a broad distribution list of interested parties. The update covered permitting, programmatic consultation, and the Rutgers study. |
| October 29, 2015 | Via letter, the Service supported a funding application by Atlantic Capes Fisheries, Inc. to test if oysters can be grown from seed to market size on offshore leases, with the market oysters then returned to intertidal flats for "seasoning." The Service supported this proposal because, if successful, these methods could allow for increased oyster production within a given footprint of intertidal flats. Subtidal methods could also potentially shift the timing that oysters need to be on the flats, if seasoning can take place after the red knots leave the bay in early June. |
| October 30, 2015 | Service staff attended an AAC meeting to update Council members on the programmatic consultation. |
| November 3, 2015 | Via letter, the Service concurred with the Corps' determination that authorization of Atlantic Cape Fisheries, Inc. to place oyster cages on Lease A-160 (located 2.25 miles (3.6 km) offshore at its closest point, entirely outside the action area for this PBO) was "not likely to adversely affect" the red knot, based on distance from shore (CENAP-OP-R-2015-127-24, NWP-48). |
| November 12, 2015 | The Corps, BSF, ENSP, and the Service met separately with oyster growers operating or authorized to operate on Leases A-19, A-28, and A-29 to discuss how permitting for their farms would be affected by the programmatic consultation. |
| November 18, 2015 | Service staff attended an ENSAC meeting to update Committee members on the programmatic consultation. |

| | |
|---|---|
| December 10, 2015 | Service staff attended a Delaware Bayshore Council (DBC) meeting to update Council members on the programmatic consultation. |
| December 23, 2015 | Via letter, the Service concurred with the Corps' determination that authorization of Elder Point Oyster Company to place oyster cages on multiple leases located 1 mile (1.6 km) offshore at their closest point (entirely outside the action area for this PBO) was "not likely to adversely affect" the red knot, based on distance from shore (CENAP-OP-R-2007-123-524, NWP-48). |
| January 21, 2016 | The BSF, ENSP, NJDA, and the Service met to discuss the programmatic consultation. |
| February 10, 2016 | The NJDFW transmitted its BA for the programmatic consultation to the Corps. |
| February 11, 2016 | The Corps transmitted the BA to the Service, starting the 90-day timeline specified in Federal regulations at 50 CFR 402.14(e). |
| February 25, 2016 | On behalf of the NJDFW, the ENSP submitted Appendix C of the BA, supplemental information. |

## BIOLOGICAL OPINION

### ACTION AREA

#### Action Area Limits

The NJDFW, NJDA, and Corps, in consultation with the Service, delineated an action area for this consultation extending approximately 6.5 miles (10.5 km) along the Delaware Bay shoreline on New Jersey's Cape May peninsula, from Bidwell Creek in Middle Township to West Miami Avenue in the Miami Beach section (part of Villas) of Lower Township, Cape May County (Figures 1 to 3). The agencies limited the consultation to this action area for several reasons.

1. Leases farther offshore were excluded from the action area because aquaculture activities (both structural and traditional) away from shore are expected to have minimal or no adverse effects on red knots.

2. The lower portion of the Cape May bayshore (south of West Miami Avenue) was excluded because it offers low potential for expansion of intertidal aquaculture. Within Miami Beach and Villas, high-density residential development is considered to preclude intertidal aquaculture due to high user conflicts. South of Villas, the intertidal flats begin to narrow.

3. Portions of New Jersey's bayshore north of Bidwell Creek were excluded because there is currently no structural aquaculture in these areas, and there are no Corps authorizations or pending applications for structural aquaculture in these areas. The intertidal flats are also comparatively narrow relative to those in the action area.

Federal regulations implementing the ESA define the "action area" as all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR 402.02). Under Effects of the Action, below, we have evaluated the potential for the proposed action to adversely affect red knots outside of the action area, as it was defined by the above-listed agencies. In particular, we have assessed the potential for baywide impacts on horseshoe crabs, which could indirectly affect red knots. We have concluded that no measurable effects to red knots outside the agency-established action area are expected (see Baywide Effects, below). Thus, this action area encompasses the full geographic scope that must be considered in this PBO.

**Subdivision of the Action Area**

As described under Species Status, below, Delaware Bay is the single most important migration stopover for the red knot, supporting an estimated 50 to 80 percent of all rufa red knots during the month of May (USFWS 2014). Even parts of the bay with <u>relatively</u> lower red knot use support considerable numbers of birds compared to other Atlantic coast stopover habitats. Notwithstanding the overall importance of Delaware Bay to the red knot, the NJDFW, NJDA, and Corps, in consultation with the Service, undertook an assessment of best available data regarding the <u>relative</u> levels of red knot use across the action area. The agencies undertook this assessment to determine if a reasonable way to minimize conflicts between red knots and aquaculture might be subdividing the action area. In one portion of the action area, aquaculture would be clustered, facilitated, and expanded, recognizing that there would be localized adverse effects to red knots in this portion. In the other portion of the action area, red knot conservation and recovery would be prioritized over development of new oyster farms, partially as a compensatory mitigation measure to offset red knot impacts in the other (aquaculture) portion.

In determining whether and where to subdivide the action area, the agencies first evaluated best available data regarding levels of red knot usage. The ENSP has conducted annual, baywide, red knot surveys in Delaware Bay since 1986, with multiple counts per year (also see Species Status and Environmental Baseline, below). The agencies analyzed this 29-year data set (1986 to 2014) of red knot counts, which is broken down into 81 survey segments, of which 48 segments are in New Jersey (Figures 1 to 3). The agencies recognized that the geographic distribution of red knot usage has shifted in response to population trends over the 29-year period. They considered a partial time series looking only from 2009 to 2014 (following a period of steep population declines) as a reasonable representation of the current distribution. However, they did not discount areas that were relatively more important during earlier years, since such areas will be needed to accommodate the recovery and continued redistribution of the population from its current low level. Thus, the agencies also considered the full time series of 1986 to 2014.

The agencies summed all red knot counts across all survey dates and years for each segment. Summing all counts in a segment results in a metric that reflects both the magnitude and consistency (inter- and intra-annual) of use (*e.g.*, year-to-year, early as well as late in the stopover season). A similar method (summing all counts) was used by Niles *et al*. (2008) in a status assessment for the red knot. For each time period, the agencies used Microsoft Excel's Percentrank.inc function to calculate the percentile of each segment's total count (*i.e.*, that segment's relative position (or rank) in the 48-segment data set, on a scale from 0 to 100). The percentiles provide a metric that can be compared across time periods. Because the survey segments are various lengths, the agencies also used ESRI ArcMap to calculate the approximate area (in acres) of each segment. They then divided each segment's red knot total count by that segment's acreage, and calculated another set of percentiles. Although the segments were not delineated or mapped for this purpose, this exercise does allow comparison across segments at least roughly controlling for their different sizes. The four maps presented in Figures 4 to 7 show each time period, both based on the raw total counts and based on the area-adjusted totals. The legend on each map color codes the percentiles in 20-point intervals to allow visual comparisons among the maps.

The NJDFW, NJDA, and Corps, in consultation with the Service, drew the following conclusions.

1. All four maps in Figures 4 to 7 show a general pattern of higher red knot use in the northern portion of the action area and <u>relatively</u> lower use in the southern portion.

2. The majority of current aquaculture operations is in the southern portion. The southern area also offers potential for ADZ expansion, which the northern area does not due to existing private leases (see Background on Aquaculture, below).

3. The tidal flats are wider in the south. Wider flats offer more space for aquaculture, and possibly lower potential for bird disturbance if knots are more spread out at lower tides.

4. By looking at the "big picture" of both industry and the red knots, the agencies attempted to minimize conflicts by dividing the area into two complementary management zones. To the north—where tidal flats are narrower, red knot use is highly concentrated, and aquacultural use is low—the emphasis is on red knot conservation. To the south—where flats are wider, knot use is somewhat lower, and aquaculture is already well-established—the emphasis is on providing sufficient space, flexibility, and support to allow for aquaculture expansion.

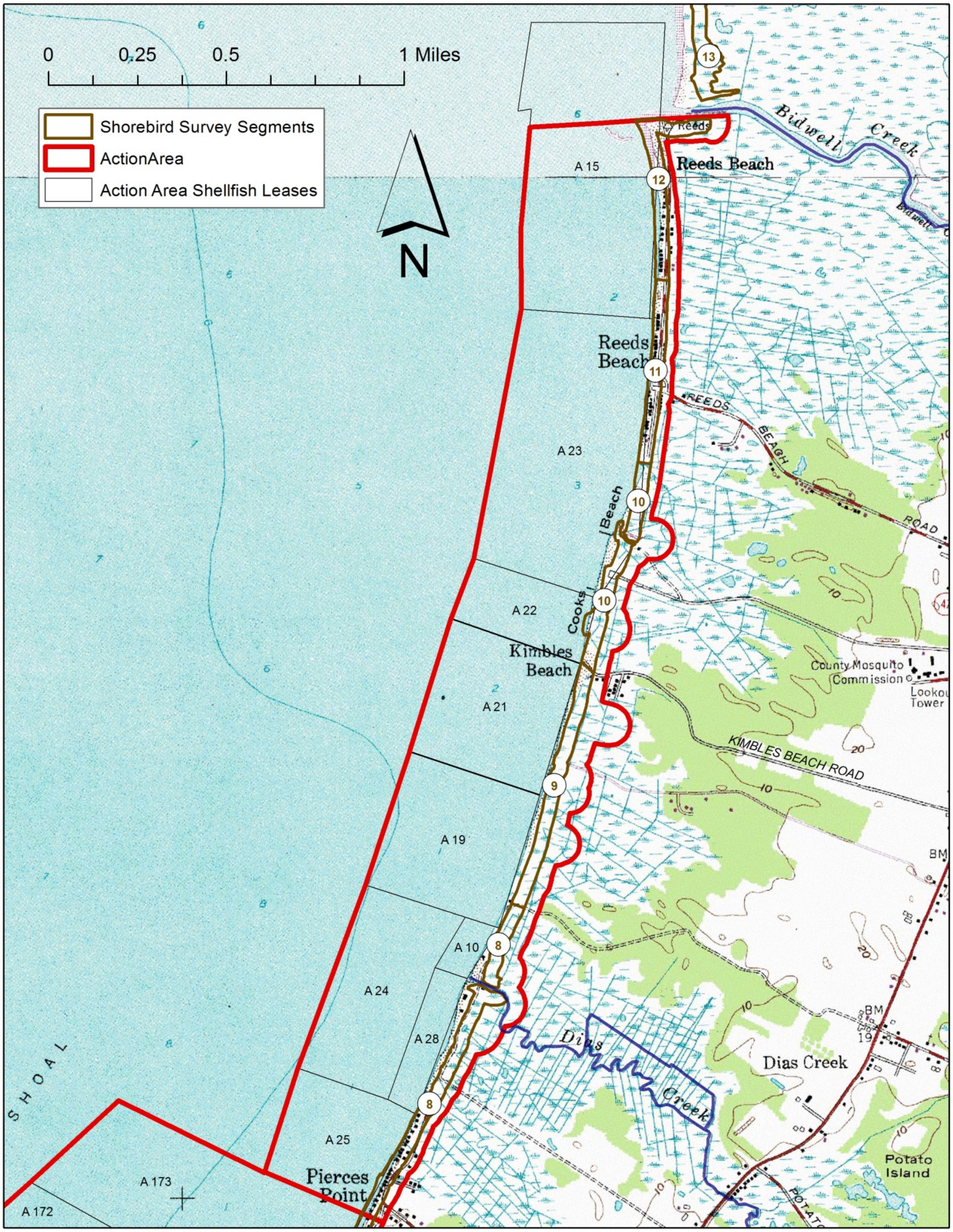


**Figure 2. Northern Segment overview**

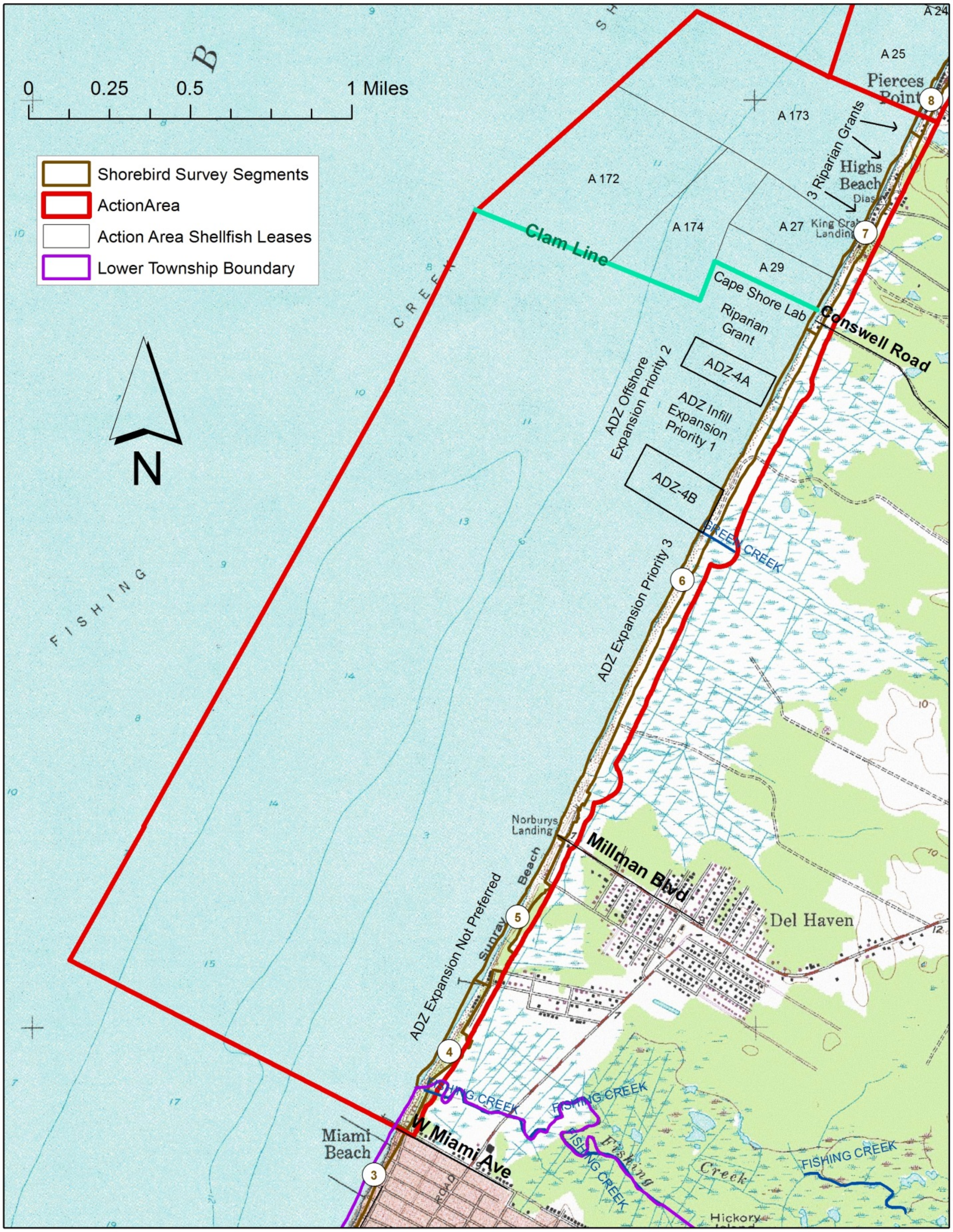


**Figure 3. Southern Segment overview**

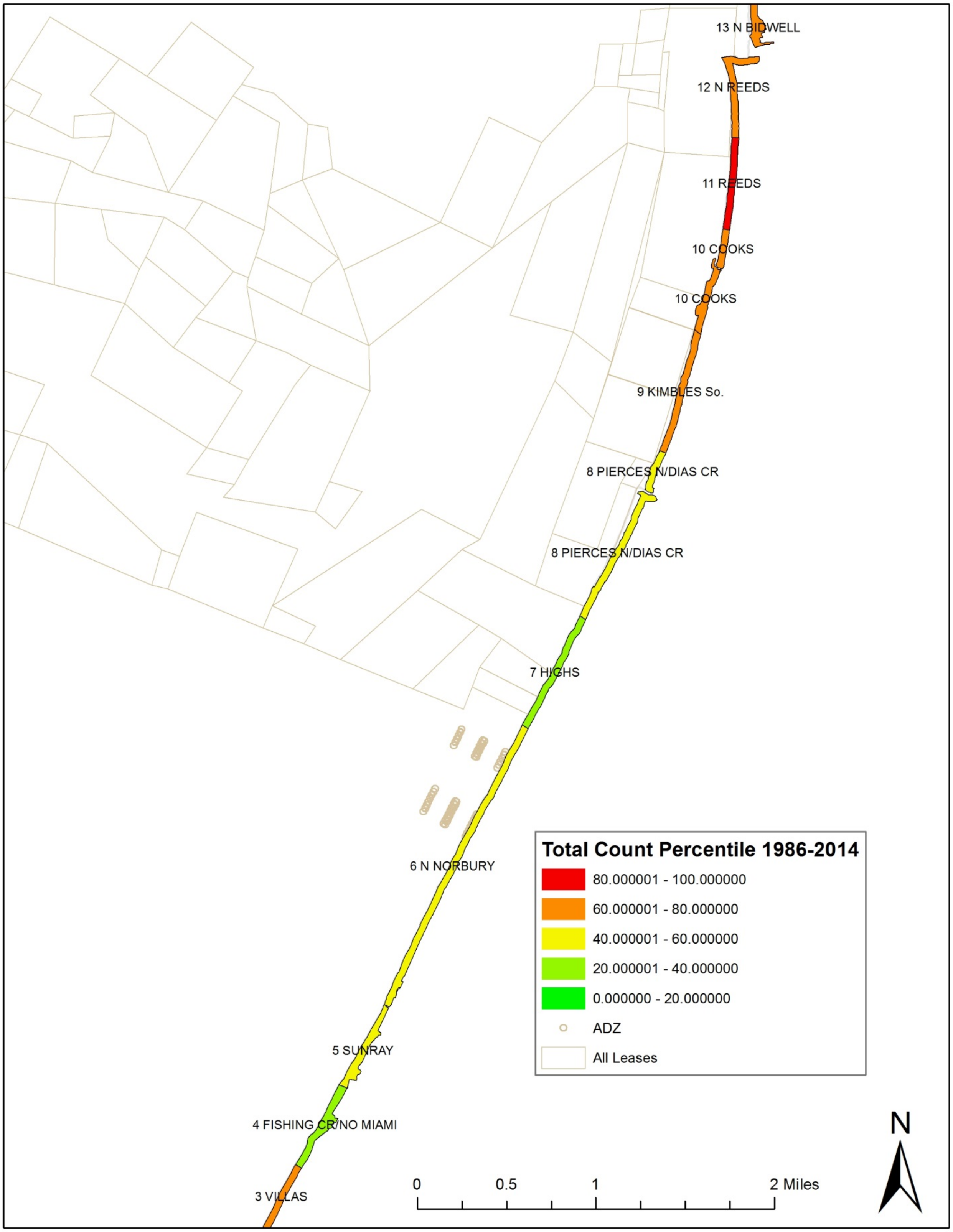


**Figure 4. Survey segment percentiles within New Jersey based on sum of all red knot counts 1986 to 2014**

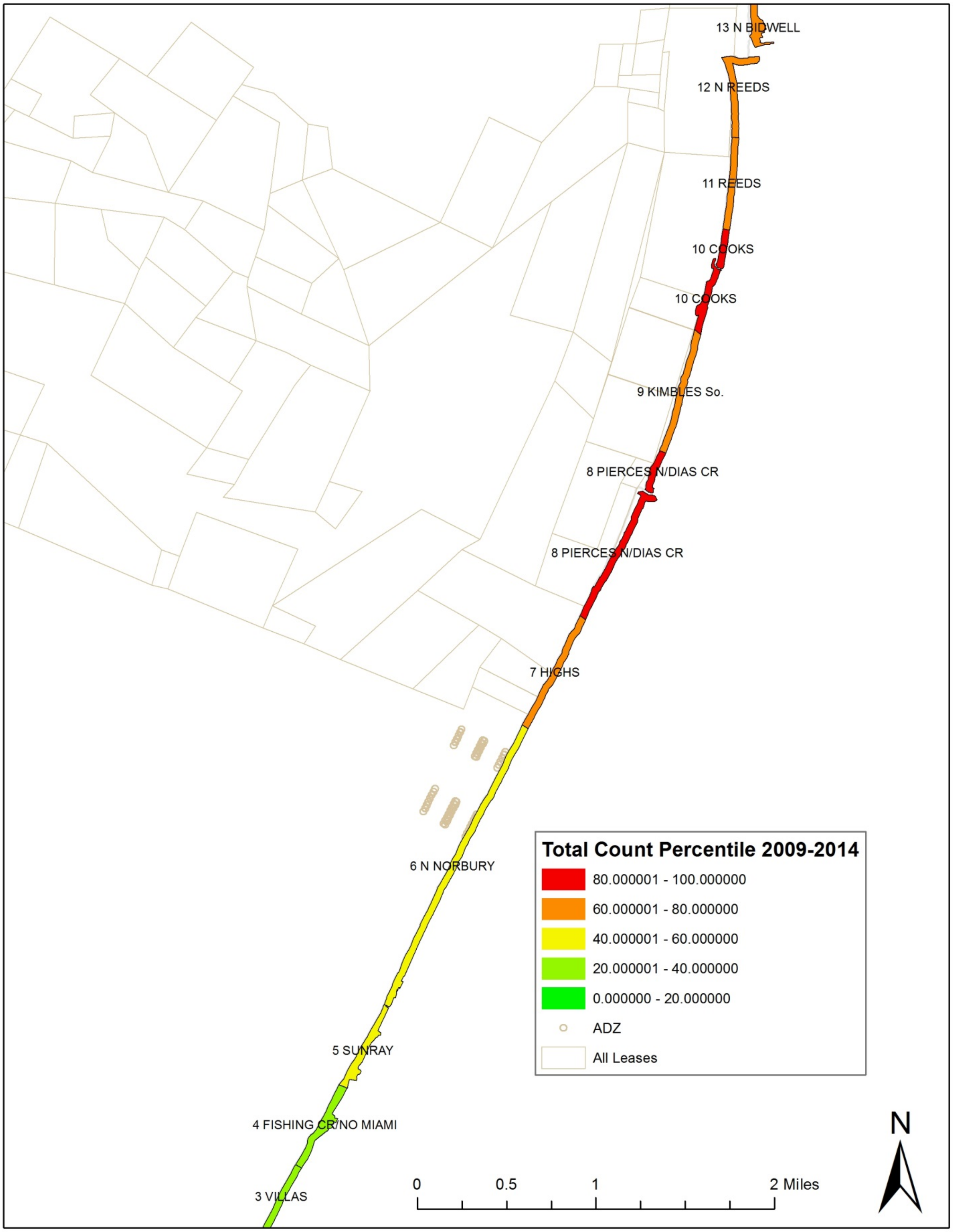


**Figure 5. Survey segment percentiles within New Jersey based on sum of all red knot counts 2009 to 2014**

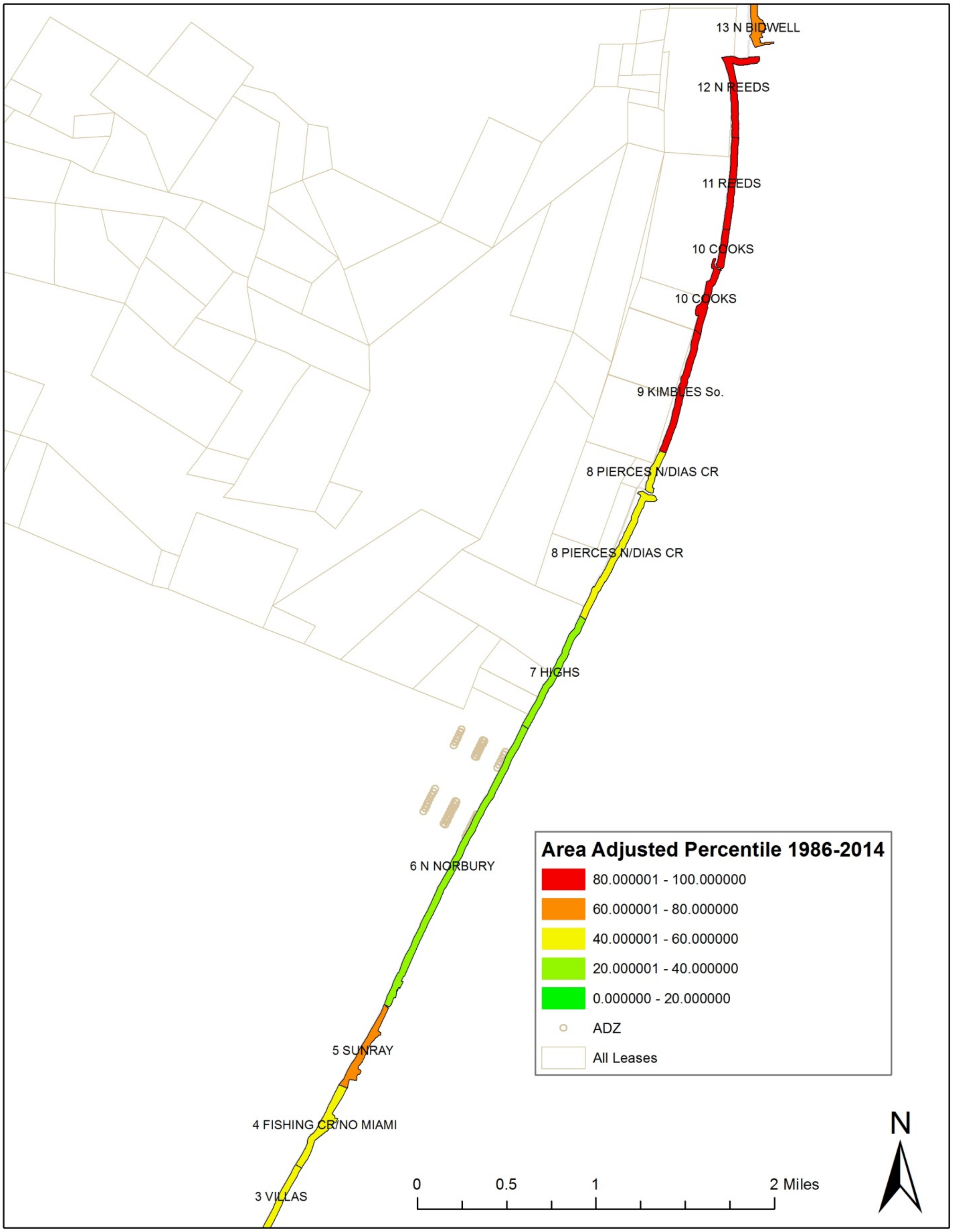


**Figure 6. Survey segment percentiles within New Jersey based on area-adjusted sum of all red knot counts 1986 to 2014**

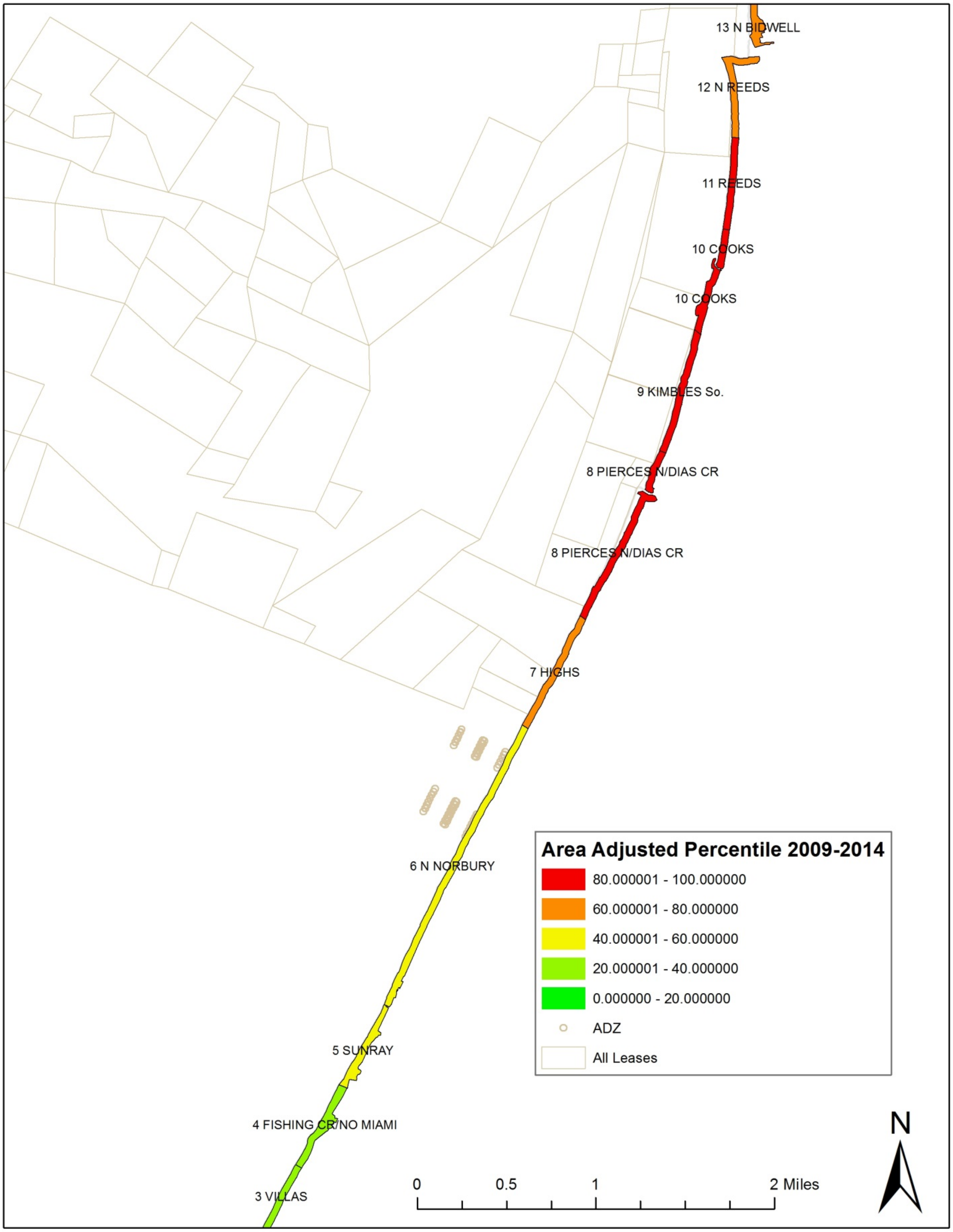


**Figure 7. Survey segment percentiles within New Jersey based on area-adjusted sum of all red knot counts 2009 to 2014**

## Northern Segment Limits

The Northern Segment consists of valid riparian grants and individual leases beginning at Bidwell Creek (in the north) and extending south about 3 miles (4.8 km) to a line at the northern inshore corner No. 2 of shellfish Lease A-173 (39.083N / 74.907W). A land-based reference for this lease is south of the northern extent of Pierces Point Road, where it intersects with Beach Avenue. The entire Northern Segment is within Middle Township, Cape May County (Figure 2). The Northern Segment begins at the landward limit of the beach or dune (*i.e.*, demarcated by the line of contiguous vegetation, maintained lawn, or man-made structure) and extends seaward to include any valid riparian grants for shellfish culture and the following nearshore individual shellfish leases in their entirety: Section A Leases 23, 22, 21, 19, 10, 28, 24, and 25. Most of Lease A-15 is also included, from the Bidwell Creek jetty to the southern limit of this lease. The seaward limit for the Northern Segment was established to coincide with a State regulatory demarcation known as Commissioner's Line, from Bidwell's Creek to its intersection with shellfish Lease A-173.

## Southern Segment Limits

The Southern Segment of the Action Area consists of ADZ-4, valid riparian grants, individual leases for shellfish culture, and an area to be proposed for potential ADZ expansion (see ADZ Expansion, below). It is not the intent of the NJDEP to secure the entire Southern Segment for structural aquaculture, but this Segment has been identified to provide flexibility in expanding the existing ADZ-4 given foreseeable challenges.

The Southern Segment begins at a line at the northern inshore corner No. 2 of shellfish Lease A-173 (39.083N / 74.907W) and extends about 3.5 miles (5.6 km) south to West Miami Avenue, at the northern limit of Miami Beach, part of the Villas area of Lower Township, Cape May County (Figure 3). Only about 770 feet (235 m) of the Southern Segment are in Lower Township, while the rest of the Southern Segment (from Fishing Creek north) is in Middle Township. The Southern Segment begins at the landward limit of the beach or dune (*i.e.*, demarcated by the line of contiguous vegetation, maintained lawn, or man-made structure) and extends seaward to include certain leases in their entirety (Section A Leases 27, 29, 173, 174, 171 and 172), as well as the Rutgers Cape Shore Laboratory (Cape Shore Lab, part of the Haskin Lab), a riparian grant immediately south of the Cape Shore Lab, the current ADZ-4, and additional areas not currently authorized for aquaculture. In the Southern Segment, the seaward edge is demarcated by a line running in a southerly direction along the seaward edge of shellfish leases A-173 and A-172, then continuing south of a State regulatory demarcation called the Clam Line (see Background Aquaculture) until a point in Delaware Bay west of West Miami Avenue. This wider extent in the Southern Segment allows for seaward expansion of ADZ-4 for shallow subtidal aquaculture.

## Description of the Action Area

Delaware Bay is relatively shallow, with an average depth of 15 to 25 feet (5 to 8 m), a tidal range of 4 to 5 feet (1.2 to 1.5 m), and prevailing winds (northwest in winter and southwest in summer) approximately along its major axis. These factors contribute to high turbidity and prevent the growth of aquatic vegetation, such as eelgrass (*Zostera marina*) and macroalgae that is common in coastal lagoons (Ford 1997). The lower Delaware Bay shoreline, along the western shore of the Cape May peninsula, typically consists of narrow sandy beaches and, in the more southern region, also includes extensive intertidal sand flats that are exposed at low tide. The area also includes small sandy dunes, sandy shoals associated with tidal creek mouths, and tidal salt marshes fed by manmade ditches or natural creeks. Ownership along the bayshore is a mix of private, State, and Federal land (Manomet 2008).

The shoreline of this area of Delaware Bay is generally undeveloped and the beaches are used for recreational purposes during the summer months. Large areas of the fringing saltwater wetlands are either in State ownership, as Wildlife Management Areas (WMAs), or part of the federally protected CMNWR that is administered by the Service (Manomet 2008). A number of private upland properties have access to the beaches in this area. However, public beach access in this part of Delaware Bay is limited to a few municipal road ends adjacent to localized residential development (NJDFW 2016). Several bay beaches, including areas on the Cape May peninsula, are restricted for public access annually from May 7 to June 7. These seasonal restrictions, covering both pedestrians and vehicles, have been implemented annually since 2003 to protect red knots and other migrating shorebirds. Restricted areas are marked with printed signs and rope fencing from the street end to the water's edge. Designated public shorebird viewing areas are staffed by NJDFW and volunteers during the shorebird stopover season (NJDFW 2013). (Also see Environmental Baseline, below).

The total action area (Northern and Southern Segments) encompasses just over 3,200 acres (1,255 hectares (ha) of the Delaware Bay including about 700 acres (283 ha) of intertidal sand flats (NJDFW 2016). As measured all the way to the Mean Lower Low Water (MLLW) line, the action area has about 800 intertidal acres (325 ha). The intertidal flats are the sandy areas that have a gradual slope and are typically exposed at low tide. North of the Clam Line, the majority of this intertidal area is already leased to private entities and is capable of supporting structural shellfish aquaculture. These areas are also vitally important to the migrating red knot during its stopover period (NJDFW 2016).

At the north end, the action area is bounded by a jetty at the mouth of Bidwell Creek. Just south of the jetty, adjacent to Leases A-15 and A-23, is the community of Reeds Beach, where the beach is backed by moderate density residential development. The Reeds Beach bayshore consists of steep sloping narrow beaches and approximately 50 bayfront homes, mostly on pilings that sit over the water at high tide (NJDFW 2016). The dry beach (above the MHW line) is narrow, typically less than 100 feet (30 m), and in some areas there is no dry beach in front of the houses. However, South Reeds Beach received beach nourishments in 2013, resulting in wider beaches in that area (USFWS 2016a; USFWS 2014; Niles *et al.* 2013a; Niles *et al.* 2013b). An experimental "shell bag" oyster reef was also installed off the southern end of Reeds Beach in 2015, within the north end of Lease A-23 (USFWS 2015). (These and other restoration projects are discussed further under Environmental Baseline, below). The intertidal area (between the MHW line and the MLLW line) is also narrow, typically under 75 feet (23 m) and as little as 25 feet (8 m) in some areas. There are no creek mouth shoals in the Reeds Beach area. The southern end of Reeds Beach, just south of the houses, is part of CMNWR.

South of Reeds Beach is an undeveloped area known as Cooks Beach, adjacent to Leases A-23 and A-22. Cooks Beach is slightly wider, typically 100 to 150 feet (30 to 46 m), and the intertidal zone is considerably wider—from roughly 200 feet (61 m) to over 500 feet (152 m). Cooks Beach received beach nourishment in 2013 (USFWS 2016a; Niles *et al.* 2013a) and is scheduled for additional beach nourishment in 2016 (USFWS 2016b). Land ownership in the northern part of Cooks Beach includes a condominium campground, but the developed areas are along Cooks Beach Road and do not extend along the bayshore. The southern portion of Cooks Beach is part of CMNWR. Cooks Beach features shoals associated with two creek mouths.

South of Cooks Beach, starting at Kimbles Beach Road, is an undeveloped area consisting of Kimbles Beach and contiguous habitats to the south including the mouth of Dias Creek. This area is adjacent to Leases A-22, A-21, A-19, A-10, and A-28. Beaches range from roughly 75 to 200 feet (23 to 61 m) wide. Intertidal areas range from roughly 500 (152 m) to over 1,000 feet (305 m) wide. Kimbles Beach received beach nourishment in 2013 (USFWS 2016a; Niles *et al.* 2013a) and is scheduled for additional beach nourishment in 2016 (USFWS 2016b). This area features shoals associated with the mouth of Dias Creek and several smaller creeks. There are small communities and bay access along Kimbles Beach Road and at the Bay Cove resort, but there is no development directly on the bayfront (NJDFW 2016). Nearly all the bayfront land is in conservation ownership, mainly within CMNWR, including property south of the mouth of Dias Creek. The Dias Creek Oyster Company currently operates on Lease A-19, and the Sweet Amalia Oyster Farm is authorized by the Corps to begin operations on Lease A-28.

Just south of Dias Creek, intertidal flats begin to emerge, consisting of extensive widths of shore-parallel “ridges” (low shoals) and “runnels” (also called “sloughs” or “troughs”). These wide flats continue south past the southern end of the action area.

At the southern end of the Northern Segment, starting at the southern end of Lease A-28 and extending adjacent to Lease A-25, is the community of Pierces Point. The beach is backed by moderate density residential development of about two dozen bayfront homes. Pierces Point also has several piers that extend into the bay as well as several bulkheads (NJDFW 2016). The dry beach is narrow, typically less than 25 feet (8 m). The intertidal area is roughly 750 to 900 feet (229 to 274 m) wide. Pierces Point received beach nourishment in 2014 (USFWS 2016a; Niles *et al.* 2013a). There are no creek mouth shoals in the Pierces Point area.

At the northern end of the Southern Segment is an area known as Highs Beach or King Crab Landing. This area is adjacent to Leases A-173, A-27, and A-29 (Figure 3). The Highs Beach area has only localized areas of development interspersed with undeveloped areas. Development consists of scattered bayfront homes as well as the community of Highs Beach, with about half a dozen bayfront homes (NJDFW 2016). The dry beach is typically 30 to 70 feet (9 to 21 m) wide, and the intertidal area is roughly 850 to over 1,500 feet (259 to 457 m) wide. There are no creek mouth shoals in the Highs Beach area. Most of the Highs Beach area is in private ownership. There is currently a private oyster farm a riparian grant that abuts Lease A-173, and additional growers operating on Lease A-29.

Between Lease A-29 and Green Creek are the following, moving from north to south: a small riparian grant occupied by the Rutgers Cape Shore Lab for aquaculture research, a larger private riparian grant, and ADZ-4. Until recently, Atlantic Cape Fisheries, Inc. operated an oyster farm on the riparian grant between Rutgers and ADZ-4, but this farm was relocated to ADZ-4 in late

2015. The ADZ-4 is split into a northern and southern section (referred to as ADZ-4A [northern] and ADZ-4B [southern]), separated by approximately 1,500 feet (457 m). The Rutgers Lab buildings at the northern end represent the only development in this otherwise undeveloped stretch of bayshore (NJDFW 2016). Beaches are roughly 60 to 100 feet (18 to 30 m) wide, and intertidal areas are 1,400 to 1,500 feet (427 to 457 m) wide. There are shoals associated with Green Creek in this area. Roughly half this area is State-owned while the other half is privately owned.

Between Green Creek and Millman Boulevard is an undeveloped area. Beaches are roughly 100 to 250 feet (30 to 76 m) wide, and the intertidal area is 1,400 to 1,600 feet (427 to 488 m) wide in this area, which includes shoals associated with Green Creek and another creek to the south. Roughly half this area is within CMNWR, and the rest is privately owned.

From the end of Millman Boulevard (known as Norburys Landing) to the southern end of the action area (at West Miami Avenue) are three areas of residential development, interspersed with undeveloped areas owned by The Nature Conservancy or Cape May County. The three developed areas are: (1) about six bayfront homes and a public beach access at Millman Boulevard; (2) the community of Sunray Beach, with about 15 bayfront homes in the central part of this stretch; and (3) six bayfront homes just north of West Miami Avenue (NJDFW 2016). The dry beach in this area is roughly 40 to 70 feet (12 to 21 m) wide, and intertidal areas are roughly 1,000 to 1,300 feet (305 to 396 m) wide. This area includes the mouth of Fishing Creek near the southern end of the action area. Although the Fishing Creek inlet is modified by pipes, it is associated with sand spits and shoals.

## BACKGROUND ON AQUACULTURE

This PBO covers structural aquaculture of any native species of bivalve. Currently, the vast majority of bivalves farmed in the action area are eastern oysters, primarily triploid (a genetic variant) oysters that have been developed for disease resistance. Throughout this document, we frequently refer to the proposed action as "oyster growing" or "oyster farming," but we do not mean to imply exclusion of other native bivalve species that may be proposed for future aquaculture in the action area. For example, one grower is experimenting with culturing hard clams (*Mercenaria mercenaria*) in the action area (NJDFW 2016). Likewise, references to "shellfish" are not meant to imply inclusion of any farmed taxa other than bivalves. (Note that this usage of the term "shellfish" differs from the definition found in State law at N.J.S.A. Title 50.) (See Excluded Activities, below.)

Shellfish aquaculture is divided broadly into two main categories: 1) non-structural or "traditional" on-bottom shellfish culture; and 2) structural aquaculture that uses gear or equipment to contain shellfish for cultivation purposes. These structures, all of which require Corps and State permitting, typically include but are not limited to rebar racks, plastic (mesh) bags, and cages, as well as buoys, floats, and poles marking structures (see Aquaculture Methods and Gear, below). Structural aquaculture generally involves the tending and harvesting of purchased (hatchery-produced, not wild) oyster "seed" as it is grown to market size in bags, cages, or other containment structures (NJDFW 2016).

This PBO <u>does not</u> cover non-structural (or "traditional") aquaculture, which typically involves moving "wild" (not purchased seed) oysters to favorable growing locations and/or the placement of shell for wild oyster recruitment ("shell planting"). Throughout this document, we use "aquaculture" interchangeably with "structural aquaculture," but we do not mean to imply inclusion of non-structural methods. Any references to non-structural aquaculture will be so specified. See Excluded Activities, below.

There are three types of authorized areas within which growers can legally conduct structural aquaculture in New Jersey's part of Delaware Bay. These are mutually exclusive and cannot overlap.

- **Riparian Grant.** Certain areas of bay bottom are held by private individuals or entities under historical riparian grants. Growers operating on riparian grants require authorizations from DLUR and the Corps.

- **Private Lease.** Aside from riparian grants, tidally flowed submerged lands in New Jersey are held in the public trust and cannot be sold. However, beginning in the 1850s, the right to privately lease bay bottom areas (Figures 1 to 3) was established by the State of New Jersey in an effort to "promote planting and growth of oysters" (Ford 1997). This leasing system remains largely the same today. Oyster growers can apply for shellfish aquaculture leases through the Shellfisheries Council (SFC). These leases are renewed annually, and may be used for traditional and/or structural aquaculture. Growers operating on private leases require authorizations from DLUR, the New Jersey Tidelands Resource Council (TRC), and the Corps.

- **ADZ Lease.** South of a State regulatory demarcation known as the Clam Line (Figure 3), no private leases are permitted and aquaculture can be conducted only within established ADZs or on riparian grants. While there are subtidal ADZs to the north of the Clam Line (outside the action area), to date the only intertidal ADZ is south of the Clam Line due to the large number of nearshore private leases north of that line. Within ADZs, the BSF obtains and administers authorizations from DLUR, the TRC, and the Corps on behalf of individual growers. Thus, individual growers need only obtain authorization from BSF to operate within a designated ADZ parcel, substantially streamlining the permitting process.

The goal of New Jersey's ADZ program is to cluster structural shellfish aquaculture. This management system attempts to minimize environmental, social, and user-group conflicts while streamlining the permitting process that growers are required to navigate. An ADZ can be beneficial for groups of growers seeking joint upland or water access, technical support, entrance into markets, access to seed and equipment, and centralized postharvest services (FAO and WBG 2015). The clustered approach also allows the State to effectively manage the ADZs by providing centralized oversight from NJDFW staff and enforcement, while also improving product safety and public health oversight. The ADZ approach creates a permit-in-hand system ("one-stop-shop") where user and natural resource conflicts are vetted beforehand as opposed to a piecemeal system of permitting and leasing on a case-by-case basis across numerous private leases throughout Delaware Bay (NJDFW 2016).

The eastern oyster has a long history as a commercially and ecologically important species in Delaware Bay. Although oyster stocks have been significantly affected by disease, habitat loss, and in some cases, over-harvesting, the eastern oyster remains an integral part of the Delaware Estuary (Baab 2005). From 1880 until 1930 oyster production ranged from one to two million-bushels annually (Ford 1997). Today, the bay's wild oyster population is inhibited by disease, allowing for much lower, but sustainable, harvest levels. The oyster disease commonly known as Dermo (caused by the waterborne protozoan parasite *Perkinsus marinus*) is the primary cause for depressed wild populations. This disease is host-specific and does not affect humans, but does cause elevated mortality of wild oysters (NJDFW 2016).

Relative to the long history of traditional oyster aquaculture in New Jersey, structural aquaculture is still comparatively new, though intertidal oyster aquaculture has been practiced in various forms along much of the Cape Shore region of Delaware Bay for more than a century. In the 1930s, containerized culture methods began to be practiced (NJDFW 2016). Hatchery production technologies became available in the early 1960s, and oyster breeding programs since that time have focused on disease resistance and fast growth rates (Guo *et al.* 2008). The number of oyster hatcheries remains few, but selectively bred, disease-resistant seed can be purchased from hatcheries including the Haskin Lab (Haskin Lab 2015; Guo *et al.* 2008). In the 1990s, a commercial oyster aquaculture farm began pilot-scale structural aquaculture operations using off-bottom gear on the riparian grant just south of the Rutgers Cape Shore Lab in Middle Township (Figure 3). By the late 1990s, Atlantic Capes Fisheries, Inc. began commercial-scale operations in this location.[5] Operations at ADZ-4, immediately south of the Atlantic Capes Fisheries, Inc. farm, began in 2012 after a long period of siting, review, and permitting. Annual farm production grew gradually to about 1.5 million oysters per year since its start in the late 1990s. Production has remained at this level for the past three years (NJDFW 2016).

Most active structural aquaculture is currently within ADZ-4. Twelve individual 1.5-acre (0.6-ha) parcels were made available for leasing in the inshore area of ADZ-4. Twelve more 1.5-acre (0.6-ha) parcels (also within ADZ-4) were established directly offshore (seaward) of those inshore leases. The offshore, adjoining leases are held for expansion of the inshore leaseholder's operations, provided the leaseholder has attempted to utilize his/her inshore ground. Following a lottery in 2012, all 12 inshore parcels were leased and ADZ-4 remains fully leased to date. A waiting list for ADZ-4 parcels is maintained by BSF. The offshore, adjoining ADZ leases are currently being offered to qualified inshore leaseholders. Located outside the action area (and not covered by this PBO), offshore space in ADZ-2 and ADZ-3 is available in 10-acre (4-ha) parcel increments. While individuals continue to express interest in these offshore grounds, none have actually entered into an offshore ADZ lease to date, because growers view land-based intertidal aquaculture as a lower-cost and lower-risk option, as discussed below (NJDFW 2016).

A key reason for the popularity of ADZ-4 (relative to ADZ-2 and ADZ-3 farther offshore) is the broad and extensive intertidal sand flats that are exposed at low tide and offer convenient land access. With land-based access, growers do not incur the expense and logistical burden of owning and maintaining a large open-water vessel. Compared to boat-based aquaculture, land-based aquaculture presents a much lower barrier to entry for prospective growers due to

[5] This farm remains in operation at the time of this PBO but relocated off the riparian grant to ADZ-4 at the end of 2015.

considerably lower start-up and capital costs. In the vicinity of ADZ-4, the exposed tidal flats generally extend approximately 1,200 feet (366 m) offshore, allowing ample space for intensive aquaculture activities that yield a high-quality oyster, ideal for the high-value half-shell market. These oysters are typically sold in raw bars and restaurants as boutique or “table cloth” oysters under various brand names (NJDFW 2016), such as “Cape May Salts.” Oysters typically take two or more years to reach market size, though some growers report as little as 1.5 years to reach market size due to fast growth rates in the lower bay and/or an emerging market for smaller oysters. During the final grow-out stage, the oysters reach a market size, which can range from approximately 2 to 3 inches (5.1 to 7.6 centimeters [cm]) as measured from hinge to lip (NJDFW 2016).

Currently, the majority of oyster production in the action area is intertidal, with a lesser amount of shallow subtidal aquaculture. Most growers access their leases or grants by land, but may use a boat or amphibious vehicle to utilize more of the tidal cycle and tend to shallow subtidal areas. Intertidal gear is best accessed at low tide, which in this area is typically a period of 4 to 6 hours including the end of the ebb tide into the following flood tide. Racks and bags, currently the predominant gear used in the action area, are tended by hand around low tide when the intertidal sand flats are exposed. Tending and maintenance is known as “husbandry,” which generally means any activity related to the cultivation and management of shellfish on a leased or granted ground. Husbandry typically includes grading, sorting, washing, cleaning, planting, or moving of seed or shellfish aquaculture structures within the lease or grant. Growers typically use power washers, trash pumps, and various scrubbing brushes to wash biofouling organisms off of their gear. Culling tables, buckets and baskets are also used to sort shellfish seed and marketable product on the leases or grants (NJDFW 2016).

Biofouling is one of the most prominent issues facing the structural aquaculture industry. Growers maintain their product and/or gear almost daily during the peak months, or run the risk of high mortalities due to sedimentation and biofouling (Gaine 2012). Labor costs associated with biofouling management on a mid-sized Cape Shore farm (250,000 market oysters) have been estimated at up to 700 man-hours, with equipment and supplies costing up to $2,000 annually (Haskin 2014). The majority of biofouling in Delaware Bay is caused by two marine polychaetes. *Polydora cornuta* (formerly *P. lingi*) are commonly referred to as “mud worms.” Mud worms create thick colonies of mud tubes on the exterior of oyster bags, causing suffocation and mortality of oysters (Haskin 2014; Brown 2012). Delaware Bay provides ideal conditions for the settlement of *P. cornuta* due to its high turbidity, high sediment loads, wide intertidal flats, and temperate climate, and the gear used in shellfish aquaculture provides prime settling locations for the worms and their larvae (Haskin 2014). *Polydora websteri*, referred to as “mud blister worms,” cause internal shell blisters that create physiological impacts on the oyster, increasing its susceptibility to predators and environmental conditions (Brown 2012). In addition, the market value of oysters affected by mud blister worms is decreased due to the occurrence of unsightly blisters, along with weak shells that make shucking difficult (Brown 2012).

Structural shellfish aquaculture in the action area is a year-round industry. Similar to shellfish aquaculture practices worldwide, growers in this area typically retain their gear on site throughout the year and only remove it for maintenance or for protection from winter ice.

Growers in this area begin to prepare for their growing season in early March, though purchasing of seed and gear can begin as early as November of the prior year. By early spring, growers begin to move their gear out of the deeper, overwintering areas, sort through bags to determine winter mortality, resize and cull bags appropriately, and conduct a general inventory of the farm's needs. At this time, gear is moved to areas of the lease or grant offering the best growing conditions, and growers begin to prepare for the spring/summer months when high biofouling is common (NJDFW 2016).

During the colder winter months, growers often move their gear into subtidal areas where the oysters are covered by water at all tides. Those growers choosing to retain their gear on the exposed intertidal areas throughout the winter commonly move racks into nearby sloughs (*i.e.*, slightly deeper channels on the flats that hold water at the lowest normal tides) and push the racks into the sediment until flush with the bay bottom to maximize the amount of time the oysters are covered by water. This practice also can reduce ice scour that is common during the winter. In warmer winter months, most growers will continue to operate their farms, sometimes having enough market oysters to continue to harvest and sell during this time. Winter mortality is typically 20 to 50 percent (NJDFW 2016), mainly due to decreasing food (phytoplankton) supplies as day lengths shorten and water temperatures drop (A. Wenczel pers. comm. March 15, 2016). Winter mortality can be 80 to 90 percent during years of severe weather due to ice damage and prolonged or extreme cold (NJDFW 2016).

## DESCRIPTION OF THE PROPOSED ACTION

### Included Activities

The action being evaluated in this PBO includes all Corps authorizations of existing and expanded structural aquaculture of native bivalves[6] over a 10-year period along a roughly 6.5-mile-long (10.5-km-long) section of Delaware Bay shoreline on the Cape May peninsula in New Jersey (see Action Area, above, and Figures 1 to 3). The action includes both intertidal and subtidal structural aquaculture currently existing or proposed within the action area over the next 10 years. For the purposes of this PBO, "subtidal aquaculture" is defined to mean that no gear is visible during mean low tide, with the exception of marker buoys or poles. "Intertidal aquaculture" is defined to mean that gear is visible during mean low tide.

The proposed action includes the deployment and maintenance of structural aquaculture gear to grow native bivalves, including but not limited to the gear types listed below in this section. The proposed action also includes access and activities associated with bivalve tending and harvesting, including: access by foot, motor vehicle, and motorized or non-motorized boat or amphibious vehicle (see Upland Access, below); use of motorized and non-motorized transport equipment such as carts and trailers on land or in water; power washing, use of trash pumps, and other cleaning activities; sorting and culling including use of tables, other work platforms, buckets, and baskets; harvest activities; storage and staging of gear, seed, product, and other materials and supplies; and all other activities and practices that are generally considered part of structural aquaculture operations. Power washing uses motorized equipment to remove mud and

[6] This PBO does not cover non-structural (or "traditional") aquaculture, nor does it cover aquaculture of any taxa other than native bivalves. See Excluded Activities, below.

fouling organisms with local bay water. The structural and operational details of each farm or aquaculture activity will be specified during the Tier 2 consultation process.

### ***Aquaculture Methods and Gear***

Structural aquaculture within the action area currently includes the following methods and gear types, listed below in descending order of prevalence within the Cape Shore region at the time of this PBO (NJDFW 2016). Structural methods covered by this PBO include, but are not limited to, those listed in this section. This PBO evaluates the possibility that the predominant structural methods may change over time, and that new structural gear or methods may be developed. We cannot anticipate currently available but unused gear types that may be introduced in the action area, let alone new gear types that may be developed over the 10-year life of this PBO. Therefore, this consultation includes flexibility to deploy gear types not described in this section. Any new or modified gear types would be subject to CM 8, all other applicable provisions of this PBO, and any new or modified CMs adopted as part of the adaptive management process (CM 6). Any new or modified gear types would also be evaluated during the Tier 2 process.

#### Rack and Bag

Estimated at 95 percent of structural gear currently in use, “rack and bag” systems consist of steel rebar rod racks that support and elevate mesh bags off of the bay bottom. These rack systems are typically laid out in rows separated by alleyways (or “lanes”) at least as wide as the racks themselves to allow access for tending the structures and the oysters. The majority of individual racks currently deployed in the action area are approximately 10 feet (3 m) long by 2.5 to 3 feet (76 to 91 cm) wide, though some growers use a 5-foot-long (1.5-m-long) rack. All racks hold plastic mesh bags that are generally wider than the rack (typically three feet [1 m] wide by 20 inches [21 cm] long) with varied size mesh. The bags are kept closed by sliding a small-diameter PVC pipe, cut along its length, over the bag ends, or by folding over the bag end and securing with plastic cable ties or other closure clips. Rubber straps or clips are used to hold the bags to the racks. Over the course of growing a batch of oysters to market size, several sizes of mesh are used in this culture system, with progressively larger mesh openings on the bags as the oysters increase in size.

#### Bottom Cages

Estimated at 3 to 5 percent of structural gear currently in use, “bottom cages” are typically a 3-foot by 4-foot (91-cm by 122-cm) rectangular shape, ranging in height up to 3 feet (1 m). Cages sit off of the seafloor via two small legs spanning the cage’s width, providing a clearance of several inches. Cages usually consist of three tiers, each tier providing enough space to contain one of the bags described in the rack and bag system, above. These structures are typically made with heavy-gauge vinyl-coated metal and contain three full plastic mesh bags. These culture systems are typically placed into subtidal areas and tended by boat. Some growers may choose to place cages in intertidal or shallow subtidal areas to access via land, or may modify this system to limit the number of bags and the weight of the loaded cage.

*Trays*

Estimated at less than one percent of structural gear currently in use, trays are a grow-out system that consist of stackable wire mesh or molded polyethylene or polypropylene mesh containers. This system can be used as individual stacks, rows, or a system connected by long lines. Trays can be on the bottom or floating.

*Longline, Floating, and Hanging Bags*

Estimated at less than 1 percent of structural gear currently in use, suspended oyster culture involves hanging oyster trays, baskets, or nets of young oysters within surface waters so they can feed almost continuously. This method may be used in the intertidal or subtidal zones and includes a wide range of practices. Some of the variants of this method include supporting the line by floats or poles, as well as a vast array of containment systems for the oysters. The bags used in this system are similar to those described above, consisting of a durable plastic mesh bags. The bags, lines, and potential arrays that can be created with this generic system are only limited by the local conditions and needs of the grower, with a variety of systems in use throughout other parts of the U.S. east coast (Walton *et al.* 2012). The floating cage system is a relatively recent development, with several proprietary designs currently on the market. Typically, these systems consist of floats that support heavy-gauge vinyl-coated wire mesh cages at or near the water's surface. Multiple compartments within the cages contain oyster bags. Cages that are tethered on each end to an anchored long-line are routinely flipped over to control biofouling on both the gear and oysters (Walton *et al.* 2012).

*Spat Attraction Devices*

Spat are a juvenile (or larval) life stage of bivalves, ranging from first settlement up to one year of age. Spat attraction devices are used to obtain wild oyster spat, thus reducing the cost of purchasing seed from a hatchery. Shell bags and "Chinese hats" are two types of spat recruitment methods proposed for use within the action area. Shell bags consist of placing cured shell or cultch (*e.g.*, broken shells, typically oyster shell) into plastic mesh bags and deploying the bags during the oyster spawning season (usually mid-June to early August). Oyster spat set (*i.e.*, attach themselves) on the shell within the bags, and are then transferred to bags and deployed on rack systems or in cages for grow-out. "Chinese hats" are an alternate method for collecting spat. The structure is constructed of 10 to 12 disks or "hats," spacing rings, a central support, and a locking collar. Once assembled, the stack is dipped in a lime-based cement solution. Oyster larvae are attracted to the lime in the cement coating, while the shape of the hats provides the favorable flow velocities for settlement. Following spat setting, the hats are disassembled and each hat is torqued or twisted to break off the cement. Oyster spat are then transferred to bags and deployed on rack systems or in cages for grow-out. Following seed retrieval in mid- to late summer, spat attraction devices are typically removed from the lease or grant and placed into storage to avoid possible losses from ice and storm damage.

*Permissible Methods Not Currently In Use*

Oyster tubes can be used for spat collection, juvenile grow-out, as well as full-term grow-out to market size. The tube is typically deployed horizontally, with roughly 80 tubes arranged together and spaced about 1.5 inches (4 cm) apart. If designed to catch wild spat, the tubes are spaced to have 2 to 6 inches (4 to 15 cm) of clearance from the bottom.

Lantern nets are constructed with heavy-gage wire frames and four hanging ropes that string multiple tiers of compartments together, then the entire system is encased in netting. To access the inside, each cage has a hinged door along one side, held together with two clips.

Submerged longlines are often engineered by balancing between positive and negative buoyancy, while maintaining stable anchoring. These submerged longline methods employ various containers to hold oyster, such as lantern nets. Submerged longlines often provide benefits such as avoiding biofouling, which allows for more consistent grow-out conditions, lower costs, decreased damage from ultraviolet rays, and reduced surface turbulence.

***Upland Access***

Nearshore structural shellfish aquaculture throughout the action area is almost entirely contingent on land-based access to growing areas. Access by foot, all-terrain vehicle (ATV), and boat are all used by growers within the action area. A few growers access their farms only by foot. Many growers, particularly at ADZ-4, use ATVs to transit to, from, and within their farms. Some growers float equipment in and out of farms in flat-bottomed boats. Others have developed similar vehicles or work platforms. For example, the owners of one small oyster farm teamed with a local architect to design and build a non-motorized, environmentally friendly Amphibious Farm Vehicle customized for working an intertidal oyster farm (NJDFW 2016).

Of all of the growers in the action area, only one uses boat access as the primary mode of oyster farm access (Dias Creek Oyster Company, see Appendix C). Boat access is not practical for most growers largely due to the lack of public marinas in or near the action area. For example, the closest public marina or commercial docks are over 8 miles (12.9 km) to the south and 5 miles (8 km) to the north from ADZ-4. This makes consistent water-based access to ADZ-4 and nearby farms in the Southern Segment non-viable. Within the action area, the only public marinas are on Bidwells Creek near Reeds Beach at the northern limit of the action area. Use of those marinas would require Southern Segment growers to travel 3 to 5 miles (4.8 to 8 km) each way, representing an increase in nearshore vessel traffic in the Northern Segment and potentially increasing disturbance to red knots. The high wind and wave conditions in Delaware Bay present another challenge to boat access. Open water boating in Delaware Bay generally requires larger boats with higher capital and operating costs compared to lower-energy bays. Such boats, suitable for the high energy of Delaware Bay, typically have relatively high draft that precludes them from working on the nearshore flats. Based on the need for growers to transport various husbandry and harvest equipment, and the high costs and logistical challenges associated with boat-based access, land-based access remains a critical component of the ADZ approach, and is also vital to operations on intertidal leases or riparian grants in the action area (NJDFW 2016).

Upland access is currently a major issue and challenge for structural aquaculture in the action area. While a number of beaches in the action area are accessible from road ends, access to ADZ-4 from a nearby road is not secure over the long term. Until recently, upland access to ADZ-4 has primarily been via Conswell Road, with just one grower typically accessing via Millman Boulevard to the south (Figure 3). Conswell Road is owned by a private landowner.

Rutgers University is permitted to utilize this road via a right-of-way agreement to access their Cape Shore Lab. However, Conswell Road may no longer be available to ADZ-4 leaseholders in the future. If Conswell Road cannot be used, upland access to ADZ-4 might be limited to the road end at Millman Boulevard (Norburys Landing) about 1 mile (1.6 km) to the south and/or Highs Beach Road about 0.6 mile (1 km) to the north. Both of these entry points would require significant linear (shore-parallel) travel along lengthy stretches of beach, likely causing substantial disturbance of red knots as well potentially creating additional landowner and user conflicts (NJDFW 2016). Thus, access to ADZ-4 in its current location via either of these distant entry points during the red knot stopover season is not covered by this PBO, and will not be considered through the Tier 2 process. (Likewise, long-distance beach travel will not be considered as an allowable means of accessing any future ADZ areas/locations, or non-ADZ leases or grants.)

The NJDEP recently secured a temporary agreement to allow continued access via Conswell Road during the 2016 growing season. However, at the time of this PBO, no long-term access arrangements are in place for ADZ-4. The NJDEP will continue to work with growers and landowners in an attempt to find a workable solution to the upland access issue. Ideally, the NJDEP endeavors to establish and maintain a single land-based access point near the center of ADZ-4 in an effort to consolidate, centralize and minimize ingress and egress points with the overriding objective of minimizing resource (including shorebird), user group, and landowner conflicts (NJDFW 2016).

The NJDFW, NJDA, and the Corps, in consultation with the Service worked cooperatively for six months to develop CMs designed to minimize red knot disturbance from shellfish aquaculture activities. Throughout the process, limiting or concentrating access to single points of ingress/egress wherever possible remained a primary focus of the group and a consistent concern. Given the intent to minimize disturbance, leaseholders accessing ADZ-4 in its current location (primarily via ATVs) from road ends far to the north or south is not a viable option, and would require re-initiation of this programmatic consultation. Thus, controlled and focused upland access is critical to the long-term success of the State's ADZ approach (NJDFW 2016). If Conswell Road is not available in future years, and if no other nearby land access is available to ADZ-4 growers, then the NJDFW, NJDA, and the Corps, in consultation with the Service, will have to evaluate options that could be considered under this PBO, such as limiting ADZ-4 access to boat only, or moving all or part of ADZ-4 closer to a viable entry beach point. As with all other aquaculture operations in the action area, the allowable access point(s) for ADZ-4 will be specified during the Tier 2 process.

***ADZ Expansion***

As discussed above (Background on Aquaculture), the ADZ model offers several benefits to growers and to the State as a result of clustering aquacultural operations. In light of current demand for intertidal growing space, particularly at ADZ-4, and considering factors suggesting continued growth in this industry (discussed further under Current and Future Extent of Aquaculture, below), the State of New Jersey endeavors to expand available leasing in the immediate vicinity of the existing ADZ-4. Based on the factors discussed under Subdivision of the Action Area, above, and by virtue of clustering, the State concludes that expansion around ADZ-4 will allow for industry growth that has the lowest likely impact on red knots. In pursuing

ADZ expansion, the State will follow the priority sequencing described below. (Also see CM 12, below.) Further, the NJDEP will explore adding explicit "use it or lose it" provisions to the existing ADZ lease agreements to ensure these valuable growing areas are actively utilized prior to further ADZ expansion. Land access to the current and potentially expanded ADZ-4 is also a critical issue and a major limiting factor, and continues to be addressed by the NJDEP, as discussed in the preceding section (NJDFW 2016). Land access agreements may also limit the total number of growers that are able to use different parts or all of the intertidal ADZ.

*Priority 1: Intertidal In-Fill Area Between ADZ-4A and ADZ-4B*

An area between the two existing ADZ-4 parcels, referred to as the "in-fill" area (Figure 3), has been identified by the NJDEP as its top priority for potential ADZ expansion. This site is seaward of three upland properties (Block 388, Lots 19.01, 24 and 33), from whose owners the State will be seeking permissions under New Jersey's Tidelands rules for use of the intertidal nearshore. The in-fill area is an intertidal site similar to ADZ-4A and ADZ-4B and is approximately 52.6 acres (21.2 ha) in size. This acreage calculation is considered a maximum and does not account for expected reductions from the Protected Areas as defined in CM 10, below. Therefore, the total useable area that could contain structural aquaculture will be far less than 52.6 acres (21.2 ha) (Table 3). If leased, the in-fill area would likely accommodate up to 14 growers (*i.e.* 14 ADZ leases). If Tidelands permissions are not obtained from all upland owners, this number would be reduced to six, five, or zero based on the 1.5-acre (0.6-ha) lease size model used in ADZ-4. Smaller lot sizes, such as 1 acre (0.4 ha), are also being considering as a means to accommodate more growers.

*Priority 2: Nearshore Subtidal ADZ*

A second area deemed suitable for ADZ expansion, based on minimal impacts on red knots, is directly seaward of ADZ-4 (Figure 3). This site would be established for subtidal structural aquaculture (*e.g.*, primarily submerged cage culture in water greater than 5 feet (1.5 m) deep at Mean Low Water (MLW), and more than 500 feet (152 m) from the water's edge at MLW; see CMs 8 and 11, below) and would be approximately 700 acres (283 ha) in size. Due to the different culture methods likely to be used in this area, relative to the intertidal flats, the NJDFW anticipates the lease sizes would be at least 5 acres (2 ha) to accommodate vessel maneuvering and gear tending. This subtidal area could allow some growers to experiment with offshore (*i.e.*, boat-based) operations to complement their inshore intertidal operations, or even to transition to subtidal-only operations (NJDFW 2016). Subtidal, boat-based operations are expected to have considerably lower impacts on red knots (*e.g.*, no loss of red knot foraging habitat, no disturbance of knots during tending).

*Priority 3: Intertidal Area Immediately South of ADZ-4*

A third identified expansion opportunity lies south of ADZ-4B, beginning just south of the delineated Green Creek shoal (Figures 3 and 9). This intertidal stretch of shore could potentially include any nearshore area from immediately south of the Green Creek shoal southward to just north of the delineated creek mouth at Norburys Landing, north of Millman Boulevard. This area would be approximately 150 acres (61 ha) in size if the entire reach of shore were incorporated into the new ADZ. This acreage calculation is considered a maximum and does not account for expected reductions from Protected Areas as defined in CM 9, below. Therefore, the total useable area supporting structural aquaculture will be far less than 150 acres (61 ha). If leased, this area would likely accommodate approximately 22 growers (*i.e.*, 22 ADZ leases). The NJDEP does not plan to utilize this stretch of the shoreline until expansion opportunities within the "in-fill" area are totally exhausted. If expansion in this area is pursued in the future, it is NJDEP's intention to slowly phase in any new leases after careful consideration. Given past siting issues, however, the entire stretch of shore identified here is included for consideration to allow for flexibility in siting decisions following careful review of site-specific factors. The 150-acre (61-ha) estimate entails all potential lease area (including both intertidal and subtidal) in this section. The NJDEP estimates only about 60 acres (24 ha) out of these 150 acres (61 ha) are intertidal and outside of Protected Areas (see CM 10, below), and therefore capable of supporting the typical rack-and-bag type of farming currently used in the action area (Table 3) (NJDFW 2016).

*Not Preferred*

The final and least-preferred option is the establishment of a new ADZ disjunct from ADZ-4, south of Norburys Landing (Figures 3 and 9). The NJDEP will pursue this option only if all the priority expansion options listed above prove insufficient to meet industry demand and/or prove impossible to implement. Under this option, NJDEP would aim to site the new ADZ as near as possible to an existing road end, in cooperation and consultation with local governments, in order to facilitate access and reduce disturbance to red knots and other shorebirds.

**Excluded Activities**

This PBO does not cover any action or activity other than those listed above under Included Activities. Proposals to conduct other activities will necessitate separate review regarding potential effects to the federally listed species. For example, this PBO does not cover any of the following:

- activities outside the action area;
- traditional (non-structural) aquaculture such as moving "wild" (not purchased seed) oysters to favorable growing locations and/or the placement of shell for wild oyster recruitment ("shell planting");
- aquaculture (structural or non-structural) of any taxa other than native bivalves (*e.g.*, aquaculture of non-native bivalves, non-bivalve mollusks, arthropods, finfish, algae, and marine plants is not covered);
- non-commercial bivalve propagation or enhancement (*e.g.*, small-scale recreational bivalve growing for personal consumption ("oyster gardening"), creation of oyster reefs or other bivalve habitats as part of "living shoreline" or other littoral habitat restoration efforts);

- use of any liquid or material other than local bay water for power washing (*e.g.*, no off-site water sources, additives, or chemicals);

- use of any gear or equipment made of wood treated with preservatives, such as copper–chromium–arsenic (CCA) or creosote;

- use or storage of any hazardous or toxic substances or materials as regulated by any Federal or State agency;

- use or storage of any petroleum products (except use of oil and gas in power washers, ATVs, or other powered equipment generally considered part of structural aquaculture operations, which is included in this PBO as discussed above);

- use of any aircraft, including drones, for any purpose;

- any discharge of fill material into a wetland or open water as regulated by the Corps and/or DLUR; and

- construction, installation, enlargement, repair, improvement, or modification of any infrastructure, including but not limited to buildings, sheds, shacks, docks, piers, moorings, bulkheads, seawalls, artificial reefs, other erosion control structures, roads, paths, boardwalks, towers, poles, and utility lines.

**Action Implementation**

The proposed action entails the continued operation of existing and previously authorized structural aquaculture of native bivalves within the action area, as well as the potential expansion of existing farms and/or the establishment of new operations within the action area over the next 10 years. No single Federal or State agency has the authority on its own to carry out this proposed action. Instead, the State of New Jersey supports and regulates structural aquaculture in numerous ways, both direct and indirect. The following is a listing of the agencies tasked with various aspects of structural aquaculture regulation and/or development, and a description of how each is involved with this industry (NJDFW 2016). As described below, the State has legislative mandates both to support aquaculture and to promote the recovery of the red knot and other shorebirds. The NJDEP will be primarily responsible for implementing this PBO, but will continue to coordinate closely with other agencies as per CM 6. All structural aquaculture covered by this PBO will require authorization from the Corps.

***Bureau of Shellfisheries***

The BSF is the natural resource management agency charged with directing the State's shellfish programs, projects, and restoration efforts on both the Atlantic coast and in Delaware Bay. The BSF is within the NJDFW, part of NJDEP. Personnel within the BSF work with their counterparts in the Bureau of Marine Fisheries, the Marine Enforcement Unit, and other State agencies to form and implement plans for the protection and wise use of marine habitat and the State's valuable shellfish resources, as well as the coordination of the State's shellfish leasing program. State law (N.J.S.A. 50:1-5) provides that the Commissioner of NJDEP "shall have full control and direction of the shellfish industry and resource and of the protection of shellfish throughout the entire State." The BSF currently maintains a coastal office that oversees the shellfish aquaculture leasing program along the Atlantic coast, and a separate regional office that oversees the shellfish aquaculture leasing program in Delaware Bay. In recent years, the BSF has assumed a more prominent and broader role in the development of the State's shellfish aquaculture program, both structural and non-structural. The BSF has worked to assist in the development of a more predictable and consistent regulatory and permitting structure for prospective shellfish aquaculture growers, and is working to expand shellfish leasing and revise the State's shellfish leasing policies and regulations. This expanded role is due to the industry's significant growth potential, its capacity to create a source of new jobs, and for the ancillary ecosystem benefits that can be realized by shellfish farming (*e.g.*, removal of excess nutrients and through the creation of hard structural habitats in the marine environment, see Beneficial Effects, below). http://www.state.nj.us/dep/fgw/shelhome.htm

***Shellfisheries Council***

As authorized by State law (N.J.S.A. Title 50:1-1, *et seq.*), the SFC is a vital conduit between the State of New Jersey and the native shellfish industry. The SFC is the primary advisory body to the NJDEP Commissioner on shellfish matters. The SFC represents commercial industries worth hundreds of millions of dollars to New Jersey's economy and is especially critical to the coastal communities where shellfish are grown and harvested. The SFC is divided into two regional sections, Atlantic Coast and Delaware Bay, and is responsible for the formulation of comprehensive policies for the preservation and improvement of the shellfish industry and resources within each region. The SFC has the exclusive power to administer leased bottom for the cultivation of shellfish. The Delaware Bay Section consists of five members from the counties of Cumberland (3) and Cape May or Salem (2). The SFC members are unpaid appointees that strive to ensure the shellfish industry remains viable in New Jersey. The chairpersons of the two sections of the SFC also hold seats on the New Jersey Marine Fisheries Council. Each member must be a licensed and practicing shellfisherman, selected with due regard to his or her knowledge of and interest in the culture of harvesting of shellfish, the shellfish industry, and in the conservation and management of shellfish.
http://www.state.nj.us/dep/fgw/councils.htm#shellfish

***Endangered and Nongame Species Program***

The ENSP is the primary program within the NJDFW responsible for implementing the State's Endangered and Nongame Species Conservation Act (N.J.S.A. 23:2A). Consistent with this Act's legislative authority to enter into agreements with the Federal agencies, ENSP is also the primary program charged with implementing a cooperative agreement with the Service under Section 6 of the ESA. The ENSP has no direct regulatory authority over aquaculture activities, but provides its technical expertise and assistance within the NJDFW, to DLUR, and to the Service with respect to anticipated direct and indirect impacts of aquaculture activities on State and federally listed wildlife. In this case, ENSP's role has been to apply its considerable experience and biological expertise with regard to the federally (threatened) and State-listed (endangered) red knot, and this species' use of Delaware Bay, to evaluate the potential impacts of aquaculture activities on knots, and to assist in the development of CMs designed to avoid and minimize such impacts. http://www.njfishandwildlife.com/ensphome.htm

### *Endangered and Nongame Species Advisory Committee*

Established in 1974 by the New Jersey Endangered and Nongame Species Conservation Act (N.J.S.A. 23:2A-7e), the ENSAC is appointed by the NJDEP Commissioner and serves as an advisory body to that office in matters of New Jersey endangered and nongame wildlife resources. The Committee consists of 11 members from four broad public affiliations, as outlined in N.J.A.C.7:25-4.18. Four members come from the research and academic community, one is a veterinarian or public health professional, three represent nonprofit organizations with strong interest in nongame wildlife conservation, and three are appointed from the public-at-large. The ENSP staff present research agendas, policies, and current important wildlife conservation topics to the ENSAC for their review and advice. The ENSAC formally recommends status listing changes to the State nongame wildlife list biennially. In addition, ENSAC members often introduce and pursue issues of importance and recommend action to the ENSP, NJDFW or NJDEP. The input of the ENSAC members based on their personal experience and interest is of great value to the ENSP, NJDFW, and NJDEP. The ENSAC's formal recommendations can become an integral part of the State's development of policy and decision making; however, the role is advisory only. There is no legal obligation for the NJDEP to adopt the ENSAC's recommendations. An excellent working relationship among the ENSP, NJDFW, and the NJDEP and the ENSAC has developed over the years, and policies often reflect the ideas generated at Committee meetings. http://www.state.nj.us/dep/fgw/councils.htm#ensac

### *Division of Land Use Regulation*

In accordance with the State's Waterfront Development rule (N.J.A.C. 7:7-2.4), DLUR (within the NJDEP) regulates all tidal waterways and lands lying thereunder, up to and including the MHW line. Both structural and non-structural aquaculture are regulated activities under this rule. Regulated non-structural activities include deposition of sub-aqueous materials (*e.g.*, shell or oyster planting). In addition, permits are required for construction of any structures (including deployment of aquaculture gear) in the waterfront area defined in this rule.

The DLUR has created three permits by rule and two general permits for aquaculture activities. Permit by rule # 16 (N.J.A.C. 7:7-7.16) is for the placement of land-based upwellers and raceways, including intakes and discharges, for shellfish aquaculture activities, provided the applicant meets all conditions of the permit by rule. Permit by rule # 17 (N.J.A.C. 7:7-4.17) is for the placement of predator screens and oyster spat attraction devices within a valid shellfish lease area pursuant to N.J.S.A. 50:1-23, provided the applicant meets all conditions of the permit by rule. Permit by rule # 18 (N.J.A.C. 7:7-4.18) is for the placement of shellfish cages within a valid shellfish lease area pursuant to N.J.S.A. 50:1-23, provided the applicant meets all conditions of the permit by rule.

In addition to the permits by rule, there are two general permits for aquaculture activities. General Permit # 30 (N.J.A.C. 7:7-6.30) authorizes the construction, placement, and/or maintenance of shellfish aquaculture equipment, including floating upwellers, shellfish rafts, racks and bags, lantern nets, and cages, provided the applicant meets all conditions of the general permit. General Permit # 31 (N.J.A.C. 7:7-6.31) authorizes the placement of shell in an area with a valid shellfish lease, provided the applicant meets all conditions of the general permit. If an applicant is proposing an activity not described in the permits by rule or general permits, then he or she would likely need to apply for a Waterfront Development Individual Permit. http://www.nj.gov/dep/landuse/

***Tidelands Resource Council***

The State asserts a title interest in tidelands (riparian lands), not previously sold via a grant, for the benefit of all the citizens' Public Trust rights. The NJDEP's BTM supports the TRC, which is a 12-member body appointed by the Governor with the advice and consent of the legislature. Permission from the TRC is required for occupation of tidelands, such as the placement of any structures or fill, or any activity that excludes use or access by the public. The placement of structural aquaculture operations requires a Tidelands License. The aquaculture license authorizes use of the entire area defined by the structures themselves and any passageways between them where the public would be excluded. The TRC establishes policies for approval of all tidelands conveyances and makes the decision to rent (via leases or licenses) or sell (via a grant) tidelands. Tidelands License applications that follow established TRC policy are issued by the BTM. Any license application that does not follow TRC policy, and all grants to sell or tidelands, have to be presented to the TRC for a vote for approval. In 2010, the TRC adopted an "Aquaculture License Fee Policy" which is posted on the NJDEP web site.[7] Traditional (non-structural) shellfish aquaculture and harvesting that does not include the placement of structures does not require a Tidelands License.
http://www.nj.gov/dep/landuse/tl_main.html

***Bureau of Marine Water Monitoring***

The Bureau of Marine Water Monitoring (BMWM) is within the NJDEP's Division of Water Resource Management. The BMWM is involved in many aspects of the State's coastal water quality program including monitoring for compliance with the National Shellfish Sanitation Program (NSSP). Compliance with the NSSP is necessary to allow for interstate commerce of New Jersey shellfish product. The BMWM is currently proposing amendments, repeals, and new rules to N.J.A.C. 7:12 to comply with NSSP requirements. The existing and proposed rules classify shellfish growing waters and determine whether and how the harvest of shellfish from those waters must be restricted in order to protect the public from risks associated with the consumption of shellfish. Two permits dealing with aquaculture are among the proposed new rules: a Commercial Shellfish Aquaculture Permit, and a Permit for a Hatchery to Produce and Grow Seed or for a Nursery to Grow Seed. The proposed Commercial Shellfish Aquaculture Permit will implement the applicable standards for commercial aquaculture (for both structural and non-structural) from the NSSP "Guide for the Control of Molluscan Shellfish," to ensure the safety of aquaculture shellfish, including defining seed size and requiring each aquaculture permittee to have and implement an approved operational plan. The proposed regulatory changes aim to promote and protect the State's valuable shellfish resource, and support aquaculture by following NSSP member State requirements to ensure interstate commerce of shellfish product.
http://www.nj.gov/dep/bmw/

[7] http://www.nj.gov/dep/landuse/download/TD_009.pdf

*Bureau of Law Enforcement – Marine Unit*

The Marine Unit of NJDEP's Bureau of Law Enforcement (BLE) patrols 31 shellfish growing areas. As per NSSP guidelines, patrols must be conducted by police-trained law enforcement officers. The BLE is also responsible for: enforcement of statutes related to shellfish harvest or possession and related to taking, possession, distribution, or sale of shellfish from condemned waters; administering fines and license suspensions; administering rules regarding licensing, methods and times of harvest, shellfish leasing, and product tagging requirements; and administering the State's *Vibrio parahaemolyticus* (Vp) Control plan.[8]
http://www.state.nj.us/dep/fgw/lawhome.htm

*New Jersey Department of Health*

The New Jersey Department of Health's (NJDOH) Seafood and Shellfish Project (Project) primarily regulates post-harvest shellfish processing operations under State rules at N.J.A.C. 8:13. While the Project does not regulate aquaculture, it does stay involved with aquaculture issues on a professional level in order to assist with the safety and security of shellfish in the State of New Jersey. Part of the Project's responsibility is to provide input to ensure compliance and protect the integrity of environmental conditions for all New Jersey shellfish species.
http://www.nj.gov/health/foodanddrugsafety/ssp.shtml

*New Jersey Department of Agriculture*

The NJDA is the lead State agency for the development, marketing, promotion, and advocacy of the aquaculture industry. The NJDA works to support the growth of all aquaculture sectors within the State, including shellfish, finfish, aquatic plants, and aquaponics (*i.e.*, systems that combine conventional finfish aquaculture with the hydroponic cultivation of plants). This includes assisting growers with the marketing and promotion of their products at both the local and regional levels; providing guidance and interagency coordination for appropriate permitting; and facilitating grower participation in Federal assistance programs. The NJDA is also the lead agency for providing technical assistance to aquaculturists on a suite of topics from best management practices to permitting. The NJDA serves the role of advocate for the aquaculture industry when dealing with regulatory changes. New or revised rules that have an impact on the aquaculture industry are reviewed by NJDA staff and the AAC. http://www.nj.gov/agriculture/

*Aquaculture Advisory Council*

The AAC was established by the 1998 Aquaculture Development Act (N.J.S.A. 4:27-1 *et seq.*). The AAC meets regularly and is an efficient means for agencies, universities, and the public to meet and discuss matters affecting aquaculture development. The New Jersey Secretary of Agriculture serves as chairman. The AAC acts in an advisory capacity to the NJDA and other State agencies on aquaculture matters, evaluates proposed and existing rules and regulations, and

[8] *Vibrio parahaemolyticus* is an organism that occurs naturally in coastal waters that is not related to pollution. Consumption of raw or undercooked shellfish, usually oysters, with high levels of *V. parahaemolyticus* may result in gastrointestinal illness in humans. Symptoms typically resolve within 72 hours, but can persist for up to 10 days in immunocompromised individuals. The State's *Vibrio* control plan is updated annually, and can be found online at http://www.nj.gov/dep/bmw/

develops policies mandated by the provisions of 1998 Aquaculture Development Act. http://www.nj.gov/agriculture/divisions/anr/sea/#2

***Haskin Shellfish Research Laboratory***

The Haskin Lab is a New Jersey Agricultural Experiment Station and a field station for the Department of Marine and Coastal Sciences, both part of the School of Environmental and Biological Science at Rutgers, the State University of New Jersey. This dual role permits the Haskin Lab to draw upon the strengths of both programs to fulfill its mission in support of fisheries and aquaculture research. The station has a 120-year tradition of disseminating research results and working cooperatively with State and Federal agencies and the fisheries and aquaculture communities in New Jersey. The Haskin Lab generates and disseminates research information directly applicable to all aspects of fisheries and aquaculture science, concentrating on species of commercial importance to New Jersey. The Haskin Lab maintains four facilities in southern New Jersey, including the Cape Shore Lab within the action area (Figures 3 and 9). http://hsrl.rutgers.edu/

***Delaware Bayshore Council***

Established in 2015, the DBC is an unofficial body composed of local officials and public interest groups. Goals of the DBC include sustainable economic opportunities for residents, representation in State and Federal government, maintaining the quality and value of natural resources, resiliency planning, increased funding, streamlined permitting, and increased public awareness of the region's value. Current priorities include gaining recognition for the Delaware Bayshore region, supporting ecotourism, and advancing restoration projects. The DBC includes representatives from municipal and county governments, Congressional and State legislative offices, various environmental organizations, Rutgers, and Stockton University.

**Conservation Measures**

Conservation Measures (CMs) are actions to benefit or promote the recovery of listed species that are included by the Federal agency as an integral part of the proposed action. These actions will be taken by the Federal agency or applicant (*i.e.*, once adopted, CMs are non-discretionary), and serve to minimize or compensate for project effects on the species under review. These may include actions taken prior to the initiation of consultation, or actions that the Federal agency or applicant have committed to complete in a BA or similar document (USFWS and NMFS 1998).

On behalf of the State, NJDFW, which includes both BSF and ENSP, with assistance from the NJDA, prepared a BA (NJDFW 2016) to establish a framework by which both structural aquaculture and red knot recovery can be accommodated along the Cape May peninsula's Delaware Bay shoreline. As listed below, the CMs have been revised slightly from the BA, with concurrence of the NJDFW.

As the permit holder for the ADZ, the NJDFW (within NJDEP) commits to implementing all the CMs described in this section over the 10-year life of this PBO. As the agency charged with administering the State's programs for both aquaculture and shorebirds, the NJDFW commits to a leadership role in implementing these CMs. As the Federal action agency, the Corps commits to reflect the following CMs, to the extent applicable, as conditions of its individual authorizations for structural aquaculture in the action area. This PBO is intended to allow for adaptive management of structural aquaculture as it relates to effects on red knots. The NJDEP, the NJDA, the Corps, and the Service commit to periodic review of these CMs in light of new information (see CM 6). These agencies agree that the CMs may be altered by mutual agreement, so long as the types and levels of adverse effects (including incidental take) described in this PBO, and in any subsequent Tier 2 consultation documents, are not exceeded.

***Operational Measures***

*1. PBO Implementation*

a. Within all ADZs in the action area, the State, as the Corps permittee, will implement all provisions of this PBO.

b. Outside of ADZs (*e.g.,* within shellfish leases and/or riparian grants), the State will seek to reflect the provisions of this PBO in its support, permitting and regulation of structural aquaculture, within the limits of its legal and regulatory authorities. (See Action Implementation, above.)

c. The Corps will implement this PBO throughout the action area by referencing the provisions of the PBO in its permit conditions.

*2. Geographic Differentiation*

By looking at the "big picture" of both industry and the red knots, the NJDFW, the NJDA, and the Corps, in consultation with the Service, have attempted to minimize conflicts by dividing the action area into two complementary management zones (see Subdivision of the Action Area, above). In the Southern Segment, intertidal flats are wider, red knot use is relatively lower, and aquaculture is already well established; therefore, the emphasis is on providing sufficient space, flexibility, and support to allow for aquaculture expansion. In the Southern Segment, aquaculture will be clustered, facilitated, and expanded, recognizing that there will be localized adverse effects to red knots as a result. In the Northern Segment, intertidal tidal flats are narrower; red knot use is more highly concentrated (see Environmental Baseline); and existing aquacultural use is low; therefore, the emphasis is on red knot conservation. In the Northern Segment, red knot conservation and recovery will be prioritized over development of new shellfish aquaculture farms, partially as a compensatory measure to offset red knot impacts in the Southern Segment. To these ends, several of the CMs differ markedly between the Northern and Southern Segments.

*3. Habitat Mapping*

In cooperation with the NJDEP, the Service has identified the extent of red knot habitat (including both foraging and roosting areas) (Figures 8 and 9) within the action area. As defined in this PBO, "red knot habitat" includes all beaches, marsh, tidal flats, and creek mouth shoals from the landward limit of the beach/dune to the MLLW line. The agencies have also delineated "Protected Areas" (Figures 8 and 9). Protected Areas are considered the most important red knot foraging habitats within the action area, and include all areas within 300 feet (91 m) of the MHW line (both seaward and landward of MHW), as well a 500-foot (152-m) buffer around all creek mouth shoals. The Protected Areas include all lands and waters (subtidal, intertidal, and supratidal) within these buffers.

The 500-foot (152-m) buffer on the shoals at the mouth of Green Creek has been waived to accommodate existing aquaculture operations within ADZ-4. However, aquaculture structures and equipment will not be allowed on the Green Creek shoal proper. That said, at the time of this PBO, some structural aquaculture is located on the Green Creek shoals. The BSF will work with ADZ leaseholders and assist them to relocate off the Green Creek shoals on or before April 14, 2019 (see CM 10).

The shoal mapping methodology is also different for Green Creek. For all the other creek mouths in the action area, the mapping is based on a delineation of shoals from all available aerial imagery from 1995 to 2013, to allow space for the natural processes of shoal accretion, erosion, and migration. In contrast, the shoals at Green Creek will be mapped by the BSF annually in April, such that the Protected Area will cover only the actual extent of the shoal each year (Figure 9). In this area around Green Creek (and only in this area), the Protected Area will move from year to year. The BSF will coordinate closely with all growers near the mouth of Green Creek to ensure annual compliance with restrictions on activities in the Protected Area (*e.g.*, see CM 10).

### *4. <u>Restricted Seasons</u>*

Tables 1 and 2 give the various seasonal restrictions referenced elsewhere in the CMs. All restricted seasons are inclusive of the first and last date listed. The seasonally restricted periods on access will be shortened if red knots depart Delaware Bay before June 7, based on coordination between NJDFW and the Service. The BSF will notify growers if the restrictions are lifted early; the BSF and the growers will develop a communication plan. The seasonally restricted periods on vehicle use and gear will not be shortened.

Note that the restricted seasons in Table 2 start April 15 instead of May 1. More intensive driving is expected during periods of gear installation or re-configuration. Concluding such work by April 15 gives the habitat a chance to recover (*e.g.*, from rutting or dispersal of wrack material) before red knots return in early May (see Effects of the Action—Habitat Modification, below). Notwithstanding this concern to limit driving during the second half of April, the Vehicle Use Plans do not go into effect until May 1, because early May is the earliest we expect any red knots or appreciable horseshoe crab spawning activity in the action area.

**Table 1. Seasonal restrictions on driving and access** (The number of the applicable CM is given in parentheses.)

| | **Southern Segment** | **Northern Segment** |
|---|---|---|
| May 1 to June 7* | Vehicle Use Plan** (CM 9).<br>Intertidal Access Plan** (CM 15).<br>Subtidal measures (CM 11).<br>Emergency gear retrieval (CM 16). | No driving (CM 9).<br>No intertidal access (CM 15).<br>Subtidal measures (CM 11).<br>Emergency gear retrieval (CM 16). |
| June 8 to September 15 | Vehicle Use Plan (CM 9). | Vehicle Use Plan (CM 9). |
| September 16 to April 30 | No driving or access restrictions. | No driving or access restrictions. |

*In the unlikely event that red knots do not depart Delaware Bay by June 7, these measures will remain in effect until birds depart or June 15, whichever comes first. If the measures are extended beyond June 7, BSF will notify growers.
**These may be combined into one plan.

**Table 2. Seasonal restrictions on gear** (The number of the applicable CM is given in parentheses.)

| | **Southern Segment** | **Northern Segment** |
|---|---|---|
| April 15 to June 7 | Gear specifications (CM 8).<br>No gear in Protected Areas (CM 10).<br>No installation of new intertidal gear (CM 13).<br>Preferential use of sloughs (CM 14). | No intertidal structures/gear (CM 12).<br>Gear specifications (subtidal) (CM 8).<br>No gear in Protected Areas (subtidal) (CM 10). |
| June 8 to July 31 | Gear specifications (CM 8). | Gear specifications (CM 8). |
| August 1 to April 14 | No gear restrictions. | No gear restrictions. |

*5. <u>Monitoring</u>*

Growers will cooperate with all research and monitoring programs endorsed by the NJDEP and the Service related to red knots, horseshoe crabs and/or aquaculture. Cooperation will entail allowing access for authorized research personnel under various conditions (*e.g.*, times of day, tidal cycles, and periods when tending is not occurring). There will be regular communication between growers and researchers regarding the timing and nature of both aquaculture activities and research activities. If any research or monitoring program would involve active data collection by the growers, each grower can elect whether or not to participate in that aspect of the program.

*6. <u>Adaptive Management</u>*

The NJDEP, NJDA, Corps and the Service will meet at least annually for the life of the PBO (10 year period) to review any new scientific and commercial data. At their discretion, these agencies may include other stakeholders or experts in these meetings and/or in preparation for these meetings. The overall nature and level of adverse effects described in this PBO will not be exceeded. Likewise, the amount of incidental take authorized in this PBO, and in any subsequent

Tier 2 consultations, will not be exceeded. The specifics of the CMs may be adjusted if the agencies (with Service concurrence) determine, based on new data or new reviews of existing data, that modified or alternative management practices can: (a) reduce adverse effects to red knots; (b) benefit the aquaculture industry without increasing adverse effects to red knots; or (c) both.

### *7. Phased Build-out*

*Southern Segment*

Within each non-ADZ lease or riparian grant, no more than half of the total authorized new structures, covering no more than half of the total authorized area, will be constructed each year, requiring at least two years for full build-out (*e.g.*, at least two years to deploy all the gear authorized in the Corps permit). This requirement for phased build-out may be waived for projects involving small amounts of gear, and/or for existing operations. ("Small amounts" of gear will be determined in the Tier 2 process). This phasing requirement does not apply to repair or replacement of gear, and does not apply to existing operations that are already at full build-out as of the effective date of this PBO. This phasing requirement does not apply to the existing ADZ-4. For any new or expanded ADZ areas, a site-specific phasing plan will be developed during the Tier 2 process.

*Northern Segment*

Growers proposing to utilize a private lease or riparian grant in the Northern Segment (which is permitted only between June 8 and April 14, as per CM 12) will prepare a Build-Out Plan that describes gear types and amounts over the life of the Corps permit or NWP authorization. For proposals involving large amounts of gear between June 8 and September 15, the Build-Out Plan should describe a phased deployment over three years. A site-specific phasing plan will be developed during the Tier 2 process, considering factors such as the types, amounts, and location of gear, and the season(s) in which it will be in use.

### *8. Gear Specifications to Reduce Risk of Horseshoe Crab Impacts*

The following gear specifications will be implemented from April 15 to July 31 in all intertidal parts of the action area, and in subtidal parts of the action area shallower than 5 feet (1.5 m) at MLW. It should be noted that in the Northern Segment there will be no intertidal structural aquaculture from April 15 to June 7 (see CM 12), thus in the Northern Segment this CM applies only to shallow subtidal areas, and to intertidal areas between June 8 and July 31.

The purpose of this measure is to minimize any potential impacts that that aquaculture structures might have on nearshore horseshoe crab activity, including crab spawning, passage and foraging. The NJDFW, NJDA, and the Corps, in consultation with the Service, acknowledge considerable uncertainty regarding horseshoe crab impacts from structural aquaculture. The following CMs were developed based on published literature of horseshoe crab size, anatomy, and behavior, and based on observed entanglement and entrapment in other settings. These Measures are generally similar to current industry gear standards and practices, with one key difference—an emphasis on keeping gear raised up off the bottom. Recognizing uncertainty around this issue, the State reached out for industry feedback on current practices and these particular CMs dealing with gear specifications. In addition, the agencies have built in a long transitional period for industry adoption of CM 8.c., below.

Through the adaptive management process, additional gear specifications may be developed if impacts to horseshoe crabs are observed. For example, limits may be placed on the percentage of intertidal and shallow water area that can be covered by gear. Conversely, the following gear provisions may be relaxed or waived if lesser or alternative gear specifications are shown to effectively avoid or minimize horseshoe crab impacts.

The following specifications were developed with oyster aquaculture in mind. Gear considerations specific to cultivation of other species of native bivalves (*e.g.*, clam screens) will be evaluated during the adaptive management and Tier 2 processes.

a. Cables or ropes used for any purpose will be at least 0.5 inch (1.3 cm) (rope) or 0.25 inch (0.6 cm) (stiff cable) in diameter, made of materials resistant to fraying, maintained in good condition, and configured in way to avoid crab entanglement. Neither monofilament line nor fibrous materials (*e.g.*, jute cloths) should be used for any purpose.

b. For all gear types, linear, shore-perpendicular configurations and grid arrangements will be used preferentially over shore-parallel or grid arrangements, to the extent practicable.

c. All gear (*e.g.*, cages, racks), will be maintained at least one 1 foot (30 cm) off of the bottom—to the extent practicable—to allow crab passage and minimize the risk of crab entrapment. Legs (not including a foot or bend) shall be at least 14 inches (36 cm). In areas of existing aquaculture operations this height requirement can be phased in over four years from the date of the first annual agency PBO review meeting (see CM 6), to which (or before which) the agencies will invite a selected panel of horseshoe crab experts. These (raised) structures will be arranged in arrays no more than 6 feet (1.8 m) wide (*e.g.*, two racks side-by-side), and 4 to 6-foot (1.2 to 1.8-m) lanes will be maintained between each array, to facilitate crab passage.

d. No spacing requirements are required for floating structures located in water sufficiently deep to remain floating at least 1 foot (30 cm) off the bottom at MLLW, to allow crab passage.

e. Any gear that rests on the bottom (*e.g.*, cages with short or no legs, floating gear that rests on the bottom at certain tides) will not exceed a total area of 1,000 square feet (93 square m) (footprint of actual gear) in each lease or grant, and will be clustered in a designated area of the lease or grant. These structures will be arranged in arrays, and 4 to 6-foot (1.2 to 1.8-m) lanes will be maintained between each array, to facilitate crab passage. To the extent practicable, all gear will be maintained less than 1 inch (2 cm) OR at least 12 inches (30 cm) off the bottom, to limit the risk of horseshoe crab entrapment that may be presented by gear with bottom clearance between 1 and 12 inches (2 and 30 cm). Alternative bottom gear configurations, and exceptions to this total coverage area maximum, may be considered on a case-by-case basis with regard to horseshoe crab impacts. The total area covered by gear that rests on the bottom will be evaluated during the adaptive management process, allowing for greater floating or experimental gear when it can be shown to have minimal impacts on horseshoe crabs or red knots.

*9. Measures to Reduce Horseshoe Crab Impacts from Vehicle Use*

Unrestricted beach driving during the horseshoe crab spawning season could impact horseshoe crab adults, eggs, and larvae. To reduce such impacts, each proposal for a structural aquaculture operation involving use of motorized land-based vehicles will include a site-specific intertidal vehicle use and ingress/egress plan (Vehicle Use Plan) covering the period May 1 to September 15.

In both the Northern and Southern Segments, the Vehicle Use Plans will reflect the following CMs: (a) designate and consistently use approved beach entry and exit points, and driving routes, preferentially selecting routes already in use for aquaculture and avoiding undisturbed stretches of beach; (b) minimize the amount of driving on the beach parallel to the shoreline; (c) when driving parallel to the shoreline cannot be avoided, drive as far seaward of the high water line as practical; (d) avoid driving through concentrations of crabs and in the wrack line.

In the Southern Segment, the Vehicle Use Plans must be coordinated with, and may be combined with, the Intertidal Access Plans that govern the period from May 1 to June 7, as required by CM 15.

In the Northern Segment, the Vehicle Use Plans will specify that no driving may take place from May 1 to June 7. (As per CM 12, intertidal structural aquaculture is prohibited in the Northern Segment from April 15 through June 7, with two exceptions described in Measures 20 and 21. Thus, no driving is necessary during the red knot stopover window of May 1 to June 7.) From June 8 to September 15 vehicle use will be allowed in the Northern Segment as long as it is in accordance with an approved Vehicle Use Plan. (Note that, as specified in Appendices C and D, no driving is allowed on Leases A-19 and A-28 from May 1 to August 31 during the transitional years on those two leases. See also CMs 20 and 21.)

*10. Protected Areas*

From April 15 to June 7, there will be no structures, gear, associated materials, or stockpiling of material or equipment in any portion of the Protected Areas (see CM 3 and Figures 9 and 10). This restriction applies to both intertidal and subtidal aquaculture, and applies to all Protected Areas including all water, dry land, and intertidal areas.

At the time of this PBO, some structural aquaculture is located on the shoals associated with the mouth of Green Creek, at the southern end of ADZ-4. The BSF will work with ADZ leaseholders and assist them to relocate off the Green Creek shoals on or before April 14, 2019. As discussed under CM 3, the shoals at Green Creek will be mapped by the BSF annually in April of each year, such that the Protected Area will cover only the actual extent of the shoal each year. In this area around Green Creek (and only in this area), the Protected Area will move from year to year. The BSF will coordinate closely with any growers near the mouth of Green Creek to ensure annual compliance with the Protected Area restrictions, as described above.

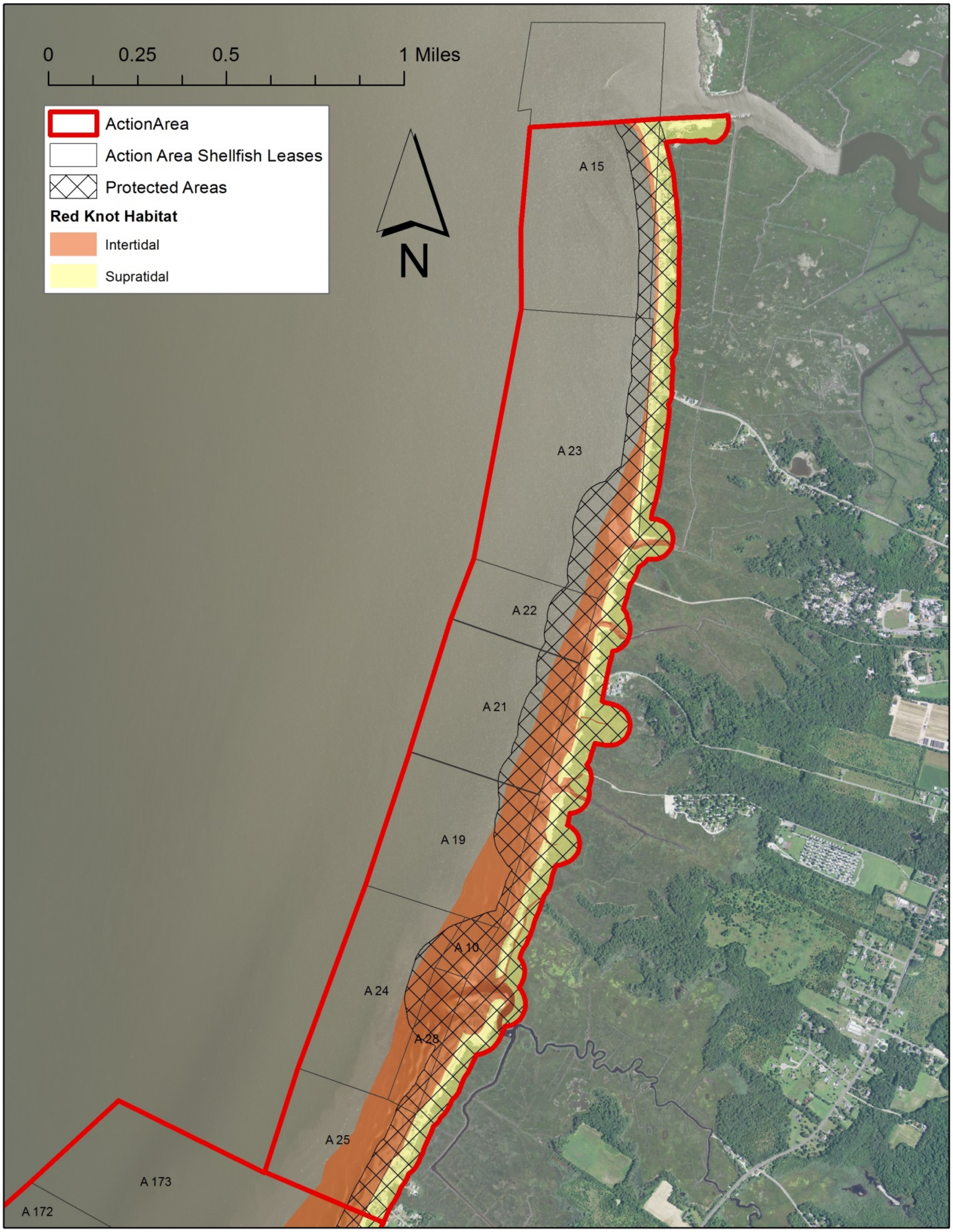


**Figure 8. Red knot habitat and Protected Areas, Northern Segment**

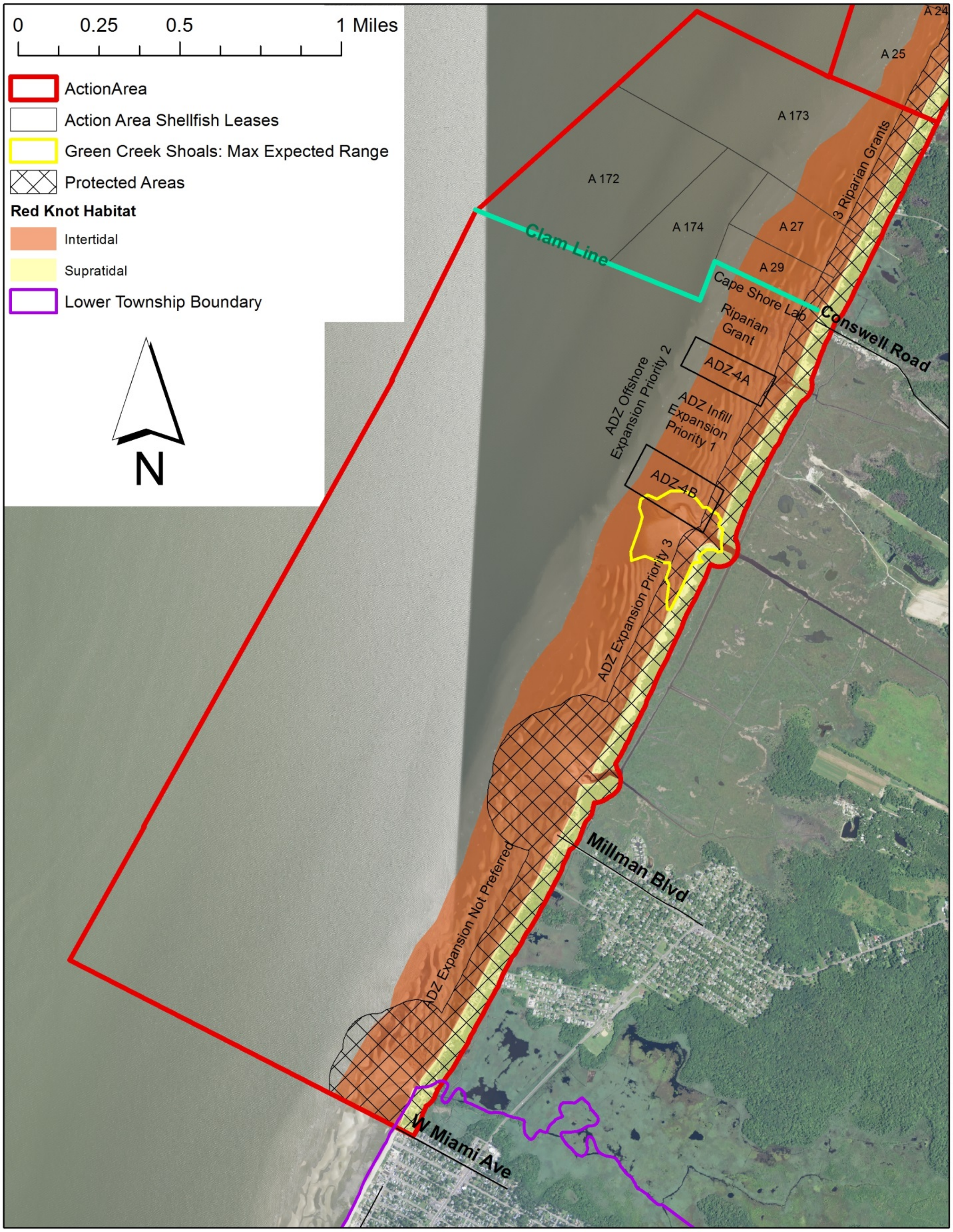


**Figure 9. Red knot habitat and Protected Areas, Southern Segment**

*11. Measures Specific to Subtidal Aquaculture*

The following Measures will apply to subtidal aquaculture from May 1 to June 7, in order to minimize disturbance of red knots.

a. Boat access via creeks that run through red knot habitat (*e.g.*, between creek mouth shoals) will be direct, and will minimize time spent crossing the red knot habitat (*e.g.*, no docking, stopping, or anchoring in these areas except in an emergency).

b. Notwithstanding Item 11.a. above, all boats that must pass through red knot habitat will do so at low speeds that do not produce a wake.

c. Growers will ensure consistent use of designated entry and exit points to, and travel routes within, their growing areas (to be approved during the Tier 2 process).

d. Northern Segment:

   i. All access will be only via boat (no land-based access).

   ii. During all aquaculture activities (*e.g.*, tending, harvesting), the boat(s) will remain at least 500 feet (152 m) from the water's edge during all parts of the tidal cycle.

   iii. The 500-foot (152-m) buffer distance may be evaluated during the adaptive management process (CM 6). The intent is to avoid all disturbance to red knots, particularly from any larger-scale subtidal operations (*e.g.*, those involving large boats and/or large numbers of boats).

e. Southern Segment:

   i. Access will be by boat unless there is an adjacent intertidal farm, in which case access may also be via land (with permission, as needed, to cross the adjacent intertidal farm).

   ii. Access by land will follow the approved Intertidal Access Plan for the adjacent intertidal farm, as required by CM 15.

   iii. For access by boat, all boat(s) will remain at least 500 feet (152 m) from the water's edge during all parts of the tidal cycle, OR will follow the same schedule as adjacent intertidal farm (within the approved Intertidal Access Plan; see CM 15). If boat(s) follow the same schedule as the adjacent intertidal farm and approach closer than 500 feet (152 m) from the water's edge, there will be no dogs allowed on the boat(s) during such times.

   iv. The 500-foot (152-m) buffer distance may be evaluated during the adaptive management process (CM 6).

*12. Intertidal Aquaculture: Protection of Red Knot Foraging Habitat*

*Southern Segment*

From April 15 to June 7 the total area occupied by aquaculture (*e.g.*, total footprint of aquaculture, including both gear and lanes/spaces around the gear) will not exceed 150 acres (61 ha). This acreage limit will include the total intertidal footprint of both ADZ and non-ADZ operations in the Southern Segment. Following the existing State ADZ program model, expansion of intertidal aquaculture south of the Clam Line will occur only within a State-established ADZ that has been approved by the Delaware Bay Section of SFC. [9] The locations for ADZ expansion are prioritized to maximize clustering of intertidal aquaculture and thereby minimize aggregate effects to red knots. As described under ADZ Expansion, above, the NJDEP will sequence ADZ growth in the following priority order.

- First priority: Infill between ADZ-4A and ADZ-4B (Figures 3 and 9)
- Second priority: Expand ADZ-4 seaward (Figures 3 and 9)
- Third priority: Expand ADZ-4 immediately south of the Green Creek shoals (Figures 3 and 9)
- Not-preferred: Establish a new ADZ disjunct from ADZ-4, well south of Green Creek (Figures 3 and 9). This option will only be pursued if the First, Second, and Third priorities, above, prove insufficient to meet industry demands for growing space and/or prove impossible to implement.

A limit on the total size of the intertidal footprint is important in assessing the Effects of the Action, below. In arriving at this 150-acre (61-ha) limit, the BSF, ENSP, and NJDA considered the following factors: (a) current demand (*e.g.*, the area of all existing operations and the nearly four-year-old waiting list for the current ADZ-4) and the expected rate of growth in demand over the 10-year life of the PBO (see Current and Future Extent of Aquaculture, above); and (b) the total area of available intertidal flats (outside of Protected Areas) in both the Northern and Southern Segments.

*Northern Segment*

From April 15 through June 7, no structural aquaculture gear may be present in any intertidal areas of the Northern Segment, except as discussed under CMs 20 and 21. Intertidal structures

[9] Because no private leases are permitted south of the Clam Line, aquaculture can be conducted only within established ADZs or on riparian grants. We are aware of only one valid riparian grant south of the Clam Line. This grant is located between Rutgers Cape Shore Lab and ADZ-4A. We conclude that no structural aquaculture will likely occur on this grant based on recent feedback from the grant holder. If this situation changes, any intertidal areas occupied by structural aquaculture (including spaces and lanes) will count toward the 150-acre cap specified by Conservation Measure 12.

may be deployed on Northern Segment leases or riparian grants outside of this time period in accordance with all other applicable CMs.

*13. Intertidal Aquaculture: Installation of New Gear*

In the Southern Segment, there will be no installation of new gear or equipment between April 15 and June 7 within allowable growing areas (outside of Protected Areas). This does not apply to maintenance of existing gear or replacement of damaged gear.

This Measure is not applicable to the Northern Segment due to the prohibition on all intertidal structural aquaculture from April 15 to June 7 as established by CM 12.

*14. Intertidal Aquaculture: Preferential Use of Sloughs*

In the Southern Segment, from April 15 to June 7, growers can consider preferentially locating gear in sloughs that retain water throughout the tidal cycle in order to reduce the visibility of the gear and to reduce the area of intertidal flats that is covered. This CM is not a requirement. The gear spacing and arrangement (*e.g.,* shore-perpendicular) specifications in CM 8 are more important than placement in sloughs.

This Measure is not applicable to the Northern Segment due to the prohibition on all intertidal structural aquaculture from April 15 to June 7 as established by CM 12.

*15. Intertidal Aquaculture: Frequency and Duration of Access*

Under CM 9, all growers in the action area will have an approved Vehicle Use Plan for the operation of motorized land-based vehicles between May 1 and September 15 to minimize impacts on spawning horseshoe crabs and developing crab eggs and larvae. From May 1 to June 7, the additional CMs listed below will also apply to other human activities (both motorized and non-motorized) in order to limit direct disturbance to red knots (Table 1).

*Southern Segment*

Each proposal for an intertidal aquaculture operation will include a site-specific access and travel plan (motorized, by boat, and/or on foot) (Intertidal Access Plan) for the period May 1 to June 7. The Plan will reflect the following: (a) limit access to the 2 hours before and 2 hours after low tide; (b) ensure all personnel enter and exit the growing area together and minimize the time spent crossing Protected Areas; (c) designate and consistently use beach entry and exit points, and beach walking/driving routes; (d) no driving parallel to the shoreline within any Protected Area; and (e) no personnel will bring dogs on the beach or on boats that are closer than 500 feet (152 m) to the water's edge. The Plan will also limit access to no more than 5 days per week, following a coordinated schedule to be developed by the NJDFW. Permittees may elect to combine the Intertidal Access Plan with the Vehicle Use Plan that is required under CM 9.

If the Intertidal Access Plan indicates that one or more boats will be used, the Plan will also specify the following: (a) boat access via creeks that run through red knot habitat (*e.g.*, between creek mouth shoals) will be direct, and will minimize time spent crossing the red knot habitat (*e.g.*, no docking, stopping, or anchoring in these areas except in an emergency); and (b) notwithstanding (a), all boats that must pass through red knot habitat will do so at low speeds that do not produce a wake.

As part of the adaptive management process (CM 6), the agencies will consider extending the tending period to 3 hours before and 3 hours after low tide. A key consideration will be documented levels of use by red knots and other shorebirds in and near oyster farms during this part of the tidal cycle. If red knot use is minimal even when humans are absent, then additional tending time would be unlikely to cause further disturbance.

*Northern Segment*

As per CM 12, no structural aquaculture gear may be present in any intertidal areas of the Northern Segment between April 15 and June 7, except as discussed under CMs 20 and 21. Thus, no access is necessary during the red knot stopover window of May 1 to June 7. Accordingly, no access will be allowed to intertidal portions of the Northern Segment for aquaculture activities from May 1 to June 7 (except as specified in CMs 20 and 21). (Further, as per CM 9, there will also be no driving in the Northern Segment from May 1 to June 7; Table 1).

*16. <u>Contingency for Retrieval of Gear and Other Emergencies</u>*

If any gear is known to be displaced from an authorized subtidal or intertidal growing area (*e.g.*, during a storm) and is deposited within the Protected Areas between May 1 and June 7, the grower will immediately notify the NJDEP who will promptly notify the Corps and the Service. When possible, retrieval will be planned and carried out to minimize disturbance of red knots. For example, if possible retrieval will occur during one of the regularly scheduled access periods (CM 15). The Service and/or the NJDEP may elect to monitor the retrieval.

If gear needs to be retrieved during normal business hours (Monday through Friday from 8:30 am to 4:30 pm) the grower is required to contact the NJDEP's Delaware Bay Office at (856) 785-0730 to report the incident and consult on a retrieval process. If no Delaware Bay Office staff are available or if the retrieval needs to occur outside of business hours, the grower will report the incident to the NJDEP at 1-800-WARNDEP and then proceed with any necessary response action.

In addition to gear retrieval other emergencies may arise. An emergency is a situation involving an act of God, disasters, casualties, national defense or security emergencies, etc. (*e.g.*, hurricane), and includes response activities that must be taken to prevent imminent loss of human life or property. The ESA includes provisions for emergency consultation.[10] Under no circumstances should this consultation requirement obstruct or delay an emergency response.

***Incentives to Growers***

The NJDFW intends to include as CMs certain incentive programs to ease the transition for lease/grant-holders in the Northern Segment to move to the Southern Segment, encourage

[10] http://www.fws.gov/northeast/njfieldoffice/pdf/EmergencyConsultation.pdf

clustering of aquaculture in the Southern Segment, and promote the development of subtidal aquaculture.

*17. Priority Status for Certain Applicants for New ADZ Lease Parcels*

Recognizing that some active growers will be impacted more than others by the north-south subdivision of the action area, and that the overall goal is to cluster aquaculture within the Southern Segment, the NJDEP has developed what is referred to as a *Right of First Refusal* for new ADZ leases. Any permitted growers that are significantly affected (either in the Northern Segment or within a currently active ADZ-4 lease) will be provided the first opportunity to obtain any new ADZ leases developed according to the ADZ expansion priorities described above (under ADZ Expansion and CM 12). Specifically, the *Right of First Refusal* involves preferentially offering any new intertidal ADZ leases to the two existing growers currently permitted to work in the Northern Segment, and to any existing ADZ-4 leaseholders that are impacted by the implementation of new Protected Areas, such as the shoal at the mouth of Green Creek. Thereafter, the NJDEP may elect to offer any additional new ADZ leases to: (a) other Northern Segment leaseholders that are significantly affected by the provisions of this PBO; (b) growers on the existing ADZ-4 waiting list; and/or (c) prospective growers via issuance of a public notice of availability. Offerings after the *Right of First Refusal* will be phased in over time and implemented incrementally.

*18. NRCS Financial Assistance*

Financial assistance for farmers to implement farm-based conservation measures has long been available from the NRCS. The New Jersey State office of NRCS recently set aside a dedicated funding source for aquaculture through its EQIP program. This competitive funding is available to help defray certain costs associated with implementing CMs on aquaculture farms. Technical and financial assistance through the Fiscal Year 2016 Program addresses excessive shoreline erosion, fish and wildlife habitat degradation, and inefficient energy use from equipment and facilities, among other issues. For example, conversion or replacement of gear to comply with CM 8 is eligible for this new EQIP funding. Any growers interested in this funding source will need to apply and undergo a review process. Because this is a competitive funding source, not all growers or applicants may be funded in a given year.

*19. NJDEP Shellfish Aquaculture Mini-Grant Program*

The NJDEP is developing a mini-grant program to financially assist growers by offsetting some of the costs incurred from relocating and/or changing culturing practices due to the provisions of this PBO. Although the details are still being developed, the NJDEP plans to begin offering mini-grants in late 2016 or early 2017. The mini-grant funding program would be established to: 1) assist with the relocation of currently permitted operations from the Northern Segment to the Southern Segment and/or outside of Protected Areas (*e.g.*, moving off the Green Creek shoal); and 2) assist existing oyster growers who want to expand their commercial oyster aquaculture operations in the Southern Segment (*e.g.*, purchasing seed, etc.).

Following a request for grant applications, the NJDEP will use NJDFW monies to incentivize industry growth within the ADZs by providing grant funds to purchase oyster seed and new equipment for approved structural aquaculture activities (*i.e.*, fully permitted activities operated in compliance with all provisions of this PBO). The NJDEP anticipates requiring some type of cost-matching requirement for the grantee over a defined period. The mini-grant program will not cover traditional shellfish aquaculture operations and will be based on funding availability. The first series of grants/awards will likely focus on the following:

- primarily, permitted intertidal Northern Segment growers who wish to relocate aquaculture activities to the Southern Segment (*e.g.*, within an available ADZ parcel);

- if funding permits, ADZ leaseholders who wish to expand operations, and;

- if funding permits, Southern Segment growers working on private leases or riparian grants that wish to expand operations.

***Transition for Existing Northern Segment Growers***

At the time of this PBO, two oyster growers have already received Corps authorizations (under NWP-48) for structural aquaculture on private leases in the Northern Segment of the action area. The Dias Creek Oyster Farm is authorized on Lease A-19, and the Sweet Amalia Oyster Company is authorized on Lease A-28. As with all the NWPs, these authorizations expire on March 18, 2017.

As part of authorizing these operations, the Corps satisfied its responsibilities under Section 7 of the ESA. Both authorizations contain Special Conditions intended to avoid adverse effects to red knots. However, these Special Conditions were developed before the initiation of programmatic formal consultation, and thus do not account for aggregate effects from expanding aquaculture along the Cape May bayshore. Further, the ESA consultations conducted for these two farms were "informal," and thus do not allow for any harassment or other incidental take of individual red knots that may occur, leaving these two growers vulnerable to unintentional ESA violations.

*20. Transition Specifications*

As part of the action proposed in this PBO, Corps-permitted aquaculture activities on Leases A-19 and A-28 will be allowed to continue operating in place during a transitional period.

- The Corps authorization for the Dias Creek Oyster Company (CENAP-OP-R-2012-798-24) is currently being modified to reflect operational changes. Although this modification is not complete at the time of this PBO, it was in progress (and nearly finalized) when programmatic consultation was initiated. During the transitional period, this farm will operate under the Special Conditions listed in Appendix C. These Special Conditions (Appendix C) will be included in the Corps' forthcoming modification to the Dias Creek Oyster Company's authorization.

- During the transitional period, the Sweet Amalia Oyster Farm will operate under the Special Conditions listed in its existing authorization (CENAP-OP-R-2014-970-24), dated April 6, 2015 (Appendix D).

- Until the end of the transitional period, the Special Conditions listed in Appendices C and D will be carried forward in all future Corps modifications or authorizations for the Dias Creek Oyster Company and/or Sweet Amalia Oyster Farm, respectively, including renewal of the NWPs in March 2017 (if these permittees wish to renew).

*21. Transition Sunset Date*

For each of these two permittees, the transitional period will end one year after that permittee has been offered an intertidal growing area within an ADZ, or on June 8, 2018, whichever comes first. After the transitional period ends, each of these two growers must cease operations, relocate, or adopt all provisions of the PBO that apply to the Northern Segment. Thus, on or before April 14, 2019, all aquaculture gear/structures will be removed from the intertidal portions of Leases A-19 and A-28. The Corps will reflect this transitioning requirement in all future modifications and authorizations for these two permittees. For the first year of the transitional period, certain levels and types of incidental take that may occur at these two farms are accounted for in this PBO and authorized in the accompanying Incidental Take Statement. If no ADZ intertidal growing areas have been offered and if these growers wish to renew the existing Corps authorizations under NWP-48 in March 2017 (conditioned as per Appendices C and D), Tier 2 consultations will be necessary and any further incidental take will be assessed at that time.

***Tier 2 Consultation Process***

To provide a full understanding of site-specific actions and potential impacts to red knots, each applicant/permittee will submit a Tier 2 consultation package to the Corps, who then consults with the Service for review and issuance, as appropriate, of a site-specific Incidental Take Statement. The Tier 2 process is required as part of all Corps permitting for all active and proposed structural aquaculture within the action area.

*22. Tier 2 Responsible Parties*

The BSF (on behalf of the permittee, NJDFW) will submit all required Tier 2 information and documents to the Corps for continued operation of the existing ADZ-4 under the provisions of the PBO, including the required Vehicle Use Plan and Intertidal Access Plan (CMs 9 and 15). The BSF will submit additional Tier 2s as needed for any future changes to ADZs within the action area, including any changes in access, expansion, relocation, or operational changes. For each Tier 2 consultation, the BSF will coordinate with ADZ leaseholders to obtain all necessary information. The NJDFW, primarily through the BSF, will be responsible for ensuring that all ADZ leaseholders comply with all provisions of this PBO.

All other growers, working outside of an ADZ, must conduct the Tier 2 process independently; the BSF will not provide a Tier 2 application for any lessee outside of an ADZ. For continuation of existing aquaculture, or initiation of new aquaculture, on private leases or grants, the lease or grant holder will be responsible for submitting all required Tier 2 information and documents to the Corps. Alternatively, the lease or grant holder may, via letter of permission, authorize another grower to utilize his/her growing area and to handle the Tier 2 submission and consultation process.

No Tier 2 consultations are necessary for operations on Leases A-19 (Dias Creek Oyster Company) or A-28 (Sweet Amalia Oyster Farm) carried out in accordance with CMs 20 and 21 (Appendices C and D) until the expiration of the NWPs on March 18, 2017. If either of these permittees wish to renew the NWP-48 authorization, each will be responsible for submitting all required Tier 2 information and documents to the Corps for continued operation under the provisions of Appendices C and D until the transition sunset date (see CM 21).

All permittees (*e.g.*, NJDFW, Dias Creek Oyster Company, Sweet Amalia Oyster Farm, any other non-ADZ growers) will be responsible for submitting the required Tier 2 information for any modifications to, or renewals of, their Corps authorizations.

In accordance with Section 7 of the ESA, the Corps is responsible for conducting the Tier 2 consultations with the Service upon receipt of all required information from the applicant or permittee. Upon initiation of Tier 2 consultation by the Corps, the Service will work cooperatively with both the Corps and the applicant/permittee to complete the consultation within the timeframe indicated under CM 23, below.

*23. Tier 2 Time Frame*

Within the constraints of available staff time, the Service will strive to complete Tier 2 consultations within 45 days of receiving complete information from the Corps. This timeframe may be extended by mutual agreement of the Corps and the applicant/permittee, for example if the agencies wish to schedule a site visit. Within the constraints of available staff time, the Service will prioritize timely completion of any outstanding Tier 2 consultations in March and April, in time for the red knot stopover period. However, applicants/permittees should avoid submitting new Tier 2 consultation requests in March and April whenever possible.

*24. Tier 2 Required Information*

The Tier 2 consultation process is in addition to any information or other requirements of the Corps, though the Tier 2 information can be combined and submitted concurrently with other information needed for Corps authorization.

To initiate Tier 2 consultation, applicants/permittees must submit the following:

a. Scale drawings of the proposed equipment/gear types and locations within the lease or grant area, both cross-sectional views (*e.g.*, to show gear heights) and plan views showing the MHW line, all red knot habitat, and all Protected Areas. (Electronic files, *e.g.*, JPG, KMZ, shapefiles, of mapped red knot habitat and Protected Areas may be required from BSF.)

b. Brief statements of how the grower(s) will implement each applicable CM. When both are required, the site-specific Vehicle Use Plan (CM 9) and Intertidal Access Plan (CM 15) may be combined.

**Current and Future Extent of Aquaculture**

In evaluating the Effects of the Action, below, key considerations are the spatial extent and distribution of structural aquaculture across the action area, both at the time of this PBO and over its 10-year life. The total area of intertidal habitat in the action area (between the MHW and MLLW lines) is about 800 acres (324 ha), about half of which is within Protected Areas. The Northern Segment has about 200 total intertidal acres (81 ha), of which about 160 acres (65 ha) (80 percent) are Protected Areas. The Southern Segment has about 600 total intertidal acres (243 ha), of which about 230 acres (93 ha) (38 percent) are Protected Areas.

***Northern Segment***

Currently, the only structural aquaculture in place within the Northern Segment is the Dias Creek Oyster Company on Lease A-19. As of February 2016, this farm consists of approximately 50 racks as well as floating arrays arranged over 0.31 acre (0.13 ha) of intertidal area.

The Corps authorization for the Dias Creek Oyster Company (CENAP-OP-R-2012-798-24) is being modified as per CMs 20 and 21 (Appendix C). Thus, we expect structural aquaculture will continue on Lease A-19 during a transitional period that may continue until June 8, 2018. During the transitional period, this grower will be authorized to place a maximum of 1,800 square feet (0.04 acre; 167 square m) of racks and floating bags (not including spaces and lanes) across a 7.3-acre (3.0-ha) designated intertidal growing area on this 97-acre (40-ha) lease, as detailed in in Appendix C.

On April 6, 2015, the Corps authorized the Sweet Amalia Oyster Farm to initiate structural aquaculture on Lease A-28 (CENAP-OP-R-2014-970-24). Based on CMs 20 and 21, we expect structural aquaculture will be established and continue on Lease A-28 during a transitional period, which may continue until June 8, 2018. During the transitional period, this grower will be authorized to place a maximum of 23,522 square feet (0.54 acre; 2,185 square m) (not including spaces and lanes) of aquaculture structures across a 7.3-acre (3.0-ha) designated intertidal growing area on this 23.3-acre (9.4-ha) lease, as detailed in Appendix D.

Based on CM 12, no new or continued structural aquaculture will be allowed between April 15 and June 7 in intertidal portions of Lease A-19 or Lease A-28 (even outside the Protected Areas) beginning June 8, 2018 at the latest (*i.e.*, on or before April 14, 2019, all structures will be removed from the intertidal portions of Leases A-19 and A-28).

Other than as described above, there will be no structural aquaculture in any intertidal portions of the Northern Segment during the red knot's stopover period of May 1 to June 7, based on CMs 10 and 12. CM 10 establishes Protected Areas where aquaculture structures cannot be placed between April 15 and June 7. The Protected Areas extend 300 feet (91 m) on either side of the MHW line, and 500 feet (152 m) around creek mouth shoals. In the Northern Segment, the Protected Areas cover the entire intertidal zone (out to or beyond the MLLW line) except for certain portions of Leases A-19, A-28, A-24, and A-25 (Figure 8). Thus, based on CM 10 alone, there will be no intertidal aquaculture between April 15 and June 7 on Leases A-15, A-23, A-22, A-21, or A-10. Further, due to CM 12, no (new) structural aquaculture will be allowed in intertidal portions of Leases A-24 or A-25 (even outside the Protected Areas) between April 15 and June 7 over the life of this PBO. (There is currently no structural aquaculture or Corps authorizations for structural aquaculture on Leases A-24 or A-25.)

***Southern Segment***

As of February 2016, the following structural aquaculture is currently in place within the intertidal portions of the Southern Segment.

- An area of approximately 1 acre (0.4 ha) (including spaces and lanes) of primarily racks on a riparian grant abutting Lease A-173. Including Protected Areas, this riparian grant is 37.9 acres (15.3 ha).

- An area of approximately 2.7 acres (1.1 ha) (including spaces and lanes) of primarily racks on Lease A-29, which has an intertidal growing area (outside Protected Areas) of 17 acres (7 ha). This area includes oyster farming operations conducted by approximately five individual growers, to whom the leaseholder has issued Letters of Permission.

- An area of approximately 0.1 acre (0.04 ha) (including spaces and lanes) of primarily racks at the Cape Shore Lab. Including Protected Areas, this riparian grant is 8.1 acres (3.3 ha).

- An area of approximately 7 acres (2.8 ha) (including spaces and lanes) of primarily racks at ADZ-4, which has an authorized intertidal growing area (under the existing permit) of 35 acres (14 ha) (excluding the infill area). This area includes oyster farming operations conducted by approximately 12 authorized growers, all of whom have been approved by BSF to operate on one of the 12 inshore lease parcels within ADZ-4.

Table 3 presents the distribution of allowable intertidal growing areas in the Southern Segment, *i.e.*, areas landward of the MLLW line but outside of the Protected Areas (Figure 9). The figures given in Table 3 are generally larger than those given under ADZ Expansion, above. For example, under ADZ Expansion, we noted that the NJDFW (2016) estimates about 60 intertidal acres (24 ha) for possible expansion between Green Creek and Norburys Landing, instead of 100 acres (40 ha) given here. Table 3 gives maximum possible acres and does not account for feasibility of ADZ development, such as access or land ownership. The acres in Table 3 also extend all the way to the estimated MLLW line, which may be too far seaward for some growers to operate from land.

**Table 3. Possible intertidal aquaculture areas in the Southern Segment**

| Area | Approximate number of intertidal acres (between the MHW and MLLW lines) outside Protected Areas | Approximate Shoreline Length (feet) excluding Protected Areas (feet) |
|---|---:|---:|
| Lease A-173 and three adjoining riparian grants | 40 | 2,100 |
| Lease A-27 | 23 | 900 |
| Lease A-29 | 17 | 600 |
| Rutgers Cape Shore Lab and riparian grant immediately to the south [a] | 34 | 1,300 |
| ADZ-4A[b] | 14 | 500 |
| ADZ-4 infill | 37 | 1,400 |
| ADZ-4B[bc] | 21 | 800 |
| ADZ-4 expansion area between Green Creek [c] and Norburys Landing | 100 | 3,200 |
| ADZ expansion area (not-preferred) south of Norburys Landing [d] | 64 | 3,000 |
| **Total** | **350** | **13,800 (2.6 miles)** |

[a] Structural aquaculture is unlikely on the riparian grant south of the Cape Shore Lab based on recent feedback from the grant holder.

[b] These combined acreage figures for ADZ-4 (35 acres [14 ha]) are smaller than the authorized intertidal growing area under the existing permit (37 acres [15 ha]) due to the expansion of the Protected Areas from 200 to 300 feet (61 to 91 m) from the MHW line (CM 9). The actual intertidal area is even smaller due to the Green Creek shoal(s), as per footnote c below.

[c] Because the Green Creek shoal(s) will be mapped each year by BSF, the number of intertidal acres and feet of shoreline shown in Table 3 are maxima, calculated with no shoals.

[d] Based on the acreage cap established under CM 12, and NJDEP's stated intentions under ADZ Expansion, above, we expect ADZ expansion will occur either between Green Creek and Norburys Landing or between Norburys Landing and Fishing Creek, but not both. This PBO does provide some flexibility for smaller-scale expansions to occur in both of these two areas, within the 150-acre (61-ha) acreage cap, but we find that unlikely.

We assume the area occupied by structural aquaculture (including spaces and lanes) will generally be in the range of 50 to 90 percent of the allowable intertidal growing area (*i.e.*, outside of Protected Areas) in each lease or grant due to environmental variability that affects suitability for oyster growing (*e.g.*, locally unsuitable substrates, water depths, or other conditions). Thus, the total intertidal acres shown in Table 3 are expected to support no more than 175 to 315 acres (71 to 127 ha) of structural aquaculture (including spaces and lanes) when even at full build-out. Where sizable gaps (due to locally unsuitable growing conditions) are interspersed throughout a farm, they may incrementally reduce any potential effects of aquaculture on horseshoe crab movement and foraging conditions, but are unlikely to be used by red knots (see Effects of the Action, below). In any case, under CM 12, aquaculture in the Southern Segment between April 15 and June 7 will be capped at 150 acres (61 ha) of intertidal structures/gear, including spaces and lanes, which is less than 50 percent of the allowable intertidal growing area. Therefore, not all of this area will be developed for aquaculture. In fact, development of the entire area is not the intention of the NJDEP (see ADZ Expansion, above). We conclude the most likely build-out scenario would involve more or less contiguous aquaculture from the northern end of the Southern Segment to some point south of Green Creek.

There is clear interest from prospective growers to enter into the structural shellfish aquaculture industry, even given numerous challenges and regulatory impediments. There are strong indications from State, County, and municipal officials that shellfish aquaculture is a regional economic development priority. A rudimentary estimate of demand for leases and permits within an expanded ADZ-4 or on private leases or grants within the action area can be surmised based on number of sources. First, the waiting list for ADZ-4 has ranged consistently from 10 to 15 individuals at any given time since ADZ-4 was opened and fully leased in 2012. Although some prospective growers who remain on the waiting list may have already pursued other options on private leases or grants, the waiting list still shows strong demand for space within ADZ-4. Further, if there is intertidal ADZ expansion, the BSF expects a short-term spike in demand as additional prospective growers realize space is available to more readily enter the industry. In addition, the two Corps-permitted growers in the Northern Segment may choose to relocate their operations to an expanded intertidal ADZ. Also, one or two existing ADZ-4 leaseholders may be impacted by the shoal mapping process, which will delineate annually variable Protected Areas at the mouth of Green Creek (see CMs 3 and 10). This mapping will compel the State to potentially accommodate these growers in a future ADZ intertidal expansion area. Finally, some of the approximately five growers currently operating on Lease A-29 may be interested in moving their farms to an expanded ADZ parcel, should space become available (NJDFW 2016).

Increasing consumer demand for New Jersey farmed oysters could also continue to drive demand for space for structural aquaculture in the Southern Segment. Market demand for off-bottom cultured oysters remains very high, and prices for farmed half-shell oysters (up to $0.85 per oyster, wholesale) are substantially higher than for wild-harvested oysters (around $0.19 per oyster, wholesale). Further, short-term disruptions in the shellfisheries along the U.S. west coast from algal blooms and species conflicts could trigger a regional shift in oyster production. Such a shift was previously observed when loss of production from the Gulf of Mexico was accompanied by an increasing market share of Virginia oysters. It is too soon to determine if the west coast issues will persist and, if so, where market share will shift. But it is reasonable to conclude there may be greater interest from prospective growers to enter New Jersey's oyster farming industry (NJDFW 2016).

We recognize considerable barriers (*e.g.*, regulatory requirements, seed supply issues, start-up costs) to growers initiating or expanding oyster farming in the action area. Based on the demand factors discussed above, we find a scenario of full build-out of the allowable intertidal growing areas (*i.e.*, outside the Protected Areas) in the Southern Segment over the 10-year life of this PBO unlikely but possible. We expect that intertidal structural aquaculture will be phased out of the Northern Segment well before full build-out might be expected to occur in the Southern Segment. Thus, we anticipate a maximum of 150 acres (61 ha) of structural aquaculture will be operating between April 15 and June 7 in any given year over the 10-year life of this PBO. We expect this entire area will be north of Norburys Landing, but do not rule the possibility that some of these 150 acres (61 ha) could be south of Norburys Landing.

***Outside the Red Knot Stopover Period***

In the Northern Segment, the prohibition against intertidal structural aquaculture established under CM 12 is in effect from April 15 to June 7. Thus, from June 8 to April 14, authorized structures may be placed in intertidal areas of the Northern Segment. In both Segments, the prohibition against aquaculture structures in the Protected Areas established under CM 10 is in effect from April 15 to June 7. Thus, from June 8 to April 14, authorized structures may be placed in the Protected Areas in both the Northern and Southern Segments. Gear specifications established under CM 8, which prescribes the density of gear due to spacing requirements, are in effect from April 15 to July 31. Thus, from August 1 to April 14, there are no requirements regarding the spacing or density of gear on the intertidal flats.

In order to assess potential indirect effect to the red knot from impacts on horseshoe crabs, we make the following assumptions regarding intertidal aquaculture outside the period when red knots are present.

- Growers may attempt to utilize the Northern Segment for intertidal winter storage. We conclude there is low likelihood of this activity over the life of the PBO because: (a) this activity would necessitate relocating gear in and out of the Northern Segment to comply with various seasonal restrictions; and (b) growers often prefer shallow subtidal areas for winter storage, and such areas are not limited in either Segment. We note that winter storage would have negligible impacts on horseshoe crabs, which typically move to deeper waters (*i.e.*, outside the action area) during the winter months (ASMFC 2004), although larvae and juveniles remain year-round (Shuster and Sekiguchi in Tanacredi *et al.* 2009; Botton *et al.* in Shuster *et al.* 2003).

- From June 8 through the fall, growers may attempt to utilize the Northern Segment for "seasoning" or "finishing" oysters for the last few weeks or months prior to harvest.

    - We conclude there is low likelihood of this activity in the next three years, based on the high likelihood of intertidal ADZ expansion, and the availability of year-round intertidal growing areas on private leases and grants in the Southern Segment. Use of Southern Segment areas for grow-out finishing would avoid the operational burden of relocating gear in and out of the Northern Segment to comply with various seasonal restrictions.

    - From 3 to 10 years, we conclude there is moderate likelihood that some intertidal portions of the Northern Segment will be used for finishing, based on anticipated high demand for authorized intertidal growing space in the Southern Segment (discussed above), combined with efforts to increase offshore oyster production, which still involves seasoning on the flats.[11] If and when this activity may arise, we expect the following:

[11] Seasoning on the flats may become prevalent as some of the industry shifts to subtidal culturing methods. Oysters grown in subtidal conditions have a different appearance than Cape Shore oysters, which are often more desirable as a half-shell product and can be achieved by placement on the flats for the last few weeks or months.

    - Growers will avoid frequent or large-scale reconfiguration of gear, and are unlikely to substantially alter their gear types or configurations after July 31.

    - Growers are unlikely to occupy more than 54 intertidal acres for this purpose based on: (a) the need to relocate gear in and out of the Northern Segment to comply with various seasonal restrictions; (b) the maximum total size of the year-round intertidal footprint over the next 10 years (150 acres [61 ha]) (discussed above); and (c) the time and expense involved with individual Federal and State permitting outside of an ADZ (*e.g.*, Corps, DLUR, and TRC authorizations).

- In the Southern Segment, growers may relocate gear to the Protected Areas after June 7. We conclude this is unlikely because the current Corps permit for ADZ-4 includes a restricted area extending 200 feet (61 m) from the MHW line from May 1 to June 7, and ADZ growers have not opted to relocated gear into the restricted area after June 7. If some relocation to the Protected Areas does occur after June 7, we do not expect it will extend all the way to the MHW line, because when oysters spend too much time exposed to the air their growth rates are typically slowed (Oesterling and Petrone 2012).

- In the Southern Segment, growers may reconfigure or replace their gear after July 31. We do not expect this will occur on a large scale, based on the operational expense involved. Also, we do not expect significant increases in gear density after July 31 because the spacing between arrays of gear, in addition to facilitating crab passage, is also necessary for growers to access their oysters on foot or via ATV. However, we do expect that some of the Southern Segment growers (more so than in the Northern Segment) will use the period from August 1 through the fall for localized experimentation with gear types, sizes, and spacing that deviate from those allowed during the restricted period (per CM 8). Thus, we expect up to 20 percent of Southern Segment gear will deviate from the specifications in CM 8 from August 1 through the fall.

***Subtidal Aquaculture***

There is currently no structural aquaculture in subtidal portions of the Northern Segment. In the Southern Segment, structural aquaculture is currently limited to 12 offshore lease parcels within ADZ-4. Atlantic Cape Fisheries, Inc. and Elder Point Oyster Company are currently authorized for additional subtidal structural aquaculture, but these authorizations are for operations well offshore and outside the action area.

CM 8 specifies the configuration of gear in shallow subtidal portions of the action area from April 15 to July 31, and CM 11 places some limits on the means and locations of boat-based access (though not the frequency or duration) from May 1 to June 7. We conclude these are not major barriers to the expansion of subtidal aquaculture. The lack of public marinas and expense of suitable boats remain substantial barriers. However, based on the support of the State and interest from certain growers (*e.g.*, Atlantic Cape Fisheries, Inc.), we do anticipate some growth in subtidal aquaculture. Over the life of the PBO, we expect a range from 0 to 20 acres of structural subtidal aquaculture (including spaces in lanes) within the action area in any given year.

## SPECIES STATUS

### Rangewide

The following summary information is excerpted from the Service's 2014 Supplemental Document in support of the listing of the red knot as threatened under the ESA (USFWS 2014), with a few minor updates. Additional background information is provided in Appendix E. The rufa red knot is a medium-sized shorebird that migrates annually between its breeding grounds in the central Canadian Arctic and several wintering regions, including the Caribbean and Southeast United States (Southeast), the Northeast Gulf of Mexico, northern Brazil, and Tierra del Fuego at the southern tip of South America. During both the northbound (spring) and southbound (fall) migrations, red knots use key staging and stopover areas to rest and feed.

Each year some red knots make one of the longest distance migrations known in the animal kingdom, traveling up to 19,000 miles (over 30,000 km) annually. Red knots undertake long flights that may span thousands of miles without stopping. As *Calidris canutus* prepare to depart on long migratory flights, they undergo several physiological changes. Before takeoff, the birds accumulate and store large amounts of fat to fuel migration and undergo substantial changes in metabolic rates. In addition, the leg muscles, gizzard, stomach, intestines, and liver all decrease in size, while the pectoral muscles and heart increase in size. Due to these physiological changes, *C. canutus* arriving from lengthy migrations are not able to feed maximally until their digestive systems regenerate, a process that may take several days. Because stopovers are time-constrained, *C. canutus* requires stopovers rich in easily digested food to achieve adequate weight gain (Niles *et al.* 2008; van Gils *et al.* 2005a; van Gils *et al.* 2005b; Piersma *et al*. 1999) that fuels the next migratory flight and, upon arrival in the Arctic, also fuels a body transformation to breeding condition (Morrison 2006).

At some stages of migration, very high proportions of entire shorebird populations may use a single migration staging site to prepare for long flights. High fractions of the red knot's rangewide population can occur together at a small number of nonbreeding locations, leaving populations vulnerable to loss of key resources (Harrington 2001). For example, Delaware Bay provides the final Atlantic coast stopover for a significant majority (50 to 80 percent) of the red knot population making its way to the arctic breeding grounds each spring (Clark *et al*. 2009; Brown *et al.* 2001). Individual red knots show moderate fidelity to particular migration staging areas between years (CSRPN 2013; Duerr *et al.* 2011; Watts 2009; Harrington 2001).

Red knots from both southern (Tierra del Fuego) and northern (Brazil, Caribbean, Southeast) wintering areas typically use mid-Atlantic stopovers from late April through late May or early June (Cohen *et al.* 2009; Niles *et al.* 2008). The stopover time in Delaware Bay for individual birds is about 10 to 14 days (Niles *et al.* 2008). From Delaware Bay and other mid-Atlantic stopovers, birds tend to fly overland directly northwest to the central Canadian breeding grounds, with many stopping briefly along the shores of James and Hudson Bays (Bimbi *et al.* 2014; Niles *et al.* 2012a; Niles *et al.* 2010a; Cohen *et al.* 2009; Niles *et al.* 2008; Morrison and Harrington 1992).

Coastal habitats used by red knots in migration and wintering areas are similar in character (Harrington 2001), generally coastal marine and estuarine habitats with large areas of exposed intertidal sediments. Migration and wintering habitats include both high-energy oceanfront or bayfront areas, as well as tidal flats in more sheltered bays and lagoons (Harrington 2001). Preferred wintering and migration microhabitats are muddy or sandy coastal areas, specifically, the mouths of bays and estuaries, tidal flats, and unimproved tidal inlets (NCWRC 2013; Lott *et al.* 2009; Niles *et al.* 2008; Harrington 2001). Along the U.S. Atlantic coast, dynamic and ephemeral features are important red knot habitats, including sand spits, islets, shoals, and sandbars, features often associated with inlets (Harrington 2008; Harrington in Guilfoyle *et al.* 2007; Winn and Harrington in Guilfoyle *et al.* 2006). In many wintering and stopover areas, quality high-tide roosting habitat (*i.e.*, close to feeding areas, protected from predators, with sufficient space during the highest tides, free from excessive human disturbance) is limited (CSRPN 2013; K. Kalasz pers. comm. November 26, 2012; L. Niles pers. comm. November 19 and 20, 2012; Kalasz 2008). In nonbreeding habitats, *Calidris canutus* requires sparse vegetation to avoid predation (Niles *et al.* 2008; Piersma *et al.* 1993).

Across all (six) subspecies, *Calidris canutus* is a specialized molluscivore, eating hard-shelled mollusks, sometimes supplemented with easily accessed softer invertebrate prey, such as shrimp- and crab-like organisms, marine worms, and horseshoe crab eggs (Piersma and van Gils 2011; Harrington 2001). A prominent departure from the typical mollusk diet occurs each spring when red knots feed on the eggs of horseshoe crabs, particularly during the key migration stopover in the Delaware Bay. Delaware Bay serves as the principal spring migration staging area for the red knot because of the abundance and availability of horseshoe crab eggs (Clark *et al.* 2009; Harrington 2001; Harrington 1996; Morrison and Harrington 1992). Red knot foraging activity is largely dictated by tidal conditions, as *C. canutus* rarely wade in water more than about 1 inch (2 to 3 cm) deep (Harrington 2001). Due to bill morphology, *C. canutus* is limited to foraging on only shallow-buried prey, within the top 1 inch (2 to 3 cm) of sediment (Gerasimov 2009; Zwarts and Blomert 1992).

Red knots and other shorebirds that are long-distance migrants must take advantage of seasonally abundant food resources at migration stopovers to build up fat reserves for the next nonstop, long-distance flight (Clark *et al.* 1993). During the migration period, although foraging red knots can be found widely distributed in small numbers within suitable habitats, birds tend to concentrate in those areas where abundant food resources are consistently available from year to year. The spatial distribution of red knots in Argentina, Georgia, South Carolina, Virginia, the Atlantic coast of New Jersey, and Delaware Bay stopover areas has been correlated with the distribution of the primary prey species in each area (USFWS 2014).

We do not have sufficient reliable data on which to derive a precise rangewide population estimate for the rufa red knot. For example, there are no rangewide population estimates for fall migration or breeding areas because birds are too dispersed. However, we can reliably infer population trend information from some areas. We have high confidence in long-term survey data from two key red knot areas, Tierra del Fuego (wintering) and Delaware Bay (spring), showing declines of 70 to 75 percent over roughly the same period, since about 2000 (NJDFW 2016; Morrison *et al*. 2004; Morrison and Ross 1989, Vol. 2); Table 4. Data from other wintering and spring stopover areas are less conclusive. Overall, however, the best available data indicate a sustained decline occurred in the 2000s, and may have stabilized at a relatively low level in the last few years. Attempts to evaluate long-term population trends using national or regional data from volunteer shorebird surveys and other sources have generally corroborated that red knot numbers have declined, probably sharply (NPS 2013; Andres 2009; Morrison *et al.* 2006).

Primary threats to the red knot include sea level rise; coastal development; shoreline stabilization; reduced food availability at stopover areas; and various effects of climate change. Secondary threats include disturbance by vehicles, people, dogs, aircraft, and boats; hunting in parts of South America; predation; harmful algal blooms; oil spills and leaks; and wind energy development (USFWS 2014). Reduced food availability at the Delaware Bay stopover site due to commercial harvest of the horseshoe crab is considered a primary causal factor in the decline of rufa red knot populations in the 2000s (see Horseshoe Crab Eggs, below). In addition, the red knot's life-history strategy makes this species inherently vulnerable to mismatches in timing between its annual cycle and those periods of optimal food and weather conditions upon which it depends (Galbraith *et al.* 2014 and Supplement 1; USFWS 2014; McGowan *et al*. 2011a; Smith *et al.* 2011). The red knot's sensitivity to timing mismatches has been demonstrated through a population-level response, as documented late arrivals of birds in Delaware Bay are generally accepted as a key causative factor (along with reduced supplies of horseshoe crab eggs) behind population declines in the 2000s (Niles *et al*. 2008; Atkinson *et al.* 2007; Baker *et al*. 2004; Robinson *et al.* 2003; USFWS 2003; Atkinson *et al.* 2003).

**Delaware Bay**

***Horseshoe Crab Eggs***

The following information is excerpted from the Service's 2014 Supplemental Document in support of the listing of the red knot as threatened under the ESA (USFWS 2014), with minor updates. In Delaware Bay, horseshoe crab eggs are a superabundant source of easily digestible food for red knots and other migrating shorebirds (USFWS 2014). Horseshoe crabs occur along the Atlantic coast from Maine to Florida, along Florida's Gulf coast, and along Mexico's Yucatan Peninsula (Brockman in Shuster *et al.* 2003; Botton and Ropes 1987). Within this geographic range, horseshoe crabs are most abundant between Virginia and New Jersey (Botton and Ropes 1987), with the largest population occurring in Delaware Bay (Gerhart 2007; Walls *et al.* 2002). Each spring, adult horseshoe crabs migrate from deep bay waters and the Atlantic continental shelf to spawn on intertidal sandy beaches. Beaches within estuaries are preferred spawning areas because they are low energy environments and are protected from the surf (ASMFC 2004). Horseshoe crab spawning generally occurs from March through July, with the peak spawning activity occurring around the evening new and full moon high tides in May and June (Smith and Michels 2006; Shuster and Botton 1985).

Over repeated spawning events, a female horseshoe crab deposits most of her 80,000 eggs in clumps of around 4,000 eggs, at depths of about 4 to 8 inches (10 to 20 cm) beneath the surface of the sand, a distance beyond the reach of most shorebirds including red knots. However, wave action and burrowing by subsequent spawning horseshoe crabs move eggs toward the surface. Thus, a high density of spawning horseshoe crabs, such as occurs in Delaware Bay, is needed for the eggs to become available to shorebirds (Smith 2007; Pooler *et al.* 2003; USFWS 2003; Berkson and Shuster 1999; Clark in Farrell and Martin 1997; Botton *et al.* 1994; Shuster and Botton 1985).

Horseshoe crabs and surface egg availability are not found in similar densities in other areas on the Atlantic coast, which may explain why shorebirds concentrate in the Delaware Bay (Berkson and Shuster 1999). Besides supporting red knots, Delaware Bay supports large numbers of other shorebirds, including semipalmated sandpipers (*Calidris pusilla*), ruddy turnstones (*Arenaria interpres*), and sanderlings (*C. alba*), and the bay ranks among the 10 largest shorebird migration staging sites in the Western Hemisphere (Clark *et al*. 2009). Despite significant shorebird predation on horseshoe crab eggs, such activity probably has little impact on the horseshoe crab population, since the surface eggs consumed by birds typically do not survive anyway due to desiccation (ASMFC 2004; Botton *et al*. 1994).

As mentioned under Rangewide, above, Delaware Bay provides the final Atlantic coast stopover for a significant majority (50 to 80 percent) of the red knot population making its way to the arctic breeding grounds each spring (Clark *et al*. 2009; Brown *et al.* 2001). Red knots stopping in Delaware Bay depend on horseshoe crab eggs to achieve remarkable rates of weight gain. Weight gains recorded on the Delaware Bay are the most rapid of any recorded for all known stopover populations of *Calidris canutus* in the world (Cohen *et al.* 2010; Piersma *et al*. 2005) and are among the highest rates observed in the animal kingdom (Atkinson *et al*. 2007). Although a single horseshoe crab egg contains a very small amount of energy, eggs are present in such superabundance that birds can eat enough in 2 weeks to nearly double their weights. No single stopover area is more important for the red knot than the Delaware Bay because the nutritive yield of the bay is so high (Harrington 1996).

Research indicates this weight gain is important to sustain the birds on their final flights from Delaware Bay to the arctic breeding grounds. Stored fat and protein are used also for initial survival on the breeding grounds (McGowan *et al.* 2011a; Piersma *et al.* 2005; Baker *et al.* 2004), particularly when conditions are adverse upon arrival (*e.g.*, snow cover, lack of insect prey) (Buehler and Piersma 2008). Such body stores may also be used by *Calidris canutus* for physical transformations necessary for breeding (Morrison 2006; Morrison *et al.* 2005). Using data on energetic flight costs by Kvist *et al.* (2001), Baker *et al.* (2004) calculated that red knots in the Delaware Bay need to achieve a departure mass of at least 6.3 to 7.1 ounces (oz) (180 to 200 grams [g]) to cover the energetic demands of the flight to the breeding grounds and to survive an initial few days of snow cover. In years that crab spawning was delayed due to weather anomalies (*e.g.*, cold weather, storms), the proportion of knots reaching weights of at least 6.3 oz (180 g) was very low (*e.g.*, 0 percent in 2003) (Dey *et al.* 2011a; Atkinson *et al*. 2007).

Some researchers have postulated that red knots from southern wintering areas (Argentina and Chile) are more reliant on horseshoe crab eggs than are birds from northern wintering areas (the Southeast) because southern birds cannot digest hard-shelled prey with the reduced digestive organs knots typically exhibit during long migration flights (Niles *et al.* 2008; Atkinson *et al.* 2006). According to this hypothesis, knots wintering in Tierra del Fuego are particularly dependent on horseshoe crab eggs for successful fattening and are more vulnerable to a decline in the availability of those eggs than are northern-wintering birds (Niles *et al.* 2008; Atkinson *et al.* 2006). There are several lines of evidence supporting this hypothesis, including chemical analysis, radio tracking, foraging habits, and patterns of population declines. However, there is not a strict correlation between wintering area and stopover diet, and there is considerable mixing of birds from various wintering regions in both Delaware Bay and other mid-Atlantic stopover sites (where horseshoe crab eggs are not the primary food). Although the relative importance of horseshoe crab eggs to birds from various wintering areas is still being refined, it is clear this food resource is crucial to the rufa red knot (USFWS 2014).

Reduced food availability at the Delaware Bay stopover site due to commercial harvest and subsequent population decline of the horseshoe crab is considered a primary causal factor in the decline of the *rufa* subspecies in the 2000s (USFWS 2014; McGowan *et al.* 2011a; Niles *et al.* 2008; COSEWIC 2007; Baker *et al.* 2004; Morrison *et al.* 2004), although other possible causes or contributing factors have been postulated (McGowan 2015; Millard in Carmichael *et al.* 2015*;* USFWS 2014; Niles *et al.* 2008).

A geographic contraction of red knots into fewer areas of Delaware Bay is one of several lines of evidence that egg availability was an important factor in the red knot's declining numbers (USFWS 2014). From 1986 to 1990, red knots were relatively evenly distributed along the Delaware Bay shoreline in both New Jersey and Delaware. In comparison, there was a much greater concentration of red knots in the fewer areas of high horseshoe crab spawning activity from 2001 to 2005 (Lathrop 2005), suggesting that, due to declining numbers, crabs (followed by the knots) had contracted to just the best spawning habitats. In 2004, Karpanty *et al.* (2006) found that only about 20 percent of the Delaware Bay shoreline contained enough eggs to have a greater than 50 percent chance of finding red knots, and that red knots attended most or all of the available egg concentrations. Newer evidence suggests that the apparent downward trend in egg sufficiency may have stabilized by the mid-2000s (Karpanty *et al.* 2011). In addition, Smith and Robinson (2015) assessed data from 1999 to 2013 and found indications of a spatial redistribution of spawning horseshoe crabs, from more concentrated and patchy to more evenly distributed throughout the bay. This finding is a preliminary sign of reversal of the earlier geographic contraction documented by Lathrop (2005). Based on these changes in geographic distribution, it is important that conservation efforts in Delaware Bay consider both historic (1980s through 2000s) as well as recent patterns of red knot use, since areas that were relatively more important during earlier years will be needed to accommodate the recovery and continued redistribution of the population from its current low level.

Due to harvest restrictions and other conservation actions, horseshoe crab populations showed some signs of recovery in the early 2000s, with apparent signs of red knot stabilization (survey counts, rates of weight gain) occurring a few years later (as might be expected due to biological lag times). Since about 2005, however, horseshoe crab population growth has stagnated for unknown reasons (USFWS 2014). Under the current management framework, known as Adaptive Resource Management (ARM), the present horseshoe crab harvest is not considered a threat to the red knot because harvest levels are tied to red knot populations via scientific modeling (Millard *et al.* in Carmichael *et al.* 2015; USFWS 2014; McGowan *et al.* 2011b). Most data suggest that the volume of horseshoe crab eggs is currently sufficient to support the Delaware Bay's stopover population of red knots at its present size. However, because of the uncertain trajectory of horseshoe crab population growth, it is not yet known if the egg resource will continue to adequately support red knot population growth over the next decade. In addition, implementation of the ARM could be impeded by insufficient funding for the shorebird and horseshoe crab monitoring programs that are necessary for the functioning of the ARM models (USFWS 2014).

***Baywide Population Trends***

The following information is excerpted from the Service's 2014 Supplemental Document in support of the listing of the red knot as threatened under the ESA (USFWS 2014), updated to incorporate the most current data. Aerial surveys have been conducted in Delaware Bay since 1981 (Table 4). Methods and observers were consistent from 1986 to 2008. The methodology during this period involved weekly counts; thus, it was possible the absolute peak number of birds was missed in some years. However, since most shorebirds remain in Delaware Bay at least a week, it is likely that the true peak was captured in most years (Clark *et al.* 1993). The surveys covered consistent areas of New Jersey and Delaware from the first week of May to the second week of June. All flights were conducted 3 to 4 hours after high tide, a period when birds are usually feeding on the beaches (Clark *et al.* 2009). Methodologies and observers changed several times since 2009. Further, problems in 2009, 2012, and 2013 prevented accurate aerial counts, and ground counts have been substituted. Caution should be used in comparing ground and aerial counts (Laursen *et al*. 2008).

Comparing four different time periods, average red knot counts in Delaware Bay declined from 59,946 (1981 to 1983), to 46,886 (1986 to 1994), to 34,060 (1995 to 2004), to 18,978 (2005 to 2015). Average counts for the last time period (2005 to 2015) are nearly 70 percent lower than during the earliest period (1981 to 1983). However, numbers appear to have stabilized or increased slightly from 2009 to 2015, despite our lower confidence in the data over this later period due to shifts in methodology and surveyors. There may have been declines in the Delaware Bay stopover population prior to 2001, but variability in the data makes it difficult to detect trends. In contrast, the decline in Delaware Bay red knot counts in the 2000s was sufficiently pronounced and sustained that we have confidence in the downward trend over this time period despite the variability in the data (USFWS 2014). Based on our analysis in the Supplemental Document in support of the red knot listing (USFWS 2014), we conclude that the declines in Delaware Bay reflected and/or contributed to a true and pronounced population decline in the Argentina-Chile wintering region, particularly considering that several lines of evidence suggest southern-wintering red knots are more reliant on Delaware Bay than are northern-wintering birds, as discussed under Horseshoe Crab Eggs above. Any effects of Delaware Bay food conditions on other wintering regions over this same time period are unclear (USFWS 2014).

**Table 4. Peak counts of red knots in Delaware Bay from aerial and ground surveys, 1981 to 2015** (NJDFW 2016; Dey *et al.* 2011a; Clark *et al.* 2009; Kochenberger 1983; Dunne *et al.* 1982; Wander and Dunne 1982)

| Year | Peak Count | Year | Peak Count |
|---|---|---|---|
| *1981 | 67,450 | 1999 | 49,805 |
| 1982 | 95,530 | 2000 | 43,145 |
| 1983 | 16,859 | 2001 | 36,125 |
| 1986 | 58,156 | 2002 | 31,695 |
| 1987 | 38,790 | 2003 | 16,255 |
| 1988 | 34,750 | 2004 | 13,315 |
| 1989 | 95,490 | 2005 | 15,345 |
| 1990 | 45,860 | 2006 | 13,445 |
| 1991 | 27,280 | 2007 | 12,375 |
| 1992 | 25,595 | 2008 | 15,395 |
| 1993 | 44,000 | **2009 | 24,000 |
| 1994 | 52,055 | 2010 | 14,475 |
| 1995 | 38,600 | 2011 | 12,804 |
| 1996 | 19,445 | **2012 | 25,458 |
| 1997 | 41,855 | **2013 | 25,596 |
| 1998 | 50,360 | 2014 | 24,980 |
| | | 2015 | 24,890 |

*Only New Jersey was surveyed in 1981. For reference, the total numbers of red knots in Delaware Bay was relatively evenly distributed between New Jersey and Delaware from 1986 to 1992 (Clark *et al.* 1993), suggesting that the true peak count for the bay could have been roughly double the number recorded in 1981.
** Data from 2009, 2012, and 2013 are from ground counts, while all other years are from aerial counts. For 2009, the actual peak ground count was 27,187, but Niles *et al.* (2010b) chose to report 24,000 as the low end of an estimated 10 percent error range. The peak ground count in 2012 was also adjusted down (from roughly 29,400 to 25,458) based on concerns that some flocks in New Jersey were double-counted.

Because birds pass in and out of a stopover area, the peak count for a particular year is lower than the total passage population (also called the total stopover population). Using resightings of marked birds, several attempts have been made to estimate the total passage population of Delaware Bay through mathematical modeling (Table 5), which should not be confused with the peak counts given in Table 4. Until 2011, these estimates were produced using different modeling methodologies and sporadic temporal coverage; thus, we do not infer any trends from the total passage population estimates given in Table 5. However, these estimates are generally consistent with the trends observed in the peak counts; namely a sharp decline in the early 2000s followed by a more recent period in which numbers appear to have stabilized or increased slightly.

It is too soon to tell if the notably higher total passage population estimate in 2015 represents a real population increase or could be an anomaly. For example, a record number of marked birds detected in that year suggests that a greater proportion of the rufa population may have stopped in Delaware Bay area in 2015 than in previous years (Lyons 2015). In addition, some experts have expressed concerns with the higher-than-usual ratio between the total passage estimate and the peak count, as well as concerns about the spatial and temporal patterns of data collection that underpinned the 2015 total passage estimate. These concerns are being addressed to improve confidence in future total passage estimates that will continue to be produced using the methodology of Lyons (2015) (ASMFC 2015; L. Niles pers. comm. August 26, 2015).

**Table 5. Estimates of total passage population in Delaware Bay, 1989 to 2015**

| Year | Peak Count | Estimated Passage Population | Range | Source |
|---|---|---|---|---|
| 1989 | 95,490 | 152,900 | ±50,300 Standard Deviation | Harrington 2001 |
| 1998-2001 | 36,125-50,360 | 77,000 (per year) | 28,000 to 126,000 (per year) 95% Confidence Interval | Atkinson *et al.* 2002 |
| 2004 | 13,315 | 17,108 | 14,515 to 19,701 95% Confidence Interval | Cohen *et al.* 2009 |
| 2004 | 13,315 | 17,707 | 12,800 to 22,614 95% Confidence Interval | Gillings *et al.* 2009 |
| 2006 | 13,445 | 19,555 | 17,927 to 21,184 95% Confidence Interval | Cohen *et al.* 2009 |
| 2011 | 12,804 | 43,570 | 40,880 to 46,570 95% Confidence Interval | Lyons 2015 |
| 2012 | 25,458 | 44,100 | 41,860 to 46,790 95% Confidence Interval | Lyons 2015 |
| 2013 | 25,596 | 48,955 | *39,119 to 63,130 95% Confidence Interval | Lyons 2015 |
| 2014 | 24,980 | 44,010 | 41,900 to 46,310 95% Confidence Interval | Lyons 2015 |
| 2015 | 24,890 | 60,727 | 55,568 to 68,732 95% Confidence Interval | Lyons 2015 |

*The range was larger in 2013 in part because approximately 21 to 25 percent fewer marked individuals were detected than in 2011 and 2012.

### *Intertidal Habitat Use*

The ENSP's annual shorebird surveys, discussed above and below (Tables 4, 8, 9, 11), were performed at mid- and falling tides and may not represent areas used by red knots at lower tidal stages (NJDFW 2016) when aquaculture activities take place (*e.g.*, under the current permit for ADZ-4 and under CM 15). These survey data allow for an annual snapshot of red knot usage patterns to be compared among the various linear survey segments of the bay (Tables 8, 9), but they do not provide any information about patterns of red knot habitat use across the intertidal zone (*i.e.*, between the MHW and MLLW lines) throughout the tidal cycle.

As discussed above under Species Status, numerous studies across the range of the red knot, including Delaware Bay, have correlated the spatial distribution of birds with the distribution of the primary food resource (USFWS 2014). Horseshoe crabs typically nest around the MHW line (Brockman in Shuster *et al*. 2003). Red knots in Delaware Bay preferentially feed in microhabitats where horseshoe crab eggs are concentrated, such as at crab nests (Fraser *et al.* 2010), which are concentrated near the MHW line, and in locations where surface eggs accumulate, such as shoreline discontinuities (*e.g.*, creek mouths) (Botton *et al.* 1994) and the wrack line (Karpanty *et al.* 2011; Nordstrom *et al.* 2006), which is typically at or slightly landward of the MHW line. As per CM 10, these highest-value foraging areas are all within Protected Areas. However, these egg concentration areas are not the only foraging areas used by red knots. Under Effects of the Action, below, we must assess the extent to which aquaculture gear farther out on the intertidal flats (outside Protected Areas) may preclude use of suitable foraging habitat, and the extent to which husbandry activities in these areas may disturb red knots. Therefore, in this section, we evaluate best available science regarding red knot foraging habits across the intertidal zone, which is, of course, closely tied to the tidal cycle.

Daylight during the red knot's stopover period in Delaware Bay is around 15 hours per day. Because horseshoe crab eggs are laid near the MHW line, birds could theoretically feed for most of these daylight hours. However, the availability of horseshoe crab eggs on the sand surface, and within probing depth of a red knot, is likely to vary throughout the tidal cycle based on the density of spawning crabs, wave action, and depletion by shorebirds and gulls. Further, eggs on the sand surface dry out rapidly (within an hour of deposition on hot, windy days) and become hardened. Red knots are not known to forage on desiccated eggs. In addition, feeding areas are not available when the tide covers them. Red knots do not feed on horseshoe crab eggs at night in Delaware Bay, and cannot feed continuously throughout the day as they need to spend time on other behaviors such as vigilance and preening (Niles *et al* 2008). Based on these factors, Niles *et al.* (2008) reported that optimal feeding is constrained to (daytime) bouts of consumption of eggs freshly deposited on the sand surface by the falling tide and/or consumption of shallow-buried eggs where they are present at sufficiently high density. However, other authors have reported differing results regarding foraging habits across the tidal cycle, discussed below and summarized in Table 6.

Botton *et al.* (1994) studied seven bayfront beaches in New Jersey, including four beaches in the action area, in 1990 and 1991. Pooling data from all seven beaches, shorebird abundance was not significantly different for high tide, mid-tide, and low tide. Median flock size, however, was significantly influenced by tidal stage, with significantly larger flocks seen at high tide than at mid-tide or low tide. At high or mid-tides, shorebirds were generally concentrated at the water's edge, apparently feeding on horseshoe crab eggs in the swash zone, while during low tide shorebirds were often dispersed over the tidal flats. Breaks in shoreline topography, particularly sand spits at the mouths of tidal creeks, were important feeding sites at low tide (Botton *et al.* 1994).

Botton *et al.* (1994) also reported that the intertidal sand flats in the action area were not extensively used by foraging shorebirds. At Norburys Landing, shorebirds were often dispersed in loose aggregations over the exposed tidal flats, typically feeding at the edges of shallow rivulets and pools. These authors repeatedly surveyed the stretch of beach between Norburys Landing and the Cape Shore Lab. Very few shorebirds were seen along this beach during high or mid-tide periods. At low tide, scattered, widely spaced shorebirds were seen on sand bars and shallow pools, but larger, more compact flocks of 20 to 200 shorebirds were only seen in the vicinities of two drainage pipe outlets, which probably functioned as traps for drifting horseshoe crab eggs (Botton *et al.* 1994).

Burger *et al* (1997) studied feeding and other behaviors of red knots and other shorebirds in 1991 and 1992. This study included one Delaware Bay beach (Moore's Beach, outside the action area) exposed to direct surf. This study also included four other survey sites—two tidal mudflats (one on Delaware Bay and one on the Atlantic coast), one tidal marsh (Delaware Bay), and one non-tidal marsh (Atlantic coast). Because all intertidal portions of the action area are exposed to direct surf, and because red knots do not typically feed on horseshoe crab eggs on the Atlantic coast, we consider only the Moore's beach findings applicable to the action area. Across all five study sites, variations in the percentage of shorebirds engaged in feeding, resting and other behaviors depended on location (*i.e.*, study site), date, time, tide and species. Although the tidal stage was a significant factor explaining the percentage of all shorebirds engaged in feeding and resting (across all five sites), tidal stage alone was not significant in explaining the percent of red knots engaged in feeding. However, the combination of site and tidal stage was significant for red knots. For most species (including red knots), site was the most significant variable explaining the percentage of birds engaged in feeding. Thus, it should be noted that only 8 percent of red knots observed in this study were at Moore's Beach (Burger *et al.* 1997). These authors found that shorebirds (including red knots and six other species) at Moore's Beach tended to feed on the rising tide, though none fed at high tide because the beach was too narrow. Across all five study sites, 53 percent of red knots observed during the falling tide were feeding, 20 percent during low tide, 59 percent during the rising tide, and 48 percent during high tide. However, these findings were not statistically significant (Burger *et al.* 1997), and for the reasons of site characteristics and sample sizes noted above, we do not consider these findings directly applicable to the action area.

Nordstrom *et al.* (2006) investigated horseshoe crab nesting at a bayfront beach in Delaware in early June 2004. Although not limited to red knots, this study is most applicable to birds that, like red knot, feed in the swash and on the surface within and between the wrack lines. These authors found that peaks in the number of horseshoe eggs in the swash uprush occur during tidal rise and around the time of high tide. The number of eggs in transport decreased during falling tide. Many more eggs moved in the active swash zone than were found on the beach after the water level fell. Greater numbers of eggs in the swash during rising tide than falling tide, and fewer eggs at lower elevations on the beach, implied that shorebird foraging may become less productive as the tide falls. More eggs were moved in the swash during the rising tide than during the falling tide at similar or higher wave heights, implying that eggs removed from the beach during rising tide are dispersed offshore or remain trapped in the breaker zone after high tide (Nordstrom *et al*. 2006).

The findings of Nordstrom *et al.* (2006) imply that foraging becomes less productive as the tide falls and may help account for the tendency of shorebirds to feed on rising tides rather than on falling or low tides on days when no spawning occurs (Nordstrom *et al*. 2006). The tendency for shorebirds to feed along the edge of the water, following the tide line, rather than feeding higher on the beach has been attributed to the softer wetted substrate. The large number of eggs in the swash and the avoidance of desiccated eggs may be additional factors. It is also possible that eggs moving in the swash zone are easier for birds to see. The tendency of shorebirds to feed during times of higher water levels rather than on falling tides or low tides, as noted by Burger *et al.* (1997), could be partially attributed to the greater number of eggs in the swash during rising or high tide than falling or low tide (Nordstrom *et al*. 2006).

In a 2013 study at south Reeds Beach, Burger *et al.* (2015) found that shorebirds, including red knots, roosted on a creek at high tide and foraged on the creek at low tide, extending well up into the creek. Red knots were present on the creek during 40 percent of surveys. Although based on only a single site and a single year, these findings of high red knot usage of creek mouths is consistent with other studies and reports (USFWS 2014). Shorebirds were also studied away from the creek, near experimental oyster racks and in reference areas. Near the experimental racks, when no people were present, red knots were most abundant at high tide, then decreased in numbers across the falling, low, and rising tides (*i.e.*, knots were least abundant during the rising tide). Across all non-creek survey areas (both with and without experimental racks), red knot abundance was highest during the falling tide, next highest during high tide, third highest during low tide, and lowest during the rising tide. These authors found that tidal state was among the most important variables explaining patterns of red knot abundance (Burger *et al.* 2015).

From May 7 to June 4, 2015, a seven-person Rutgers field crew collected shorebird census data and behavioral observations from part of the action area (*i.e.*, the "Rutgers study" discussed under Consultation History, above) (Maslo *et al.* 2016). The study area is an approximately 3-mile (4.8-km) stretch of the Delaware bayshore extending from Kimbles Beach south to Green Creek (Figures 2 and 3). The study area contained seven discrete aquaculture zones, including ADZ-4 and five private leases. Between aquaculture sites are expansive areas where aquaculture does not occur, which served as reference sites. The study area landscape ranged from wide, sandy flats to narrow, bulkheaded beaches lined with rip-rap, providing a diversity of habitat types (see Description of the Action Area, above). The entire study area was divided into roughly 100-foot-long (30-m) segments to increase accuracy and precision of data collection. Maslo *et al.* (2016) found that tidal state was the most important predictor of red knot abundance. These authors found that rising and high tides have a significant positive influence on red knot abundance, while falling tide had a significant negative impact. Though only from a single year of data so far, this study team found that, as the tide rises, red knot abundance increases by a factor of about 15, likely due to the surge of horseshoe crab egg availability resulting from wave action (Maslo *et al.* 2016).

Across all the studies discussed above, tidal stage was found to exert an important influence on both spatial and temporal patterns of red knot foraging and habitat use. However, the studies disagree on which tidal stages are the most important foraging periods. Table 6 presents a summary of these studies.

**Table 6. Summary of study findings relevant to the effect of tidal cycle on red knot patterns of foraging and habitat use**

| | High Tide | Falling Tide | Low Tide | Rising Tide |
|---|---|---|---|---|
| Niles *et al.* (2008) | | Primary red knot feeding period | | |
| Botton *et al.* (1994) | Shorebirds concentrated | | Shorebirds dispersed | |
| Burger *et al.* (1997)* | Third highest percent of red knots feeding | Second highest percent of red knots feeding | Lowest percent of red knots feeding | Highest percent of red knots feeding |
| Nordstrom *et al.* (2006) | Peak in horseshoe eggs in the swash uprush | Fewer horseshoe eggs in the swash uprush | Fewer horseshoe eggs in the swash uprush | Peak in horseshoe eggs in the swash uprush |
| Burger *et al.* (2015) | Second highest red knot abundance | Highest red knot abundance | Third highest red knot abundance | Lowest red knot abundance |
| Maslo *et al.* (2016) | Significant positive influence on red knot abundance | Significant negative influence on red knot abundance | | Significant positive influence on red knot abundance |

* Tidal stage alone was not statistically significant in explaining the percent of red knots engaged in feeding. Four of five study sites were not applicable to the action area.

In addition to when red knots use intertidal habitats, we also consider where (*e.g.*, how far seaward) this usage extends. One study is looking at spatial distribution of red knots within the intertidal area across the tidal cycle. In spring 2015, J. Burger (pers. comm. February 29, 2016) led a team to examine use of red knots and other shorebirds using intertidal areas at 17 Delaware Bay beaches, including 11 beaches in the action area, and two beaches immediately adjacent to (one north, one south) the action area. The team placed stakes perpendicular to the shore at 328, 656, and 984 feet (100, 200 and 300 m) from the MHW line, and counted red knots and other shorebirds in each zone during all parts of the tidal cycle. Excluding four northern beaches (in Cumberland County, outside the action area), the team conducted 216 censuses. On each census, birds may be physically able to use one, two, or all three of the zones depending on how much intertidal area was exposed (*e.g.*, based on tidal stage). Of the 216 total censuses, 109 were in the 2 hours before or 2 hours after low tide. Of these 109 surveys around low tide, 105 (96 percent) had shorebirds feeding, and 60 surveys (55 percent) had red knots present. When any shorebirds were present in the 2 hours before and 2 hours after low tide, red knots were present 0 to 984 feet (0 to 300 m) from the MHW line 57 percent of the time (J. Burger pers. comm. February 29, 2016).

**Table 7. Mean number of red knots present in three intertidal zones at beaches from Villas to Bidwell Creek, 2015** (excludes surveys conducted at Cumberland County beaches) (J. Burger pers. comm. February 29, 2016)

| Distance (seaward) from the MHW line | Time relative to low tide | Total number of surveys [a] | Number of red knots when any shorebird was present in the beach segment [b] | | | Number of red knots when red knots were present in the beach segment [b] | | |
|---|---|---|---|---|---|---|---|---|
| | | | n | Mean + SE | Max | n | Mean + SE | Max |
| 0 to 100 meters | 1 to 2 hours before | 22 | 16 | 162 ± 125 | 2,000 | 5 | 519 ± 377 | 2,000 |
| | 0 to 1 hour before | 28 | 19 | 86 ± 46 | 700 | 7 | 233 ± 107 | 700 |
| | 0 to 1 hour after | 37 | 26 | 104 ± 38 | 700 | 10 | 271 ± 72 | 700 |
| | 1 to 2 hours after | 22 | 14 | 91 ± 49 | 600 | 9 | 141 ± 71 | 600 |
| 101 to 200 meters | 1 to 2 hours before | 22 | 19 | 134 ± 62 | 1,000 | 9 | 284 ± 113 | 1,000 |
| | 0 to 1 hour before | 28 | 23 | 286 ± 107 | 2,000 | 13 | 505 ± 168 | 2,000 |
| | 0 to 1 hour after | 37 | 29 | 276 ± 130 | 2,500 | 12 | 668 ± 284 | 2,500 |
| | 1 to 2 hours after | 22 | 16 | 158 ± 75 | 900 | 9 | 281 ± 120 | 900 |
| 201 to 300 meters [c] | 1 to 2 hours before | 22 | 8 | 4 ± 4 | 30 | 2 | 16 ± 14 | 30 |
| | 0 to 1 hour before | 28 | 14 | 48 ± 26 | 350 | 7 | 95 ± 46 | 350 |
| | 0 to 1 hour after | 37 | 19 | 88 ± 41 | 550 | 9 | 186 ± 74 | 550 |
| | 1 to 2 hours after | 22 | 4 | 500 ± 500 | 2,000 | 1 | 2,000 | 2,000 |

a. Surveyor could survey all segments at the same time (*e.g.*, 0 to 100, 101 to 200, 201 to 300)
b. Relates only to 0 to 100 m, 101 to 200 m or 201 to 300 m.
c. Small sample is due to there being few beaches with 201-300m intertidal exposed.

In this study of intertidal habitat use, red knots were not evenly distributed among the 13 surveyed Cape May County beaches, or across the three intertidal zones (J. Burger pers. comm. February 29, 2016). Looking at data from all tide stages (not just around low tide), red knots were concentrated in the Northern Segment compared to the Southern Segment. Part of the differences among beaches can be explained by varying widths of the intertidal zone (see Description of the Action Area, above). At some beaches, the intertidal area did not extend out the full 984 feet (300 m) at low tide. Again looking at data from all tide stages, red knots were concentrated in the two zones between 0 and 656 feet (0 and 200 m) from MHW, compared to the 659 to 984-foot (201 to 300-m) zone (as would be expected for data that include higher tidal stages, since the most seaward zone is exposed the shortest duration of time). This data from all tide stages shows that: (1) red knots were present in the 0 to 328-feet (0 to 100-m) zone on most beaches, although not all; (2) beaches that were wider, as expected, had red knots in the (659 to 984-foot (201 to 300-m) zone; and (3) when red knots were present in the 331 to 656-foot (101 to 200-m) zone, mean flock sizes could be large (for example 804 ± 325 at Cooks Beach). Although the data are from 13 beaches, with a significant number of samples, they are from only one year, represent a preliminary analysis, and do not account for the lack of a 259 to 984-foot (201 to 300-m) zone on some beaches. These data also do not account for extreme low tides or stochastic factors (*e.g.*, winds) that can influence the area of available intertidal habitat (J. Burger pers. comm. February 29, 2016).

Based on the information reviewed above, we conclude the following regarding patterns of red knot foraging across the tidal cycle and across the intertidal zone:

1. Red knots do not feed at night in Delaware Bay.

2. Red knot foraging intensity is typically highest during the mid-tides and, where beaches are sufficiently wide, during the high tide.

3. The highest-value foraging habitats are areas where horseshoe crab eggs tend to be concentrated, such as along the MHW line, in the wrack line, and at creek mouths. All of these highest-value foraging habitats are within the Protected Areas (as per CM 10).

4. Red knot foraging is not limited to only the highest-value (*i.e.*, egg concentration) habitats. Knots also routinely forage farther out on the intertidal flats (*i.e.*, outside Protected Areas), sometimes in considerable numbers, ranging seaward at least 984 feet (300 m) from the MHW line.

5. Over most of the tidal cycle, red knots tend to concentrate their feeding activity near the water’s edge.

6. Due to lower-intensity feeding activity, along with a much greater area of exposed intertidal substrate, red knots are most dispersed during low tide.

## ENVIRONMENTAL BASELINE

In the context of consultations under Section7 of the ESA, the environmental baseline is the past and present impacts of all Federal, State, or private actions and other human activities in an action area, the anticipated impacts of all proposed Federal projects in an action area that have already undergone Section 7 consultation, and the impact of State or private actions that are contemporaneous with the consultation in process (50 CFR 402.02). In determining whether a proposed action is likely to jeopardize the continued existence of a species, the action is viewed against the aggregate effects of everything that has led to the species’ current status and those non-Federal actions likely to affect the species in the future.

**Species Status Within the Action Area**

Table 8 shows summary statistics from the ENSP's annual red knot counts, which were described under Baywide Population Trends, above. As discussed under Subdivision of the Action Area, above, the ENSP has conducted annual, baywide, red knot surveys at mid and falling tides in Delaware Bay since 1986, with multiple counts per year. This 29-year data set (1986 to 2014) of red knot counts is broken down into 81 roughly linear survey segments, of which 48 segments are in New Jersey (Figures 1 to 3). In Table 8, those survey segments within the action area are shaded green, with the Southern Segment of the action area lighter green (survey segments 4 to 7) and the Northern Segment darker green (survey segments 8 to 12). Data for the remaining 39 survey segments, which are outside the action area, are provided for context.

The data are shown for the entire 29-year data set (1986 to 2014), and also by three distinct periods that roughly correspond with the time before (1986 to 2001) and during (2002 to 2008) a steep, baywide population decline, as well as the most recent period (2009 to 2014) during which the baywide population has been relatively low but generally stable (for baywide totals, see Tables 4 and 5, above). As described under Species Status, above, it is important that conservation efforts in Delaware Bay consider both historic (1980s through 2000s) as well as recent patterns of red knot use, since areas that were relatively more important during earlier years will be needed to accommodate the recovery and continued redistribution of the population from its current low level.

Table 8 presents the ENSP's red knot counts summed across all survey dates and years for each survey segment. Summing all counts in a segment results in a metric that reflects both the magnitude and consistency (inter- and intra-annual) of use (*e.g.*, year-to-year, early as well as late in the stopover season). A similar method (summing all counts) was used by Niles *et al.* (2008) in a status assessment for the red knot. From 1986 to 2008, these "total counts" include data from weekly surveys, and thus are likely a fairly accurate representation of red knot distribution across survey segments throughout the stopover period. From 2009 to 2014, however, the total counts are from only about two surveys per year, conducted late in the season to capture the baywide peak population size. Therefore, total counts in this latest period may be less reflective of patterns of red knot use across survey segments.

Note that variability in these total counts across time periods reflects not only localized and baywide population trends, but also reflects differing levels and timing of survey effort in each time period (as discussed under Baywide Population Trends, above) and the different durations of each period. However, the survey efforts (both level and timing) that varied by time period did not vary among survey segments. From 1986 to 2001, there were 85 baywide surveys conducted covering all segments. From 2002 to 2008, there were 42 baywide surveys, and from 2009 to 2014, there were 16 surveys. For the entire 29-year period, there were a total of 143 surveys. Due to this variable number of surveys, we cannot compare total red knot counts across time periods. However, because there were the same number of surveys in each segment during each time period, we can make comparisons among each segment's percentage of the State-wide total of red knots (Table 8).

Also note the differing sizes of the survey segments. The survey segments were delineated using geographic features identifiable from the air (*e.g.*, creeks, points, other landmarks); therefore, the survey segments are not of consistent length. Table 8 gives the approximate acres of each survey segment. Although the segments were not delineated or mapped for this purpose, the acreage estimates included in Table 8 give at least a rough indication of their different sizes, which could naturally affect the apparent abundance of red knots (both the total counts and the percentages of State-wide totals) in each survey segment relative to the others.

Table 9 shows these same data aggregated for the Northern and Southern Segments of the action area. As shown in Table 9, the action area supported more than 21 percent of all red knots counted in New Jersey since 1986, and more than 27 percent during the most recent time period. Using additional data (not shown) for the Delaware side of the bay, we calculated that the action area supported roughly 10 percent of all red knots counted in Delaware Bay from 1986 to 2001; about 10.5 percent from 2002 to 2008; about 20 percent from 2009 to 2014; and about 11 percent for the entire 29-year period. Delaware Bay supports an estimated 50 to 80 percent of the entire red knot population each spring (USFWS 2014; Brown *et al.* 2001). We can combine the estimated percentage of baywide knots that use the action area (10 to 20 percent) with the estimated percentage of rangewide knots that use Delaware Bay (50 to 80 percent) to roughly estimate the percentage of all rufa red knots that use the action area. The action area typically supports between 5 percent (10 percent of 50 percent) and 16 percent (20 percent of 80 percent) of all rufa red knots during the stopover period.

Table 9 also shows considerably higher red knot counts in the Northern Segment relative to the Southern Segment, consistent with the maps shown in Figures 4 to 7, above. The Northern Segment has supported 2.5 to 4 times more red knots than the Southern Segment since 1986. Further, the percentage of red knots counted in the Southern Segment has been generally stable across time periods (between 5 and 6 percent of all knots counted in New Jersey), while percentages in the Northern Segment have varied more widely over time (from less than 13 to nearly 22 percent of the State-wide totals). The level of survey effort is the same in each Segment, and the Segments are roughly the same size (see Description of the Project Area, above, and Table 9 below). These consistencies lend validity to comparisons made between the two Segments.

**Table 8. Red knot total counts by survey segment,* 1986 to 2014** (source ENSP)

| Survey Seg-ment | Beach | Total Count 1986-2001 | Total Count 2002-2008 | Total Count 2009-2014 | Total Count 1986-2014 | % of NJ Total 1986-2001 | % of NJ Total 2002-2008 | % of NJ Total 2009-2014 | % of NJ Total 1986-2014 | Acres |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Town Bank | 1,490 | 0 | 5 | 1,495 | 0.22 | 0.00 | 0.00 | 0.16 | 45 |
| 2 | WW Highlands Beach/Cox Hall Cr | 2,140 | 10 | 0 | 2,150 | 0.32 | 0.01 | 0.00 | 0.23 | 32 |
| 3 | Villas | 20,258 | 5 | 391 | 20,654 | 3.00 | 0.00 | 0.35 | 2.19 | 39 |
| 4 | Fishing Cr/North Miami Beach | 8,510 | 340 | 445 | 9,295 | 1.26 | 0.22 | 0.40 | 0.98 | 15 |
| 5 | Sunray Beach Preserve | 16,335 | 1,888 | 935 | 19,158 | 2.42 | 1.20 | 0.84 | 2.03 | 14 |
| 6 | North Norbury's Landing | 13,835 | 4,572 | 1,495 | 19,902 | 2.05 | 2.91 | 1.35 | 2.11 | 43 |
| 7 | Highs Beach | 1,350 | 1,220 | 3,095 | 5,665 | 0.20 | 0.78 | 2.79 | 0.60 | 17 |
| 8 | North Pierce's Point/Dias Cr | 10,185 | 2,885 | 5,885 | 18,955 | 1.51 | 1.84 | 5.30 | 2.01 | 26 |
| 9 | South Kimbles Beach | 19,081 | 5,694 | 4,415 | 29,190 | 2.82 | 3.62 | 3.98 | 3.09 | 17 |
| 10 | Cooks Beach | 18,935 | 4,190 | 7,780 | 30,905 | 2.80 | 2.67 | 7.01 | 3.27 | 16 |
| 11 | Reeds Beach | 38,210 | 2,710 | 3,150 | 44,070 | 5.65 | 1.72 | 2.84 | 4.67 | 13 |
| 12 | North Reeds Beach | 18,130 | 4,365 | 3,100 | 25,595 | 2.68 | 2.78 | 2.79 | 2.71 | 15 |
| 13 | North Bidwell Cr | 19,632 | 3,423 | 4,415 | 27,470 | 2.90 | 2.18 | 3.98 | 2.91 | 28 |
| 14 | Goshen Cr | 19,256 | 6,170 | 9,388 | 34,814 | 2.85 | 3.93 | 8.46 | 3.69 | 24 |
| 15 | Dennis Cr | 12,108 | 3,370 | 3,428 | 18,906 | 1.79 | 2.14 | 3.09 | 2.00 | 39 |
| 16 | North East Cr | 7,820 | 1,605 | 290 | 9,715 | 1.16 | 1.02 | 0.26 | 1.03 | 30 |
| 17 | West Cr | 17,370 | 1,695 | 1,920 | 20,985 | 2.57 | 1.08 | 1.73 | 2.22 | 29 |
| 18 | East Moores Beach | 28,390 | 5,540 | 1,090 | 35,020 | 4.20 | 3.53 | 0.98 | 3.71 | 53 |
| 19 | Moores Beach | 14,080 | 4,295 | 380 | 18,755 | 2.08 | 2.73 | 0.34 | 1.99 | 24 |
| 20 | West Moores Beach | 6,335 | 2,880 | 150 | 9,365 | 0.94 | 1.83 | 0.14 | 0.99 | 10 |
| 21 | S Thompsons Beach/Riggins Ditch | 10,950 | 1,170 | 510 | 12,630 | 1.62 | 0.74 | 0.46 | 1.34 | 12 |
| 22 | Thompsons Beach | 6,150 | 1,093 | 970 | 8,213 | 0.91 | 0.70 | 0.87 | 0.87 | 32 |
| 23 | North Thompsons Beach | 12,125 | 1,875 | 950 | 14,950 | 1.79 | 1.19 | 0.86 | 1.58 | 7 |
| 24 | East Point | 15,720 | 2,850 | 2,235 | 20,805 | 2.32 | 1.81 | 2.01 | 2.20 | 45 |
| 25 | Maurice River | 2,855 | 110 | 100 | 3,065 | 0.42 | 0.07 | 0.09 | 0.32 | 85 |
| 26 | Elder Point | 1,670 | 1,190 | 1,085 | 3,945 | 0.25 | 0.76 | 0.98 | 0.42 | 35 |
| 27 | Kenny Point | 11,255 | 2,760 | 510 | 14,525 | 1.66 | 1.76 | 0.46 | 1.54 | 29 |
| 28 | Dividing Cr | 20,845 | 825 | 136 | 21,806 | 3.08 | 0.53 | 0.12 | 2.31 | 58 |
| 29 | Northeast Egg Island | 13,648 | 1,495 | 2,875 | 18,018 | 2.02 | 0.95 | 2.59 | 1.91 | 40 |
| 30 | Egg Island Point | 44,265 | 6,477 | 10,974 | 61,716 | 6.54 | 4.12 | 9.89 | 6.53 | 33 |
| 31 | Brothers | 42,880 | 13,640 | 6,565 | 63,085 | 6.34 | 8.68 | 5.92 | 6.68 | 25 |
| 32 | False Egg Island Point | 43,635 | 8,500 | 6,755 | 58,890 | 6.45 | 5.41 | 6.09 | 6.24 | 22 |
| 33 | Fishing Cr | 17,155 | 2,000 | 1,685 | 20,840 | 2.54 | 1.27 | 1.52 | 2.21 | 24 |
| 34 | Raybins Beach | 22,070 | 6,335 | 7,005 | 35,410 | 3.26 | 4.03 | 6.31 | 3.75 | 26 |
| 35 | Fortescue | 7,060 | 4,270 | 1,860 | 13,190 | 1.04 | 2.72 | 1.68 | 1.40 | 39 |
| 36 | Beadon Point | 26,030 | 13,157 | 2,910 | 42,097 | 3.85 | 8.37 | 2.62 | 4.46 | 22 |
| 37 | N Beadon Point/Sow & Pigs Cr | 11,915 | 7,085 | 535 | 19,535 | 1.76 | 4.51 | 0.48 | 2.07 | 22 |
| 38 | Dyers Cove | 27,260 | 7,420 | 2,270 | 36,950 | 4.03 | 4.72 | 2.05 | 3.91 | 30 |
| 39 | Gandys Beach | 8,510 | 4,163 | 795 | 13,468 | 1.26 | 2.65 | 0.72 | 1.43 | 28 |
| 40 | Nantuxent Cr | 11,940 | 9,250 | 5,665 | 26,855 | 1.77 | 5.89 | 5.11 | 2.84 | 39 |
| 41 | Bay Point | 1,170 | 1,320 | 50 | 2,540 | 0.17 | 0.84 | 0.05 | 0.27 | 31 |
| 42 | Tarpon Cove/Bach Cr | 3,275 | 20 | 25 | 3,320 | 0.48 | 0.01 | 0.02 | 0.35 | 51 |
| 43 | Ben Davis Point | 8,580 | 145 | 1,460 | 10,185 | 1.27 | 0.09 | 1.32 | 1.08 | 28 |
| 44 | Oyster Gut | 6,360 | 710 | 190 | 7,260 | 0.94 | 0.45 | 0.17 | 0.77 | 33 |
| 45 | Sea Breeze | 4,445 | 720 | 310 | 5,475 | 0.66 | 0.46 | 0.28 | 0.58 | 19 |
| 46 | N Sea Breeze/Midmarsh Cr | 170 | 0 | 75 | 245 | 0.03 | 0.00 | 0.07 | 0.03 | 43 |
| 47 | Cohansey Cove | 30 | 570 | 110 | 710 | 0.00 | 0.36 | 0.10 | 0.08 | 52 |
| 48 | Cohansey Point | 965 | 1,135 | 572 | 2,672 | 0.14 | 0.72 | 0.52 | 0.28 | 26 |

*Those survey segments within the action area are shaded green, with the Southern Segment of the action area lighter green (survey segments 4 to 7) and the Northern Segment darker green (survey segments 8 to 12)

**Table 9. Red knot total counts within the action area, 1986 to 2014** (source ENSP)

| | Total Count 1986-2001 | Total Count 2002-2008 | Total Count 2009-2014 | Total Count 1986-2014 | % of NJ Total 1986-2001 | % of NJ Total 2002-2008 | % of NJ Total 2009-2014 | % of NJ Total 1986-2014 | Acres |
|---|---|---|---|---|---|---|---|---|---|
| Southern Segment | 40,030 | 8,020 | 5,970 | 54,020 | 5.92 | 5.10 | 5.38 | 5.72 | 89 |
| Northern Segment | 104,541 | 19,844 | 24,330 | 148,715 | 15.46 | 12.63 | 21.93 | 15.75 | 87 |
| Total Action Area | 144,571 | 27,864 | 30,300 | 202,735 | 21.37 | 17.73 | 27.31 | 21.47 | 176 |

## Factors Affecting Species Environment Within the Action Area

### *Habitat Conditions*

The action area is comprised largely of high-use, high-value red knot habitats, and suitable horseshoe crab spawning habitats, with numerous creeks with shoals that favor horseshoe crab spawning and shorebird use for daytime foraging, resting, roosting and loafing (NJDFW 2016). The beaches and intertidal zones were described under Description of the Action Area, above.

In 2012, the New Jersey side of Delaware Bay lost considerable horseshoe crab spawning habitat during Hurricane Sandy. A team of biologists found a 70 percent decrease in optimal horseshoe crab spawning habitat since 2002, which was judged to be mostly a result of Hurricane Sandy (Lathrop *et al.* 2013; Niles *et al.* 2012b). Several areas were eroded to exposed sod bank or rubble (used in past shoreline stabilization), which do not provide suitable spawning habitat. Several restoration projects have since been completed and more are in progress, as mentioned under Description of the Action Area, above.

Prior to the spring 2013 stopover, restoration projects were completed at four action area beaches. In total, over 5,000 linear feet (1,524 m) of shoreline received nearly 24,000 cubic yards (18,350 cubic m) of beach nourishment at South Reeds Beach, Cooks Beach, Kimbles Beach, and Pierces Point (Niles *et al.* 2013a). The restoration projects provided for an 80-foot-wide (24-m-wide) beach berm (USFWS 2016a). The restoration projects also removed over 14 tons (14.2 metric tons) of timber rubble from Pierces Point and over 48 tons (48.8 metric tons) of concrete rubble from South Reeds Beach (Niles *et al.* 2013a). These projects succeeded in creating habitat that received higher use for both horseshoe crab spawning and shorebird feeding relative to unrestored beaches that had been damaged during Hurricane Sandy (Niles *et al.* 2013a).

The 2013 restoration work also included deployment of several configurations of oyster racks offshore of South Reeds Beach to test their effectiveness for attenuating (*i.e.*, calming) wave action. Attenuating wave action can both protect beaches from wave-induced erosion and provide calm water for horseshoe crabs during rough wave conditions. The restoration team tested a double row of rectangular oyster racks, a single row of racks, and a series of oyster cultivation baskets suspended from a floating longline parallel to the shore. The results indicate that the double row of oyster racks had a small but statistically significant wave attenuating effect during periods of rougher wave conditions. The single row of oyster racks and the baskets on floating longline had no discernible wave-attenuating effect (Niles *et al.* 2013a).

In April 2015, a restoration team installed a segmented 200-foot-long (61-m-long) double oyster reef parallel to South Reeds Beach to test its effects on both wave attenuation and biological communities in the littoral zone (USFWS 2015). The reef is comprised of segments, each 10 feet (3 m) long and 5 feet (1.5 m) wide, constructed of bagged whelk (Busyconidae) shell. The 10-foot-long (3-m-long) segments are separated by 5-foot-wide (1.5-m-wide) spaces to allow for horseshoe crab passage. For the inner reef, located 50 feet (15 m) offshore from the toe of the beach slope, each segment is 1 foot (30 cm) tall. For outer reef, located 100 feet (30 m) offshore from the toe of the beach slope, each segment stands 2 feet (60 cm) tall. The inner and outer reefs parallel one another in a herringbone pattern. The project also included oyster racks. The purposes of the oyster reef project are to establish nearshore non-harvested oyster habitat, and test whether it creates sheltered water for breeding horseshoe crabs; measure oyster and other invertebrate colonization of the reef; measure permeability of the reef to horseshoe crab movements; and evaluate the efficacy of the reef for shoreline protection. Shorebird usage around the reef is also being studied (USFWS 2015). Monitoring studies at the shell bag reef are still in progress.

Absent continued beach nourishment and other restoration efforts, beaches in the action area are likely to erode. The rate of sea level rise in the Delaware Bay over the past century was about 0.12 to 0.16 inches (3 to 4 millimeters [mm]) per year, and localized erosion rates in the bay can be notably rapid (Loveland and Botton in Carmichael *et al.* 2015; USFWS 2014). Botton *et al.* (1988) found that even subtle alteration of the sediment, such as through erosion, may affect the suitability of habitat for horseshoe crab reproduction, and that horseshoe crab spawning activity is lower in areas where erosion has exposed underlying peat (Botton *et al*. 1988). Beaches without sand are unsuitable for foraging shorebirds because there are no excess crab eggs (Burger *et al.* 2015). Loveland and Botton (in Carmichael *et al.* 2015) discussed the mixed effects (but often locally detrimental) of beach erosion on horseshoe crab spawning habitat, including Kimbles Beach, Reeds Beach, and beaches north of Norburys Landing. These authors concluded that hard-stabilizing the shoreline blocks beach migration, and thereby directly reduces the productivity of these beaches for horseshoe crabs and shorebirds, and they discussed options for continued provision of adequate habitat through both beach nourishment and human retreat from the shoreline (Loveland and Botton in Carmichael *et al.* 2015). The conclusions of these authors regarding shoreline hardening, beach nourishment, and human retreat are consistent with the Supplemental Document in support of the red knot listing (USFWS 2014).

Galbraith *et al.* (2002) examined several different scenarios of future sea level rise and projected major losses of intertidal habitat in Delaware Bay. Under a scenario of 1.1 feet (34 cm) of global sea level rise, Delaware Bay was predicted to lose at least 20 percent of its intertidal shorebird feeding habitats by 2050, and at least 57 percent by 2100. Under a scenario of 2.5 feet (77 cm) of global sea level rise, Delaware Bay would lose 43 percent of its tidal flats by 2050, but may actually see an increase of nearly 20 percent over baseline levels by 2100, as the coastline migrates farther inland and dry land is converted to intertidal (Galbraith *et al*. 2002). However, the net increase would be realized only after a long period (50 years) of severely reduced habitat availability, and assumes that landward migration would not be halted by development or armoring. Sea Level Affecting Marsh Modeling (SLAMM) of a 3.3-foot (1 m) sea level rise at CMNWR suggests that estuarine beaches would survive, but with increased vulnerability to storm surges as back marsh areas become inundated (Stern 2009). In areas of existing development, erosion is expected to be exacerbated because landward migration of the beach and intertidal zone is generally precluded by structures such as bulkheads and roads (USFWS 2014).

In summary, habitat conditions in the action area are generally very high quality for red knots. Some erosional and previously hard-stabilized areas have recently been restored to increase habitat value for shorebirds, and restoration efforts continue (USFWS 2016b; Niles *et al.* 2013b). Existing development is localized and sparse (see Description of the Action Area, above), and development pressure to expand commercial or residential areas is low. The primary threat to habitat quality in the action area over the next 10 years is from erosion, exacerbated by sea level rise. There is also some potential for additional shoreline hardening, if human communities perceive no other options to protect infrastructure from inundation and erosion. Hardening would substantially diminish the quality and quantity of red knot habitats. However, restoration teams are working closely with bayshore communities to promote a more balanced approach to coastal resiliency that includes protecting habitat values. Thus, we do not expect wide-spread demand for shoreline hardening in the next decade.

***Food Availability***

As discussed under Horseshoe Crab Eggs, above, the present horseshoe crab harvest is not considered a threat to the red knot at the baywide scale, because harvest levels are tied to red knot populations via scientific modeling under the ARM (USFWS 2014). To evaluate localized food conditions within the action area, we can consider finer-scale data on horseshoe crab spawning density, as well as crab egg density.

A baywide horseshoe crab spawning survey has been conducted under consistent protocols since 1999. Baywide spawning activity showed no statistically significant trends from 1999 through 2014 (Zimmerman *et al.* 2015). At the scale of individual beaches, however, Smith and Robinson (2015) did detect some trends. Individual beaches that initially had higher female densities tended to experience a decrease, while beaches that initially had lower female densities tended to experience an increase; this suggests a redistribution of females among the beaches over the study period. For males, there was a positive overall trend in spawning abundance from 1999 to 2013 that occurred broadly among beaches. Moreover, the beaches with below-average initial male density tended to have the greatest increases. Specific to the action area, the statistical methods used by Smith and Robinson (2015) showed slight increases in male crab spawning density at Norburys Landing, Highs Beach, and Kimbles Beach, and somewhat greater increases at Pierces Point and Reeds Beach.

Egg density surveys were conducted in New Jersey in 1985, 1986, 1990, and 1991, and annually since 1996. Methodologies have evolved over time, but have been relatively consistent since 2005 (Niles *et al.* 2008). Niles *et al.* (2008) reported New Jersey egg densities from 1985, 1986, 1990, and 1991 an order of magnitude higher than for the period starting in 1996. Conversion factors were developed to allow for comparison between the 1985 to 1986 and the 1990 to 1991 data points (Niles *et al.* 2008), and statistical analysis found that data points from 2000 to 2004 can be directly compared to those from 2005 to 2012 without a conversion factor (*i.e.*, a 2005 change in sampling method did not affect the egg density results) (Dey *et al.* 2011b). However, comparisons between the earlier data points (1985 to 1999) and egg densities since 2000 are confounded by changes in methodology and investigators, and lack of conversion factors. Higher confidence is attached to trends since 2005 because methodologies have been consistent over that period (USFWS 2014). Recent (2005 to 2014) surface egg densities in the action area were similar to annual State-wide means for the same period, averaging 540 eggs per square foot (5,939 eggs per square m) (NJDFW 2016, Supplement).

Very high spatial and temporal variability in surface egg densities limits the statistical power of the surveys (ASMFC 2012). Based on the sampling methodology (Dey *et al.* 2011b), the surveys would be expected to have only about a 75 percent chance of detecting a major (50 percent) decline in egg density over five years (Pooler *et al.* 2003). However, most data suggest that the volume of horseshoe crab eggs is currently sufficient to support the Delaware Bay's stopover population of red knots at its present size (USFWS 2014). For example, the proportion of red knots achieving the target weight of 6.3 oz (180 g) has generally increased since 2009 (NJDFW 2016). Since the egg densities in the action area are similar to the State-wide averages, we conclude the volume of horseshoe crab eggs in the action area is currently sufficient to support the typical number of red knots feeding in the action area in recent years.

***Human Disturbance***

Disturbance of red knots and other shorebirds from recreational beach uses (*e.g.*, walking, jogging, dog walking, fishing) is limited by several factors. First, many parts of the action area are sparsely developed, and public access to the bay beaches is limited to a few road ends and bayfront homeowners. Second, the birds typically leave the bay around Memorial Day, which is traditionally the start of New Jersey's peak beach season. Finally, beaches in the action area are managed to limit shorebird disturbance.

To manage and prevent disturbance to shorebirds, the NJDEP and the New Jersey Audubon Society have implemented a variety of actions to reduce human disturbance since the 1980s. The NJDEP instituted a program of trained Shorebird Stewards, volunteers who staff important shorebird foraging beaches to educate residents and visitors about disturbance impacts to shorebirds. Shorebird viewing areas were designated where visitors can view shorebirds without causing disturbance (NJDFW 2016).

Within the action area, there are viewing platforms at the northern end of Reeds Beach, and at the end of Milman Boulevard at Norburys Landing (NJDFW 2013). Except at designated viewing locations, and south of Eldridge Avenue in Sunray Beach, public access to all beaches in the action area is restricted from May 7 to June 7 (A. Dey pers. comm. November 14, 2014). These seasonal restrictions, covering both pedestrians and vehicles, have been implemented since 2003 to protect red knots and other migrating shorebirds from harassment (pursuant to State law at N.J.S.A. 23:2A-7e). Restricted areas are marked with printed signs and rope fencing from the street end to the water's edge (NJDFW 2013). The access restrictions are staffed by Shorebird Stewards with support from State Conservation Officers (NJDFW 2016). The State also works with recreational boaters, including through law enforcement, to minimize habitual disturbance of shorebirds during the stopover season.

Largely due to these successful management efforts (USFWS 2014; NJDFW 2013; Niles *et al.* 2008), Maslo *et al.* (2016) reported very few observations of recreational beach users in the action area during May 2015 data collection for the Rutgers study. Similarly, studying experimental oyster racks and a nearby reference site at South Reeds Beach in 2013, Burger *et al.* (2015) found that people (including both recreational beach goers and growers tending the experimental racks) were present during less than 10 percent of the surveys. The effects of those rare recreational disturbances that do occur on red knot distributions and/or energy budgets are being studied, but are not yet clear (Maslo *et al.* 2016). The Rutgers study is funded to continue in 2016 and 2017.

Maslo *et al.* (2016) found somewhat clearer disturbance impacts to red knots in the action area from low-flying aircraft, though based on only one year of data to date. In 2015 the NJDFW initiated management actions to address use of these aircraft during the stopover season. The Service anticipates supporting the NJDFW in its continuing efforts to work cooperatively with aircraft operators to reduce disturbance levels.

Temporary, localized disturbance to red knots occurs during the NJDFW's annual shorebird monitoring and research program, which includes ground and aerial surveys, as well as catching knots (via cannon netting) for purposes such as measuring weight gain, attaching leg flags, attaching or retrieving tracking devices, and chemical or genetic analyses (USFWS 2014). Red knots may also be disturbed by shorter-term research activities, such as the Rutgers study, the intertidal surveys, and monitoring at the South Reeds Beach oyster reef. In all cases, research teams employ best management and handling practices to avoid or minimize disturbance of red knots and other shorebirds.

We conclude that the potential for moderate levels of human disturbance is well managed such that actual disturbance from recreational beach users is low. Disturbance from low-flying aircraft may be more substantial, but we expect this too will be abated over the next 10 years.

***Aquaculture***

Both existing and future structural aquaculture are the subject of this PBO; thus, ongoing aquaculture is not actually part of the Environmental Baseline. However, as several active oyster farms are already in operation, aquaculture may be affecting the species environment in the action area. For example, based on preliminary data and analysis, Maslo *et al.* (2016) found that oyster tending activities appear to have a negative effect on the abundance of red knots, though the magnitude of this effect appears less influential than tidal stage. A full analysis of potential and likely effects of structural aquaculture on red knots is given below, under Effects of the Action.

Atlantic Cape Fisheries, Inc. operated on a riparian grant just south of the Cape Shore Lab from 1997 or 1998 through 2015 before moving their operation to ADZ-4. In the BA, the NJDFW (2016) raised the pertinent question of whether this commercial-scale operation could have contributed to localized declines in shorebird use and/or to locally decreased densities of spawning horseshoe crabs or crab eggs. The NJDFW (2016) concluded that no cause and effect has been established while urging further investigation. We have reviewed the following best available science relevant to this question, as follows.

- We are not aware of any red knot or other shorebird data specific to the Cape Shore Lab vicinity. The ENSP's aerial survey data for this area are recorded for the entire survey segment (segment 6), which extends roughly 9,200 feet (2,804 m) from near Conswell Road to Norburys Landing (Figures 3 and 9). Thus, it would not be possible to use this data set to detect any localized changes in or near the Cape Shore Lab. Shorebird data collected in the 2000s in connection with the siting of ADZ-4 are not available at the time of this PBO. Newer studies still in progress (Maslo *et al.* 2016; J. Burger pers. comm. February 29, 2016) are collecting site-specific red knot data across the action area, but data specific to the Cape Shore Lab vicinity are not yet available.

- Botton *et al.* (1994) repeatedly surveyed the stretch of beach between Norburys Landing and the Cape Shore Lab from mid-May to early June 1990 and 1991, and reported very few shorebirds in this area. Although this study suggests low shorebird abundance near the Cape Shore Lab, this report was not specific to the area formerly occupied by Atlantic Cape Fisheries, Inc.

- Surveying about 11 miles (17.7 km) from the Cape May Canal to Reeds Beach in early June 1977, Shuster and Botton (1985) found that the highest density of spawning crabs, by far, was in the roughly 1.2-mile (1.9-km) stretch just south of the Cape Shore Lab. Although this study suggests high spawning levels near the Cape Shore Lab, these results are not specific to the area formerly occupied by Atlantic Cape Fisheries, Inc. Further, these data are reported in a format (crabs per linear meter) that cannot be directly compared to more recent spawning surveys (crabs per square meter).

- Although not directly comparable with Shuster and Botton (1985), Smith and Robinson (2015) found that the density of spawning female crabs around the Cape Shore Lab decreased slightly from 1999 to 2013. Other nearby beaches declined at about the same rate (*e.g.*, Highs Beach, Villas, Town Bank) while others increased (*e.g.*, Norburys, Pierces Point, Reeds Beach).

- Botton *et al.* (1994) presented data collected in 1990 and 1991 from a study site located near the Cape Shore Lab. Compared to seven other study sites on the Cape May bayshore, the Cape Shore Lab had moderate levels of spawning horseshoe crabs, and among the higher levels of egg densities. These authors showed surface egg densities of over 900 per square foot (10,000 per square m) near the Cape Shore Lab.

- Over a sampling period from the late 1980s through 2001, Loveland and Botton (in Carmichael *et al.* 2015) reported a sharp drop in egg density along the beach north of Norburys Landing, reflected in both surface and deeper-buried eggs. These authors concluded that horseshoe crabs were no longer using this beach for spawning, largely due to the lack of deep sand and the increase of muddy sediments along the narrow beach caused by beach erosion. It is not clear from this publication if the study area in question overlapped with the Atlantic Cape Fisheries, Inc. operation, but the authors did imply that the drop in egg densities was not localized to the north but pervasive across the whole stretch of beach north of Norburys Landing. The authors also did not indicate that the drop in egg densities was limited to the period after establishment of the Atlantic Cape Fisheries, Inc. around 1997 or 1998. Based on the likely minimal (if any) geographic overlap, and short temporal overlap, between this data set and the Atlantic Cape

Fisheries, Inc., we conclude erosion was likely a far greater contributing factor than aquaculture to declining egg density.

- Studying 16 beaches in Delaware and New Jersey in May and June 1999, Pooler *et al.* (2003) found that the Cape Shore Lab had among the highest shallow egg densities, with 25.5 eggs per 5-cm-diameter core (SE 0.86). A rough conversion suggests egg densities of approximately 1,160 eggs per square foot (12,750 eggs per square m).

- From 2011 to 2013, NJDFW (unpublished data) reported egg densities at the Cape Shore Lab from roughly 109 to 270 eggs per square foot (1,200 to 3,000 eggs per square m), with a three-year mean of 163 eggs per square foot (1,850 eggs per square m).

- Due to differences in methodologies and investigators (*e.g.*, see Food Availability, above), direct comparisons among the three egg density numbers given above may not be valid. However, the magnitude of change between 1999 and 2011 does suggest a possible decline. This decline could be reflective of the broader, baywide decline in horseshoe crab populations that occurred over this time period (USFWS 2014; ASMFC 2012). However, the NJDFW(unpublished data) notes that egg densities at the Cape Shore Lab appear to have declined even relative to other nearby bay beaches.

- We note that, to the extent they can be compared, egg densities did not appear to decline between 1990/1991 (Botton *et al.* 1994) and 1999 (Pooler *et al.* 2003), which was one to two years after the start of commercial aquaculture operations south of the Cape Shore Lab. It is possible that aquaculture could have had a delayed effect on egg densities, or that such effects did not emerge until the farm reached a certain size or scale of operations.

- We conclude it is likely that localized erosion played an important part in any reduced spawning that may have occurred around the Cape Shore Lab (see Habitat Conditions, above). Loveland and Botton (in Carmichael *et al.* 2015) noted marsh loss due to erosion at the Cape Shore Lab from starting in the 1960s. After the demise of the marsh, a gently sloping beach became important spawning habitat for horseshoe crabs (Loveland and Botton in Carmichael *et al.* 2015). These authors did not discuss more recent erosion rates or beach loss specific the Cape Shore Lab that may be affecting densities of spawning crabs in this area. However, there has been a near complete loss of beach near the Cape Shore Lab in recent years.

Based on the above information, we concur with NJDFW (2016) that no cause and effect relationship can be established between operation of the Atlantic Cape Fisheries, Inc. and any localized changes in shorebird or horseshoe crab habitat use. However, we also concur with NJDFW (2016) that further investigation of the impacts of aquaculture activities on horseshoe crab spawning and on red knots, such as the ongoing Rutgers study, is warranted. Under Effects of the Action, below, we assess best available science regarding the likely and possible impacts of aquaculture, but further research in to these impacts would be valuable to the adaptive management process (see CM 6).

Based on the above review of available information, we find no causal effects from the action area's longest-operating oyster farm on any localized declines in the abundance of spawning horseshoe crabs or crab eggs. Though some information suggests that crab declines did occur, we are unable to verify the declines or tie them to the roughly 18-year operation of the Atlantic Capes Fisheries, Inc. farm. As discussed above, localized shorebird data is not available for the vicinity of this farm, therefore we cannot determine if the localized abundance of red knots declined in this area over the time this farm was in operation on the riparian grant. However, as noted above, Maslo *et al.* (2016) found that oyster tending activities appear to have a negative effect on the abundance of red knots, and this conclusion is supported by other information that is discussed under Effects of the Action, below. We therefore conclude that existing aquaculture is likely affecting red knot habitat use in the action area at the time of this PBO, primarily due to the effects of disturbance from human activities such as tending.

## EFFECTS OF THE ACTION

### Effects to Red Knots (Direct Effects)

#### *Disturbance*

Human activities associated with aquaculture may disturb any red knots present in the vicinity. Such activities include but are not limited to, maintaining racks or other gear (*e.g.*, repairing, replacing, repositioning), tending oysters (*e.g.*, washing, turning, culling, sorting), and harvesting oysters. Red knots will not be disturbed by installation of new gear as this activity is seasonally restricted in the intertidal zone from April 15 to June 7. Allowable aquaculture activities, such as those listed above, may involve use of boats, power washers and, in the Southern Segment, motor vehicles. In the Northern Segment, no motor vehicle use will be allowed on Leases A-19 or A-28 (see Appendices C and D) from May 1 to August 31 during the three transitional years established in CMs 20 and 21. In the Southern Segment, aquaculture activities will occur 5 days per week, and in the Northern Segment (Leases A-19 and A-28), low-tide aquaculture activities during the transitional years will be 2 days per week. In both the Southern and Northern Segments, aquaculture activities will be on a weekly schedule coordinated by the BSF and limited to the 2 hours before and after low tide (CM 15, Appendices C and D). Additional tending may occur on Lease A-19 2 hours before and after high tide, as long as the boat(s) remains at least 500 feet (152 m) from the water's edge. Disturbance to red knots from aquaculture activities may displace birds from otherwise preferred habitats, and may impact birds' ability to gain weight (*i.e.*, affect their energy budget, which is the balance between food intake and energy expenditure). As discussed under Species Status, above, adequate weight gain in Delaware Bay is vital for red knots to complete their northbound migration and breed in the Arctic.

<u>Displacement</u>

Where shorebirds are habitually disturbed, they may be pushed out of otherwise preferred roosting and foraging habitats (*e.g.*, displaced) (USFWS 2014). Roosting knots are particularly vulnerable to disturbance because birds tend to concentrate in a few small areas during high tides, and availability of suitable roosting habitats is already constrained by predation pressures and energetic costs such as traveling between roosting and foraging areas (USFWS 2014).

Exclusion of shorebirds from preferred habitats due to disturbance has been noted throughout the red knot's nonbreeding range, including Massachusetts (Pfister *et al.* 1992), the Atlantic coast of New Jersey (Mizrahi 2002), and Florida (Burger and Gochfeld 1991). Exclusion of shorebirds, or reduced shorebird use of otherwise suitable habitats, has been shown to result from vehicle use (Forgues 2010; Tarr 2008) as well as pedestrians and other beach uses.

Specific to red knots, the mean abundance of red knots on Mustang Island, Texas decreased 54 percent from 1979 to 2007, while the mean number of people on the beach increased fivefold (Foster *et al.* 2009). In 2008, Escudero *et al.* (2012) found that human disturbance pushed red knots off prime foraging areas near Río Grande in Argentinean Tierra del Fuego, and that disturbance was the main factor affecting roost site selection. In Delaware Bay, Karpanty *et al.* (2006) found that potential disturbance reduced the probability of finding red knots on a given beach, although the effect of disturbance was secondary to the influence of prey resources. Also in Delaware Bay, Harrington (2005) found that shorebird numbers were lower in areas of higher disturbance.

At two sites on the Atlantic coast of New Jersey, Burger and Niles (2013a) found that disturbed shorebird flocks often did not return to the same place or even general location along the beach once they were disturbed, with return rates at one site of only 8 percent for monospecific red knot flocks. Even when flocks returned, not all shorebirds did so, with half or less of the birds returning after a disturbance (Burger and Niles 2013a). At one of these New Jersey study sites, Burger and Niles (2013b) found that spatial use by shorebirds, especially red knots, depended upon whether the beach was open or closed to recreational beach users. Of the shorebird species in this study, red knot behavior was most affected by beach closure. Knots spread out over the entire beach when it was closed, and concentrated in a fenced (protected) area when the beach was open (Burger and Niles 2013b). When the beach was open, knots concentrated on the beach segments that were the greatest distance from where people could enter. For all shorebird species, there was a significant difference in the mean flock size depending upon whether the beach was open or closed (Burger and Niles 2013b).

In a related study, Burger and Niles (2014) found that approach of new stressors (*e.g.*, people, trucks) exerted an effect on foraging shorebirds (five species, including red knots), and that variations in the percent of flocks that were disturbed were partly explained by whether the beach was open or closed. Closing the beach resulted in fewer flocks being disturbed, and when the beach was open, the percent of flocks disturbed was affected by whether the flocks were far from the point of human entrance onto the beach. The presence of people also influenced how quickly shorebirds returned to the places they had been foraging (Burger and Niles 2014).

Burger *et al.* (2015) studied red knot abundance at experimental oyster racks off South Reeds Beach in 2013. The objective of the study was to examine shorebird use as a function of oyster racks and growers, as well as tidal cycle and the presence/absence of recreational beach users (*e.g.*, people not engaged in aquaculture). The study design consisted of 50 racks, set up 24 inches (60 cm) above the intertidal sediment, with two lines of the individual racks parallel to the beach located 82 feet (25 m) from the MHW line. The racks were constructed early in the migration period, topped with filled oyster bags, and tended by growers 1 to 2 days per week.

During low tides, the exposed mudflat extended to the racks, and growers worked only at low tide. The growers did not use any vehicles or power washers. Survey segments with racks were compared to reference segments without racks.

Statistical analysis showed that variables of racks (present/absent), tidal phase (high/falling/low/rising), and people (present/absent) could explain some, but not most, of the variability in shorebird abundance (Burger *et al.* 2015). However, the observed (limited) influence of these variables on bird abundance was highly statistically significant. Specific to red knots, people and tides contributed the most to the variation in bird numbers. When people were present (growers and/or other beach users), there were virtually no red knots in the rack segments. In addition to these statistical findings, Burger *et al.* (2015) reported anecdotally that, if growers appeared during low tide to work on the racks, shorebirds moved down the beach away from the operations. With time, some other shorebird species returned close to the racks, but the red knots remained on the adjacent reference site while growers were present at the racks (Burger *et al.* 2015)

These results from Burger *et al.* (2015) are from only one site and one year. This study reflects the lower range of oyster tending intensity currently practiced in the action area (*e.g.*, only 1 or 2 days per week, no vehicles, no power washing). Conversely, the location of the racks only 82 feet (25 m) from the MHW line is not applicable to the conditions that red knots will encounter at oyster farms under this PBO, which requires gear be at least 300 feet (91 m) from the MHW line during the stopover season (CM 10). Aquaculture activity so close to the MHW line (where horseshoe eggs are concentrated) could have caused a higher level of red knot disturbance (*e.g.*, displacement), and over a greater proportion of the tidal cycle, than might be expected to occur under this PBO, which requires gear to be located much farther out in the intertidal zone. The combination of CMs 10 (Protected Areas) and 15 (limiting of access to the 4 hours around low tide) are expected to reduce the effects of disturbance during the mid-tide foraging periods, relative to the experimental conditions of this study.

The height of the experimental racks (24 inches [60 cm]) (Burger *et al.* 2015) was also quite different from gear typically used at commercial oyster farms in the action area. Most racks in the action area currently have 8-inch-tall (20-cm-tall) legs. Under CM 8, leg heights are expected to increase to 14 inches (36 cm). Based on current practices, we do not expect racks as tall as 24 inches (60 cm), but such gear would not be prohibited under this PBO. Burger *et al.* (2015) postulated that birds could perceive racks and other gear as blocking their exit flight paths (*e.g.*, if a predator approaches). Under this theory, a taller rack could exert a greater displacement influence (with or without tending) than a shorter rack (physical and visual effects of gear are discussed under Functional Habitat Loss, below). However, we conclude that this atypical rack height was not a factor in this study's finding on the strong displacement effect of oyster tending and other human activities, because the presence or absence of racks alone was not a significant variable in explaining the abundance of red knots. When no people were present, there were no differences in the number of red knots as a function of racks being present or absent (Burger *et al.* 2015).

Most relevant to this PBO, Maslo *et al.* (2016) found, based on preliminary data and analysis, that oyster tending activities at active farms appeared to have a negative effect on the abundance of red knots. These authors collected shorebird census data and behavioral observations from May 7 to June 4, 2015 between Kimbles Beach and Green Creek. Though the magnitude of the negative effect of tending appeared less influential than tidal stage, the presence of tending was a significant factor in explaining observed red knot distributions in the action area. Though based on only one year of data to date, these preliminary findings of the Rutgers study (Maslo *et al.* 2016) are consistent with those of Burger *et al.* (2015). (The Rutgers study is funded to continue in 2016 and 2017.) Despite the aforementioned caveats regarding both of these studies, their consistent findings strongly suggest that human activities associated with aquaculture can and do suppress localized red knot use of otherwise suitable habitats in the action area. These findings are also consistent with the body of literature, summarized above, regarding displacement of red knots and other shorebirds due to human disturbance.

We have little data on which to estimate the distances over which aquaculture activities may displace red knots. When people were present in the study by Burger *et al.* (2015), there were virtually no red knots in the three 197-foot-long (60-m-long) rack segments (591 feet (180 m) total); however, we cannot ascertain from this paper how far away from the human activity this displacement extended (*e.g.*, into those reference segments adjacent to the rack segments). Of 395 red knot behavior observations collected by Maslo *et al.* (2016), no knots were seen foraging within three 100-foot-long (30-m-long) survey segments (300 feet (91 m) total) of a tended oyster rack. This is roughly consistent with an observation (discussed more under Effects to Energy Budgets, below) that red knots become alert to human activity at about 270 feet (J. Burger pers. comm. September 28, 2014). Thus, we postulate that displacement (or at least suppression) of habitat use by red knots extends at least 300 feet (91 m) from aquaculture activity. We recognize this estimate is based on preliminary information, and the actual distance is likely influenced by various factors such as tide stage, egg density, flock size, and the type, intensity, and duration of the aquaculture activity.

*Effects to Energy Budgets*

Disturbance of shorebirds can cause behavioral changes resulting in less time roosting or foraging, shifts in feeding times, decreased food intake, and more time and energy spent in alert postures or fleeing from disturbances (USFWS 2014). By reducing time spent foraging and increasing energy spent alert or fleeing, disturbance may hinder red knots' ability to recuperate from migratory flights, maintain adequate weights, or build fat reserves for the next phase of the annual cycle (Harrington 2005; Clark in Farrell and Martin 1997; Burger *et al.* 1995).

Although population-level impacts cannot be concluded from species' differing behavioral responses to disturbance (Stillman *et al.* 2007; Gill *et al.* 2001), behavior-based models can be used to relate the number and magnitude of human disturbances to impacts on the fitness of individual birds (Goss-Custard *et al.* 2006; West *et al.* 2002). When the time and energy costs arising from disturbance were included, modeling by West *et al.* (2002) showed that disturbance could be more damaging than permanent habitat loss. Modeling by Goss-Custard *et al.* (2006) was used to establish critical thresholds for the frequency with which shorebirds can be disturbed before they die of starvation. There is evidence from modeling that, under some conditions, sanderlings could spend more energy responding to human disturbances than they were able to accrue in their daily foraging; disturbance can be energetically costly to shorebirds at a migration staging area (B. Harrington pers. comm. November 14, 2013). Birds can tolerate more disturbance before their fitness levels are reduced when feeding conditions are favorable (*e.g.*, abundant prey, mild weather) (Niles *et al.* 2008; Goss-Custard *et al.* 2006).

Studying another *Calidris canutus* subspecies in Australia, Rogers *et al.* (2006) found that energy expenditure over a tidal cycle was sensitive to the amount of disturbance, and a relatively small increase in disturbance can result in a substantial increase in energy expenditure. Shorebirds may be able to compensate for these costs to some extent by extending their food intake, but only to a degree, and such compensation is dependent upon the availability of adequate food resources. The energetic costs of disturbance are greatest for heavy birds, such as just before departure on a migratory flight (Rogers *et al.* 2006). Additional shorebird studies, not specific to red knots, support the conclusion that disturbance can impact energy budgets (Forgues 2010; Tarr 2008; Burger and Gochfeld 1991).

Both modeling (West *et al.* 2002) and empirical studies (Burger 1986) suggest that numerous small disturbances are generally more costly than fewer, larger disturbances. Burger *et al.* (2007) found that repeated disturbances to red knots and other shorebirds may have the effect of increasing interference competition for foraging space by giving a competitive advantage to gull species, which return to foraging more quickly than shorebirds following a response to vehicles, people, or dogs.

Shorebirds are more likely to be flushed by dogs than by people, and birds react to dogs from greater distances than to people (USFWS 2014). Burger *et al.* (2007) found that foraging shorebirds in migratory habitat do not return to the beach following a disturbance by a dog, and Burger *et al.* (2004) found that disturbance by dogs was increasing in Delaware Bay even as management efforts were having success at reducing other types of disturbances.

Several studies have documented behavioral disturbance responses specific to rufa red knots. In two New Jersey bays, Burger (1986) found that 70 percent of shorebirds, including red knots, flew when disturbed, including 25 (Raritan Bay) to 48 (Delaware Bay) percent that flew away and did not return (see Displacement, above). Birds in smaller flocks tended to be more easily disturbed than those in larger flocks (opposite the findings of Koch and Paton (2014), below). Explanatory variables for differences in response rate included date, duration of disturbance, distance between the disturbance and the birds, and the number of people involved in the disturbance (Burger 1986). On some Delaware Bay beaches, the percent of shorebirds (including red knots) that flew away and did not return in response to disturbance increased between 1982 and 2002 (Burger *et al.* 2004). Also from Delaware Bay, data presented by Harrington (2005) suggest that shorebird foraging rates were affected by the presence of people. Along with reduced size of prey items, disturbance was a key factor explaining sharp declines in red knot food intake rates at Río Grande, Argentina, on Tierra del Fuego (Escudero *et al.* 2012). Comparing conditions in 2008 with earlier studies, total red knot feeding time was 0.5 hour shorter due to continuous disturbance and flushing of the birds by people, dogs, and vehicles during prime feeding time just after high tide (Escudero *et al.* 2012).

Some data is available regarding the distance(s) at which red knots respond to human activities. Harrington (1999) reported that larger shorebirds typically initiate flight when people are within 295 to 459 feet (90 to 140 m). In an experimental study in Massachusetts, Koch and Paton

(2014) found that about 80 percent of red knots ran before taking flight when approached by pedestrians. Red knots typically ran less than 65 feet (20 m) before flying. Across shorebird species (including red knots), flock size, behavior (foraging or not), and number of pedestrians all appeared to have mixed effects on flight initiation distance, or the distance at which birds flew when approached by pedestrians. Flight initiation distance generally increased as flock size and number of pedestrians increased, and was generally less for birds that were foraging than for birds engaged in other behaviors. Specific to adult red knots, median flight initiation distance was about 100 feet (30 m), with $5^{th}$ and $95^{th}$ percentile values of about 65 and 165 feet (20 and 50 m), respectively. Koch and Paton (2014) recommended a red knot buffer distance of 407 feet (124 m), calculated as two times the sum of mean flight initiation distance (across adults and juveniles) plus 1.6495 times the Standard Deviation.

At two Atlantic coast sites in New Jersey, Burger and Niles (2013a) found that about 70 percent of shorebird flocks with red knots flew when disturbed by people, vehicles, or dogs, whether the flocks were monospecific or contained other species as well. Unpublished data collected as part of this and related studies (Burger and Niles 2014; Burger and Niles 2013b) show that red knots first became alert when human activity was about 270 feet (82 m) away, and responded by flying or running when the human activity was about 215 feet (66 m away) (J. Burger pers. comm. September 28, 2014). We have no explanation for the substantial difference between this flight initiation distance (215 feet [66 m]) and that reported by Koch and Paton (2014) (about 100 feet [30 m]). For flocks comprised of only red knots (and no other shorebirds), 87 percent of flocks were disturbed during the New Jersey study, 72 percent of flocks returned after a disturbance, and returning flocks contained 65 percent as many birds as before the disturbance (J. Burger pers. comm. September 28, 2014). These results suggest some level of displacement from preferred habitats (*e.g.*, by the non-returning flocks and individual birds), as discussed above, as well as energetic impacts to both the returning and non-returning birds.

We expect that some red knots exposed to aquaculture, namely those that do not avoid the aquaculture area entirely, will experience effects to their energy budgets (*i.e.*, increased energy expenditure and/or decreased food intake). However, we have essentially no data on which estimate the magnitude of the energy budget effects red knots may experience as a result of disturbance from aquaculture activities. In spring 2015, Maslo *et al.* (2016) collected 395 red knot behavioral observations in the action area, looking for possible effects to the birds' energy budgets from aquaculture activities. Presumably due to the displacement effects of human activity, discussed above, these researchers did not record any red knots foraging within three 100-foot-long (30-m-long) survey segments (300 feet [91 m] total) of a tended oyster rack, and were therefore unable to assess any behavioral response of the birds to aquaculture activities to date. Thus, we have no basis on which to attempt quantifying effects to energy budgets at this time. However, the Rutgers study is funded to continue in 2016 and 2017, so new information may become available in the future.

*Subtidal Aquaculture*

We do not expect any red knots to be disturbed by subtidal aquaculture activities. Under CM 10, Protected Areas will extend 300 feet (91 m) on either side of the MHW line and 500 feet (152 m) around creek mouth shoals, including areas of open water. Under CM 11, boats engaged in subtidal aquaculture will remain at least 500 feet (152 m) from the water's edge. Because red knots rarely wade in water more than about 1 inch (2 to 3 cm) deep (Harrington 2001), birds are no farther seaward than the water's edge when foraging, and thus at least 500 feet (152 m) from the nearest aquaculture boat. Reported red knot response distances to human activities range from about 100 feet (30 m) to 270 feet (82 m) (Koch and Paton 2014; J. Burger pers. comm. September 28, 2014). As knots will be at least 500 feet (152 m) away from the nearest boats, we do not expect any disturbance to occur. However, the reported response distances were for pedestrians, not boats. If the 500-foot (152-m) buffer distance proves insufficient to prevent disturbance to red knots, it will be adjusted as needed during the Tier 2 and adaptive management processes, as stated in CM 11.

In the Southern Segment, access to subtidal growing areas by land may occur if following the approved Intertidal Access Plan for an adjacent intertidal farm (CMs 11 and 15). We do not expect any additional, incremental disturbance from these subtidal growers transiting through adjacent intertidal farms, due to the coordinated access schedule and particularly because only a small percentage of subtidal aquaculture would be accessible via land (*e.g.*, areas where all gear is covered, but the area is still wadable, at low tide).

### *Functional Habitat Loss*

In addition to displacement of red knots from habitual disturbance (*e.g.*, due to the routine presence of people), aquaculture may also result in functional habitat loss from the physical and visual effects of gear. The physical effect is one of covering suitable intertidal foraging habitat. Based on all available information, we conclude red knots cannot or will not forage under cages, racks, floating gear, or any other gear types. Thus, although not irreversibly destroyed or modified, all intertidal areas covered by gear during the red knot stopover period are lost as foraging habitat. Further, we have no information suggesting that red knots will forage in the spaces or lanes between gear. Therefore, the entire intertidal footprint of an aquaculture farm present during the stopover season is lost as foraging habitat.

In addition, perhaps due to visual effects of the gear, we conclude red knots likely avoid foraging for some distance around the perimeter of a farm (a "precluded zone"), even when growers are not present. Burger *et al.* (2015) postulated that birds could perceive racks and other gear as blocking their exit flight paths (*e.g.*, if a predator approaches). If red knots avoid foraging in the vicinity of structural aquaculture operations, regardless of human activity, this will cause additional loss of foraging habitat throughout the stopover period, not just when gear is being tended (NJDFW 2016). Unfortunately, we have little information regarding the additional distance this effect may extend around the outside of a farm. We review relevant studies below.

Areas of estuarine habitat occupied by intertidal shellfish farms have the potential to displace birds from foraging sites. Bird species that avoid structured habitats may be susceptible to displacement effects. The evidence for such effects is equivocal and indicates that influences will be species- and situation-specific (Dumbauld *et al.* 2009; Forrest *et al.* 2009). Some bird species may be attracted to bivalve farms due to increased invertebrate biomass and/or richness (Dumbauld *et al.* 2009; Forrest *et al.* 2009). However, we do not believe this applies to red knots in the action area of this PBO due to the additional trophic link (*i.e.*, knots do not feed directly on the benthic or fouling invertebrates that may attract other bird species to a bivalve farm; instead knots in the action area feed on the eggs of horseshoe crabs, which, in turn, feed on benthic invertebrates). As discussed under Effects to Horseshoe Crabs, below, we do not anticipate any beneficial effects of aquaculture on horseshoe crabs that will produce measurable benefits to the red knot.

Kelly *et al.* (1996) measured abundances of wintering shorebirds on four control plots and two aquaculture plots from November 1989 to February 1994 in Tomales Bay, California. Growers used black plastic mesh bags 2 by 3 feet (61 by 91 cm) placed on the bottom and 1 to 2 feet (30 to 61 cm) above the bottom on 4 by 8-foot (1.22 by 2.44-m) rebar frames supported by PVC pipe legs, similar to gear in the action area of this PBO. The ends of rows of bags were marked with 3.3 to 8.2-foot-high (1 to 2.5-m-high) PVC stakes. The two most abundant shorebird species in the bay (western sandpiper [*Calidris mauri*] and dunlin [*Calidris alpina*]) significantly avoided aquaculture areas. Willets (*Catoptrophorus semipalmatus*) were attracted to aquaculture plots, while four other species showed no preference between control and aquaculture plots. These authors postulated that the different species responses could be due to differing predation risk and/or differing foraging strategies (*e.g.*, both western sandpipers and dunlin tend to forage by probing rather than via visual cues). Kelly *et al.* (1996) found no differences in bird species richness, but their results suggested a net decrease in total shorebird use in aquaculture areas. These authors controlled for the presence of roosting gulls that may have displaced shorebirds, but growers were present in aquaculture areas during 62 percent of their bird counts, suggesting that human activity might have influenced bird distribution (Kelly *et al.* 1996).

Gittings and O'Donoghue (2014) assessed bird usage at an aquaculture area in Dungarvan Harbour, Ireland. The assessment was based on a desktop review of existing information, combined with the results of a detailed study of waterbird distribution in the outer part of Dungarvan Harbour that was carried out as part of a wider study of the effects of intertidal oyster culture on the spatial distribution of waterbirds (the wider study was known as the "trestle study"). The only aquaculture in this area was suspended oyster cultivation using bags and racks (called trestles) in the intertidal zone, with gear and operations very similar to those in the action area of this PBO. The oyster trestles varied in height but were typically not more than 1.6 feet (0.5 m) in height, and their height above the sediment was often less as they sank into the sediment. The trestles were usually arranged in paired rows with a separation of around 13 feet (4 m) between rows and with wider (33 to 66-foot [10 to 20 m]) access lanes. The rows were usually orientated more or less perpendicular to the tideline. Oyster spat was supplied by hatcheries and placed in mesh bags on top of the trestles. Oyster husbandry activities took place during most low tides throughout most of the year. Workers usually accessed the trestles by driving tractors across the beach using three access routes. Tractors also frequently traveled between plots by driving across open areas of intertidal habitat. During the trestle study, 9 to 13 tractors were present on the beach on each count day, with a group of around 5 to 10 workers working along one to three adjacent rows of trestles (Gittings and O'Donoghue 2014).

Gittings and O'Donoghue (2014) found that another *Calidris canutus* subspecies fed in large numbers on the upper shore zone on flood/ebb tides when the tideline was above the oyster trestle area, but usually largely left around low tide when the tideline was within the oyster trestle area. It was unclear if these movement patterns were due to the birds' avoidance of intertidal oyster cultivation; alternatively birds may have moved away due to factors unrelated to the presence of oyster trestles, such as the exposure of suitable habitat elsewhere. The trestle study concluded that *C. canutus* had an exclusion response to oyster trestles (*i.e.*, oyster trestle blocks caused complete exclusion of *C. canutus* from the areas occupied by the trestle blocks). While there was only limited data for this species that could be included in the formal analyses, observations of the flock behavior of this species provided strong evidence of avoidance of the oyster trestle blocks. Therefore, the study concluded that predictions of the impact of oyster trestle blocks should assume complete exclusion of *C. canutus* from the affected area with a high degree of confidence. However, the long-term population trends of *C. canutus* at Dungarvan Harbour did not indicate any site-specific factors causing negative impacts to their populations. There was no evidence that current levels of disturbance from other human activities (*e.g.* bait digging, shellfish gathering, horseback riding, intertidal walking) in combination with intertidal oyster cultivation were causing negative impacts to the conservation condition of this subspecies at Dungarvan Harbour (Gittings and O'Donoghue 2014). These authors did not attempt to differentiate exclusion effects due the presence of workers conducting husbandry activities versus the presence of just the trestles themselves.

Connolly and Colwell (2005) conducted bird surveys at five longline oysterculture plots and five control plots in Humboldt Bay, California in May 1999 and June 2000. Similar to Delaware Bay, Humboldt Bay is an International site in the Western Hemisphere Shorebird Reserve Network. Unlike the action area of this PBO, intertidal portions of Humboldt Bay support aquatic vegetation (eelgrass), and have a recent history of on-bottom aquaculture. The method of off-bottom, structural aquaculture in this study by Connolly and Colwell (2005) is not currently in use in Delaware Bay, and consists of seeded shell grown on ropes at 6 to 12-inch (15 to 30-cm) intervals, suspended off the bottom by rows of plastic pipes. The longline plots consisted of oyster longlines suspended from plastic pipes inserted vertically into the substrate, with the lines spaced 2.3 to 2.9 feet (70 cm to 1.5 m) apart. A 6.6-foot (2-m) gap separated every 98 to 118 feet (30 to 36 m) of longline length, creating aisles perpendicular to the longline rows. Abundances of most species differed significantly between treatments, with seven of 13 shorebirds (Charadriiformes) and three of four wading birds (Ciconiiformes) more abundant on longline plots. By contrast, black-bellied plover (*Pluvialis squatarola*) were more abundant on control plots. Marbled godwit (*Limosa fedoa*), long-billed curlew (*Numenius americanus*) and dunlin showed mixed results depending on location. Great blue heron (*Ardea Herodias*) were more abundant only on one control plot. Bird community composition was similar on longline and control plots, although diversity was greater on longline plots. Varying species' responses to longline techniques may have been associated with interspecific differences in diet and foraging behavior, and the impacts of longlines and oyster-harvesting on prey distribution. Overall, longlines did not negatively affect the foraging behavior of most species, and birds did not appear to avoid longline areas compared with adjacent tidal flats. Rather, many species were more abundant and bird diversity was greater on longline plots. However, differential species use of study plots on Humboldt Bay implies that longline oyster culture altered mudflat habitats and prey populations, and the underlying causes for increased bird use may lead to impacts on other trophic levels and over a longer temporal scale (Connolly and Colwell 2005).

Hilgerloh *et al.* (2001) conducted a brief study of birds at an oyster farm in an Irish estuary in March 1999. Gear was a rack and bag system, with the racks (called trestles) about 16 inches (41 cm) tall and positioned at the low water line, comparable to the action area. Comparing the oyster farm with a reference area, Hilgerloh *et al.* (2001) found a similar composition of bird species. Oystercatchers (*Haematopus ostralegus*), curlews (*Numenius arquata*), and two gull species occurred in significantly lower numbers in the trestle area, while for redshank (*Tringa tetanus*) and dunlin the differences were not significant. The percentage of all birds feeding did not differ between the trestle and reference areas. Some bird species spent time beneath or on top of the racks (Hilgerloh *et al.* 2001).

Luckenbach (2007) found that aquaculture of clams (*Mercenaria mercenaria*) in the lower Chesapeake Bay occurs in close proximity to shorebird foraging areas. The current distribution of clam aquaculture in the very low intertidal zone minimizes the amount of direct overlap with shorebird foraging habitats, but if clam aquaculture expands farther into the intertidal zone, more shorebird impacts (*e.g.*, habitat alteration) may occur. However, these Chesapeake Bay intertidal zones are not considered the primary habitat for red knots (Cohen *et al.* 2009), and red knots were not among the shorebirds observed in this study (Luckenbach 2007).

In a 2013 study of experimental oyster racks at South Reeds Beach, Burger *et al.* (2015) found that presence or absence of racks was a significant variable in explaining the abundance of most shorebird species, but not red knots. When no people were present, there were no differences in the number of red knots as a function of racks being present or absent. This finding is especially noteworthy given that the experimental racks were considerably taller (24 inches [60 cm]) than racks commonly in use in the action area (8 to 14 inches [20 to 36 cm]). As discussed under Disturbance, above, if the adverse visual effect of the racks is from a blocked exit flight path, we might expect taller racks to exert a greater displacement influence (with or without tending) than shorter racks. Thus, we might expect shorter gear to have even less effect on knot distribution (when people are absent).

Even with tall racks, Burger *et al.* (2015) did not report red knots foraging under the racks. These authors reported semipalmated sandpipers feeding around the edges of the racks, but this paper does not indicate that red knots foraged between the racks. Thus, this paper is not inconsistent with our conclusion that the entire intertidal footprint of an aquaculture farm present during the stopover season is lost as foraging habitat. Indeed, the lead author confirms that no red knots approached the edges of the racks or went under them (J. Burger pers. comm. March 15, 2016). However, this study does suggest that the "precluded zone" (*i.e.*, the "threshold distance" around the perimeter of a farm in which red knots will not forage) is not large, because racks alone (when people were absent) did not preclude red knot habitat use at the scale of the 200-foot-long (60-m-long) survey segments (with and without racks) evaluated in this study (Burger *et al.* 2015). When present in the "with rack" segments, red knots feeding along the MHW line would have been as close as 82 feet (25 m) from the experimental racks. (In contrast, commercial gear under this PBO will be at least 300 feet seaward of the MHW line.) The size of the precluded zone was not specified in this paper, but is discussed further below.

The lack of a significant difference in the mean number of red knots between segments with and without racks (when no people were present) indicates that the racks themselves did not prevent shorebirds from feeding along the shore at high tide (Burger *et al.* 2015). Again, this is especially noteworthy due to the experimental design of the racks, which were located much closer to the MWH line (82 feet [25 m]) than will be allowed under this PBO (300 feet [91 m]). However, it is possible that aquaculture structures could exert more of a displacement effect during the mid-tide foraging periods, when birds feeding at the water's edge would be closer to the gear. Burger *et al.* (2015) concluded that the interaction of condition (racks/no racks) and people suggests knots avoided the racks with and without people. We note, however, that that the interaction of condition (racks/no racks) and people could be driven by the strong effect of people. Nonetheless, these authors reported red knots were rarely noted near the racks, even when other species were near racks, and found this warrants further investigation (Burger *et al.* 2015).

Maslo *et al.* (2016) likewise found a much greater effect to red knots from human activity (*e.g.*, oyster tending) than from racks alone. These authors collected shorebird census data and behavioral observations from May 7 to June 4, 2015 between Kimbles Beach and Green Creek. In a preliminary analysis following the first year of data collection, Maslo *et al.* (2016) did not detect any clear trends regarding the influence of untended racks on red knot abundance. Racks appeared to be a poor predictor of red knot abundance, occurring in models with poor fit relative to the top models. This result appears to suggest that red knots are not affected by the presence of untended racks, but additional data are needed. For example, given that red knot abundance was greater at high tide, it may be that birds congregating at the high tide line were far enough away from untended structures to be affected (Maslo *et al.* 2016) or that the structures were submerged. Tending of gear is performed during low tide so human disturbance is greatest during the same time period when gear alone would potentially have an impact. With only one year of data to date, this study may not currently provide sufficient analysis of gear impacts to be useful in the context of managing such impacts. However, the Rutgers study is funded to continue in 2016 and 2017, so more information may become available in the future.

Quantifying a threshold distance at which red knots avoid racks remains a challenge (Maslo *et al.* 2016). However, since the preliminary assessment by Maslo *et al.* (2016) found no influence of racks at the scale of their 100-foot-long (30-m-long) survey segments, we tentatively conclude that the threshold distance (a "precluded zone" around the perimeter of farm) is less than 100 feet (30 m). We recognize this is confounded by the tidal cycle as discussed above, based on preliminary information, and that the actual distance is likely influenced by various factors such as tide stage, gear type, and gear location relative to the MHW line. However, we consider this best available information. Of course, even if the "precluded zone" around a farm does prove, upon further study, to be relatively small, the footprint of the farm itself (gear plus spaces and lanes) is lost as red knot foraging habitat.

Because subtidal aquaculture is defined as having no gear visible (*i.e.*, all gear submerged) during MLW, and because red knots rarely wade in water more than about 1 inch (2 to 3 cm) deep (Harrington 2001), we do not expect any functional loss of red knot habitat from this activity. In other words, water depths at subtidal farms during MLW will be too deep for red knots to forage, thus no foraging habitat will be covered by this gear.

***Habitat Degradation***

In Delaware Bay, the wrack line is an important red knot foraging habitat because it accumulates surface horseshoe crab eggs (Karpanty *et al.* 2011; Nordstrom *et al.* 2006). Red knots could be adversely affected if driving or walking causes the wrack line to become crushed or dispersed. In addition, vehicle ruts could make areas of beach less suitable for foraging or roosting.

Except as specified in CMs 20 and 21, there will be no aquaculture gear or activity in the Northern Segment during the red knot stopover period. Thus, red knots in the Northern Segment will not be affected by wrack alteration or rutting outside of Leases A-19 and A-28, and will not be affected at all after 2018 (if not sooner). During the three-year transitional period on Leases A-19 and A-28 (CMs 20 and 21), no driving will occur between May 1 and August 31 (Appendices C and D), and therefore no rutting will occur while red knots are present. On Lease A-19, the approved access plan does not involve crossing the Protected Areas on foot (access is by boat). As we expect all wrack material will be entirely within Protected Areas (which extend 300 feet (91 m) both seaward and landward from the MHW line), there will be no impacts to wrack on Lease A-19. On Lease A-28, crossing of the Protected Area (and thus the wrack line) will occur on foot a maximum of four times per week (two crossings per day, two days per week). Based on this low level of activity, we expect negligible impacts to wrack on Lease A-28.

In the Southern Segment, effects from wrack alteration and rutting are minimized by the following CMs.

- CM 9 requires a Vehicle Use Plan to be approved for each farm during the Tier 2 process. The Vehicle Use Plans call for growers to minimize the amount of driving on the beach parallel to the shoreline; when driving parallel to the shoreline cannot be avoided, growers are to drive as far seaward of the high water line as practical; and avoid driving through concentrations of crabs and in the wrack line.

- CM 13 prohibits the installation of new gear in the Southern Segment from April 15 to June 7, thereby likely reducing the amount of beach driving during the red knot's stopover season. We expect any rutting or wrack alteration caused by new gear installation prior to April 15 will be restored by normal tidal processes by early May when knots return.

- CM 15 requires an Intertidal Access Plan to be approved for each farm during the Tier 2 process. Intertidal Access Plans call for growers to ensure all personnel enter and exit the growing area together and minimize the time spent crossing Protected Areas; designate and consistently use beach entry and exit points, and beach walking/driving routes; and no driving parallel to the shoreline within any Protected Area. Based on this Measure, we expect minimal rutting within the Protected Areas. Because we expect the wrack line will be entirely within Protected Areas, we expect minimal impacts to the wrack line. Finally, we expect any rutting seaward of the Protected Areas will be eliminated during the next rising tide, and will be limited to the lanes between gear that we do not expect knots to use anyway.

Based on these CMs, we conclude that habitat degradation from rutting and wrack alternation will have a negligible additional adverse effect to red knots beyond those already described above from disturbance and functional habitat loss.

***Consequences***

<u>*Habitat Loss*</u>

Based on the information presented above, we conclude the combined physical, visual, and disturbance effects will result in functional habitat loss covering the entire footprint of structural aquaculture present during the red knot's stopover period, and an additional "precluded zone" around the farms. We have little basis on which to assess how large the "precluded zone" likely extends. We also have little basis on which to approximate the likely configuration of aquaculture. Configuration is important because the more highly clustered and concentrated the farms, the smaller the extent of the precluded zone due to the smaller total perimeter. Given this lack of information, we evaluate a high-end estimate for habitat loss that covers the entire intertidal zone of each farm outside of Protected Areas.

The total area of intertidal habitat in the action area is about 800 acres, about half of which is within Protected Areas. The Northern Segment has about 200 total intertidal acres, of which about 160 acres (80 percent) are Protected Areas. The Southern Segment has about 600 total intertidal acres, of which about 230 acres (about 38 percent) are Protected Areas.

Based on plans submitted to the Corps, authorized operations on Leases A-19 and A-28, though totaling less than 0.6 acre (2,428 square m) of gear coverage, are spread widely across the allowable growing areas of 7.3 acres (3.0 ha) on each of those two leases. Thus, we err on the high end and estimate habitat loss in the Northern Segment over the entire allowable growing areas of 14.6 acres (5.9 ha), which will be phased out (during the stopover period) after no more than three years. So from 2016 through 2018, a maximum of 7.3 percent of the total intertidal area (14.6 out of 200 acres [5.9 out of 81 ha]) may be lost for red knot foraging during mid- and low tides. Because no aquaculture will occur in the Protected Areas, we do not expect any loss of foraging habitat around high tide (*e.g.*, during high tide all gear will be at least 300 feet (91 m) away from the water's edge, and largely submerged; no land-based tending activity will take place). This conclusion is supported by Burger *et al.* (2015) who found the racks themselves, when people were absent, did not prevent shorebirds from feeding along the shore at high tide. For similar reasons, we do not expect any impacts to high-tide roosting areas. After 2018, there will be no further intertidal aquaculture in the Northern Segment during the red knot stopover period.

In the Southern Segment, current operations total 10.8 acres (4.4 ha) (includes spaces and lanes) located across four growing areas (*i.e.*, a riparian grant abutting Lease A-173, Lease A-29, the riparian grant at the Cape Shore Lab, and ADZ-4; see Current and Future Extent of Aquaculture). Because we lack electronic mapping of the two riparian grants, we are unable to calculate the total allowable intertidal growing area (outside of Protected Areas) on these four parcels. However, we can consider the full build-out scenario. We find the full Southern Segment build-out scenario unlikely, namely an increase from the current aquaculture footprint (including lanes) of 10.8 acres (4.4 ha) to the cap of 150 acres (61 ha) (a nearly 14-fold increase) in the next 10 years. However, if full build-out does occur, the most likely distribution would be across the 286 intertidal acres (116 ha) (outside Protected Areas) from Lease A-173 to Norburys Landing. Thus, a very high estimate of habitat loss at build-out would be about 48 percent of the intertidal area of the Southern Segment (286 out of 600 acres (116 out of 243 ha). As in the

Northern Segment, this high-end estimate (48 percent at full build-out) represents habitat lost to red knot foraging during mid- and low tides. For the reasons discussed above, we do not expect any loss of foraging habitat around high tide or any impacts to high-tide roosting areas.

As mentioned above, we feel the habitat loss estimates given above are rather high, but detailed information to make more accurate estimates (*e.g.*, actual farm configurations) is not available. When estimating incidental take from habitat loss during the Tier 2 process, we will take site-specific gear and farm configurations and tending practices into consideration, as well as distance to neighboring farms. As discussed above, for example, we tentatively conclude that disturbance effects (mostly in the form of displacement) extend at least 300 feet (91 m) from aquaculture activity when humans are present, and that the visual "precluded zone" extends less than 100 feet (30 m) from gear when no people are present. Whenever possible during the Tier 2 process, we will apply these or similar "precluded zone" estimates (based on best available science at the time) to the actual perimeter of the proposed farm footprint, rather than assuming loss of the entire intertidal zone outside of Protected Areas.

To put the extent of habitat loss in context, we looked at baywide habitat availability in two ways. First, we considered the survey segment acreages given in Table 8 as a proxy measure for habitat availability, recognizing that the survey segments were not delineated for this purpose. The Southern Segment represents about 6.1 percent of the total survey segment area in New Jersey, and about 3.3 percent of the total survey segment area baywide. These percentages represent an over estimate of possible habitat loss because not all of the Southern Segment will be authorized for intertidal aquaculture even at full build-out, as discussed above. Because the survey segments were not delineated to capture the wide flats in the Southern Segment, we also looked at total intertidal area. We used ESRI ArcMap at a scale of 1:10,000 to crudely estimate the intertidal area (between the MHW and MLLW lines) across all Delaware Bay survey segments in New Jersey at about 1,800 acres (728 ha). Therefore, a 150-acre (61-ha) aquaculture footprint (including lanes) would represent about 8 percent of total intertidal habitat in New Jersey. This 8 percent does not account for the "precluded zone" around the perimeter of farms, but detailed information (*e.g.*, farm configurations) to estimate the size of that zone is not available. Therefore we also considered the entire 286-acre (116-ha) intertidal area that was discussed above, and roughly estimate this area would represent about 16 percent of total intertidal habitat in New Jersey. We stress that 16 percent is clearly an over-estimate, and that these percentages (8 and 16 percent) do not include the Delaware side of the bay. We did not consider the Northern Segment in these analyses because we expect it will be gear-free during the red knot stopover season (CMs 12, 20, and 21) well before full build-out might be expected to occur in the Southern Segment.

The second set of calculations (8 to 16 percent of total intertidal area in New Jersey) is relevant because we have observational data that red knots do use intertidal areas well seaward of the Protected Areas (J. Burger pers. comm. February 29, 2016). However, we conclude that the wide intertidal flats in the Southern Segment (where structural aquaculture will be located) are not a primary foraging habitat for red knots in Delaware Bay, based on: (1) our conclusion under Intertidal Habitat Use, above, that the highest-value foraging habitats ("egg concentration areas") are all in Protected Areas (*i.e.*, along the MHW line, in the wrack line, and at creek mouths); (2) the data presented in Tables 8 and 9 showing that red knot numbers Southern Segment are

<u>relatively</u> lower (*i.e.*, compared to the Northern Segment); and (3) the report by Botton *et al.* (1994) very few shorebirds were observed on the flats during repeated surveys of the stretch of beach between Norburys Landing and the Cape Shore Lab, pre-dating both commercial-scale structural aquaculture and the peak of the horseshoe crab harvest. We conclude that: (1) maximum habitat loss is somewhat more than 8 percent, but well under 16 percent, of total intertidal habitat in New Jersey; (2) additional intertidal habitat is available on the Delaware side of the bay; and (3) the area subject to this habitat loss is of secondary importance to red knots in Delaware Bay.

Because subtidal aquaculture is defined as having no gear exposed during low tide, and because red knots rarely wade in water more than about 1 inch (2 to 3 cm) deep (Harrington 2001), there will be no loss of red knot habitat due to subtidal aquaculture.

*<u>Effects to Individuals</u>*

Based on the habitat availability analysis presented above, we expect birds displaced by disturbance and/or the functional habitat loss estimated above will forage in other portions of Delaware Bay rather than die or avoid Delaware Bay altogether. To rise to incidental take, habitat loss/modification (harm) and disturbance (harassment) must result in "injury" to the individual birds by significantly impairing or disrupting normal behavioral patterns such as breeding, feeding, or sheltering. We expect red knots displaced by disturbance and/or functional habitat loss may be impacted by lower food availability and/or higher competition upon relocating to other portions of the bay. We also expect that some of the red knots exposed to aquaculture (*i.e.*, those that do not avoid the farms entirely) will—at least when humans are present—exhibit behavioral responses that further impact their energy budgets (*e.g.*, increased vigilance, increased running or flying, reduced food intake rates); at a minimum these birds will expend energy to relocate elsewhere in the bay. We expect these adverse effects to impact the birds' rate of weight gain and therefore constitute an injury. Thus, we expect the combined effects of displacement, functional habitat loss, and/or behavioral changes will result in annual incidental take of all individual red knots exposed to aquaculture (*e.g.*, through a combination of harm and harassment).

However, not all such injuries are likely to result in reduced rates of survival or reproduction. As discussed above, birds can tolerate more disturbance before their fitness levels are reduced when feeding conditions are favorable (*e.g.*, abundant prey, mild weather) (Niles *et al.* 2008; Goss-Custard *et al.* 2006). Lower-end effects to a bird's energy budget may constitute incidental take without impacting survival (*e.g.*, if favorable food and weather conditions are such that the bird can still achieve the threshold departure weight of 6.3 oz [180 g]). In most years, we do not expect the adverse effects to the energy budget to impact the survival or reproduction of the red knots exposed to aquaculture (*i.e.*, we expect the incidental take will be non-lethal). However, in years of adverse weather conditions (*e.g.*, delayed migration to Delaware Bay, delayed horseshoe crab spawning, storms during the stopover window), these combined effects of harm and harassment may impact survival or reproductive rates of knots exposed to aquaculture.

We project that 3 years in 10, adverse weather conditions will be such that the combined adverse effects discussed above may impact survival and/or reproduction rates of those red knots exposed to aquaculture, most likely as a result of the exposed birds being unable to achieve the target weight of 6.3 oz (180 g). This projection is based on the number of documented years (three) in which weather conditions (either locally or elsewhere in the species range) have clearly impacted red knot weight gain during the Delaware Bay stopover. This is based on our review of available information dating back to the 1980s, but with most of the relevant papers/reports published since the mid-1990s (USFWS 2014). The three documented instances are a La Niña that caused birds to arrive late in 1999 (Robinson *et al.* 2003), cold water temperatures that caused late crab spawning in 2003 (Atkinson *et al.* 2007), and a nor'easter that reduced May crab spawning activity (via altered habitats and low water temperatures) in 2008 (Dey *et al.* 2011a).

Atkinson *et al.* (2007) stated, "in 2000, 2003 and 2005, at least, fuelling did not proceed as normal and was caused by poor foraging and weather conditions within the bay," suggesting that weather may have also been poor in 2000 and 2005. However Atkinson *et al.* (2007) did not specify that adverse weather conditions occurred in 2000 and 2005, and these authors may have been lumping poor foraging conditions (*i.e.*, reduced food availability due to the commercial horseshoe crab harvest) that occurred in all three of these years with poor weather that perhaps occurred only in 2003. So we cross-referenced these years with information on the percent of red knots achieving weights of 6.3 oz (180 g) by the end of May from 1997 to 2015 (NJDFW 2016). These weight gain data show considerable variability between years, but generally a decline through 2006 followed by an increase since 2006. In this data set, 2003 stands out as by far the lowest (0 percent) of red knots achieving the target weight. No other years stand out from the overall pattern of decline followed by reversal of the decline. We find no confirmation of poor weather in 2000 and 2005 in Atkinson *et al.* (2007), other references, or in the weight gain data (NJDFW 2016), and therefore we do not conclude that 2000 and 2005 were "bad weather" years. Thus, we are aware of three documented years (1999, 2003, and 2008) since the mid-1990s (nearly 20 years) in which adverse weather conditions unequivocally impacted red knot weight gain in Delaware Bay. Thus, a projection of three such events occurring over the 10-year life of this PBO is precautionary.

Our projection that all red knots exposed to aquaculture either will ("good weather years") or will not ("bad weather years") be able to achieve 6.3 oz (180 g) is a necessary simplification. In other words, we assume that, in "good weather" years, knots exposed to aquaculture will still be able to reach the target weight despite having to relocate to other parts of the bay—that effects to the energy budget from aquaculture will not prevent exposed birds from reaching 6.3 oz (180 g). The more probable scenario is that in good weather years a much higher percentage of birds exposed to aquaculture will achieve 6.3 oz (180 g) compared to bad weather years, but we are not able to adjust for this. This projection also assumes that, in bad weather years, exposure to aquaculture will be the key causative factor preventing the aquaculture-exposed birds to achieve the 6.3-oz (180-g) threshold (in other words, if these birds were not exposed to aquaculture they would be able to compensate for the poor weather and still reach the target weight).

Further, our projection that in most years (7 of 10) the expected severity of red knot harm and/or harassment will not impact the exposed birds' survival or reproductive rates is based on current (near optimal) conditions in the action area including high-quality habitat, adequate food availability, and low human disturbance, as described in the Environmental Baseline. Birds can tolerate more disturbance before their fitness levels are reduced when feeding conditions are favorable (*e.g.*, abundant prey, mild weather) (Niles *et al.* 2008; Goss-Custard *et al.* 2006). To some extent, shorebirds may be able to compensate for human-induced impacts to their energy budgets by extending their food intake, but only to a degree, and such compensation is dependent upon the availability of adequate food resources (Rogers *et al.* 2006). If the near-optimal baseline conditions (*e.g.*, habitat quality, food availability, low levels of non-aquaculture disturbance) degrade over the next 10 years, birds may not be able to compensate for harm and/or harassment from aquaculture and still achieve target weights even in favorable weather years. Our projection could also be invalidated by a higher-than-expected frequency of adverse weather years. Each of these factors will be reassessed annually as part of the adaptive management process (CM 6).

*Exposure and Incidental Take*

As discussed under Effects to Individuals, above, we conclude the combined effects of displacement (from disturbance), functional habitat loss (from gear), and/or behavioral changes (from disturbance) will result in annual incidental take of those individual red knots exposed to aquaculture through a combination of harm and harassment. Therefore, we must attempt to estimate how many red knots will be exposed to aquaculture in a typical year. An estimated number of birds exposed to adverse effects from aquaculture is necessary to assess the effects of the action on the baywide and rangewide population. Further, a detailed analysis of exposure across the action area will also be necessary in this PBO, and in subsequent Tier 2 consultations, to estimate levels of incidental take at the scale of individual farms.

As shown in Table 9, the action area supported more than 21 percent of all red knots counted in New Jersey since 1986, and more than 27 percent since 2009. On a baywide scale, the action area supported an estimated 11 percent of the birds counted in Delaware Bay since 1986, and about 20 percent since 2009. As discussed under Environmental Baseline, above, we estimate the action area typically supports between 5 and 16 percent of all rufa red knots during the stopover period. These birds are not evenly distributed across the action area. The Northern Segment has supported 2.5 to 4 times more red knots than the Southern Segment since 1986. The Southern Segment has consistently supported between 5 of 6 percent of all knots counted in New Jersey, while percentages in the Northern Segment have varied from less than 13 to nearly 22 percent of the State-wide total.

Although the above percentages of State-wide, baywide, and rangewide populations provide useful context, they do not provide useful estimates of how many actual birds may be exposed to aquaculture across the action area. For this purpose, we extrapolated using several sources of available information, as detailed below. We did not use the “total count” methodology (as shown in Tables 8 and 9) for this purpose because we have no way of relating those total counts (which vary with survey effort) to the localized stopover population (*i.e.*, the total number of birds likely to use a particular stretch of beach each year). We instead used peak counts, due to the availability of conversion factors that allow us to produce at least a rough estimate of numbers of knots exposed to aquaculture across the action area. We note, however, that to an even lesser degree than total counts, peak counts may not be representative of the actual geographic distribution of red knot usage across survey segments because peak counts are just a 1-day snapshot of bird distribution. Nonetheless, we consider this best available data for the purpose of estimating exposure.

Because the only comprehensive data set of red knot abundance is linked to the ENSP's survey segments, we first estimated maximum proportion of each survey segment that could be occupied by aquaculture during the red knot's stopover season (Table 10).

**Table 10. Percent of the action area (by shoreline length) available for aquaculture during the red knot stopover period, by survey segment**

| Survey Segment | Approximate Length (feet) | Authorized Aquaculture Areas | Approximate Length of Authorized Aquaculture Areas (Outside Protected Areas) (feet) | Percent of Length Potentially Exposed to Aquaculture | Notes |
|---|---|---|---|---|---|
| 12 | 2,400 | none | 0 | 0 | |
| 11 | 2,700 | none | 0 | 0 | |
| 10 | 3,100 | none | 0 | 0 | |
| 9 | 3,700 | A-19 | 990 | 27 | |
| 8 | 5,400 | A-19, A-28 | 1,520 | 28 | 420 feet on A-19; 1,100 feet on A-28 |
| Northern Subtotal | 17,300 | | 2,510 | 15 | |
| 7 | 3,600 | A-173, A-27, A-29, riparian grants, Cape Shore Lab | 3,600 | 100 | |
| 6 | 9,200 | riparian grant, ADZ-4, ADZ expansion areas | 6,900 | 75 | 3,700 from northern segment end to Green Creek; 3,200 feet from Green Creek to Norburys Landing. Not counting Protected Areas (shoals) at Green Creek. |
| 5 | 2,700 | ADZ expansion areas | 2,300 | 85 | |
| 4 | 2,700 | ADZ expansion areas | 740 | 27 | |
| Southern Subtotal | 18,200 | | 13,540 | 74 | |
| **Action Area Total** | **35,500** | | **16,050** | **45** | |

Next, we compiled annual peak counts from ENSP's annual survey data (Table 11), considering historic use (1986 to 2008), but emphasizing recent use (2009 to 2014) for reasons discussed above (sections on Subdivision of the Action Area and Horseshoe Crab Eggs). To calculate the average annual peak count shown for each time period, we extracted the single highest count for each segment for each year. Then, for each segment, we averaged these one-year high counts for each time period. In addition to the average annual peak count for the most recent period, we also considered the single highest count to ensure we err on the high side (*i.e.*, take a precautionary approach to our jeopardy analysis). It should be noted that this field represents the single highest 1-day count recorded over this six-year period.

**Table 11. Red knot peak counts in the action area by survey segment, 1986 to 2014**

| Survey Segment | Average Annual Peak Count 1986 to 2001 | Average Annual Peak Count 2002 to 2008 | Average Annual Peak Count 2009 to 2014 | Highest Annual Peak Count 2009 to 2014 |
|---|---|---|---|---|
| 12 | 854 | 519 | 450 | 1,000 |
| 11 | 1,619 | 297 | 419 | 1,550 |
| 10 | 939 | 377 | 1,033 | 2,700 |
| 9 | 1,032 | 444 | 637 | 1,100 |
| 8 | 475 | 337 | 837 | 2,000 |
| 7 | 68 | 170 | 422 | 1,330 |
| 6 | 709 | 509 | 194 | 425 |
| 5 | 783 | 163 | 148 | 600 |
| 4 | 464 | 49 | 73 | 300 |

Next, we used the data from Tables 10 and 11 along with conversion factors to roughly estimate the numbers of red knots annually exposed to aquaculture by segment. These calculations are shown in Table 12. The minimum and maximum annual peak counts shown in Table 12 are taken from Table 11. The conversion factors are based on the ratios of estimated total baywide stopover population to the baywide peak count data (shown in Table 5). The minimum stopover population estimates were derived by multiplying the minimum peak counts by a low-end conversion factor of 1.82 that utilizes population modeling data from 2012 and 2013 only (ASMFC 2013). The maximum stopover population estimates were derived by multiplying the maximum peak counts by a higher-end conversion factor of 2.25, which includes all available population modeling data points from 2011 to 2015 as presented in Lyons (2015). Finally, both the minimum and maximum stopover population estimates were multiplied by the maximum proportion of shoreline length potentially occupied by aquaculture in each segment (taken from Table 10).

We note that neither the peak count data nor the conversion factors were intended for this purpose, but we consider these data sources best available information for assessing exposure. In addition, this exercise is a necessary oversimplification and requires the following assumptions, some of which are associated with high uncertainty. First, we are not able to account for probable differences in the distribution of red knots within survey segments. Although birds likely concentrate in the Protected Areas (especially at creek mouths), we must assume ENSP's red knot peak counts are evenly distributed along each survey segment. Second, we have no means to adjust for patterns of red knot habitat use across the intertidal zone (as discussed under Intertidal Habitat Use, above); thus, we have estimated exposure on a linear basis (Tables 10 to 12). Third, we must assume that the distributions reflected in the peak count data are sufficiently representative of actual levels of red knot use, which, as discussed above, may not be the case because peak counts are just a 1-day snapshot of bird distribution. Fourth, we cannot account for the known movement of birds among survey segments. Thus, we must assume that the estimated total number of birds in each survey segment (stopover populations, Table 12) represent the same birds throughout the stopover period, and that no other birds move in or out of that segment (*i.e.*, assume that this number of birds is exposed to aquaculture during the entire season, but that these are the only birds exposed to aquaculture.) Fifth, we cannot adjust for within-year large-scale, baywide variability in red knot distribution in response to weather, predators, etc. That is, we cannot account for stochastic factors that may result in temporary, localized exposure to aquaculture far greater or less than estimated below. Finally, we must assume that the conversion factors developed at a baywide scale (and for a different purpose) can be applied to individual survey segments, and can be applied to peak counts from 1986 to 2010 that pre-date the population modeling (Lyons 2015) underpinning those conversion factors. If, over the life of this PBO, new/improved information and/or methodologies become available for estimating the level of red knot exposure to aquaculture, we will evaluate and possibly adopt them as part of the adaptive management process (CM 6).

**Table 12. Estimated maximum and minimum numbers of red knots exposed to aquaculture, by action area survey segment**

| Survey Segment | Minimum Annual Peak Count | Maximum Annual Peak Count | Minimum Stopover Population (Minimum Annual Peak Count * 1.82) | Maximum Stopover Population (Maximum Annual Peak Count * 2.25) | Proportion of Length Potentially Exposed to Aquaculture | Minimum Estimated Number of Birds Exposed to Aquaculture per Year | Maximum Estimated Number of Birds Exposed to Aquaculture per Year |
|---|---|---|---|---|---|---|---|
| 12 | 450 | 1,000 | 819 | 2,250 | 0.00 | 0 | 0 |
| 11 | 297 | 1,619 | 541 | 3,642 | 0.00 | 0 | 0 |
| 10 | 377 | 2,700 | 686 | 6,075 | 0.00 | 0 | 0 |
| 9 | 444 | 1,100 | 807 | 2,475 | 0.27 | 218 | 668 |
| 8 | 337 | 2,000 | 614 | 4,500 | 0.28 | 172 | 1,260 |
| 7 | 68 | 1,330 | 125 | 2,993 | 1.00 | 125 | 2,993 |
| 6 | 194 | 709 | 353 | 1,595 | 0.75 | 265 | 1,197 |
| 5 | 148 | 783 | 270 | 1,761 | 0.85 | 229 | 1,497 |
| 4 | 49 | 464 | 88 | 1,045 | 0.27 | 24 | 282 |
| **Total** | | | | | | **1,033** | **7,897** |

We do not expect the total of roughly 1,000 to 7,900 red knots shown in Table 12 to be exposed to aquaculture in any given year. For example, we expect that the ADZ expansion area between Green Creek and Norburys Landing (approximately the southern half of survey segment 6) will not be operational before the sunset date of oyster farms adjacent to survey segments 8 and 9 (considering that NJDEP intends to first pursue the infill and offshore areas). Further, based on the acreage cap established in CM 12, it is not possible for ADZ expansion to occupy the entire area from Green Creek to Fishing Creek; neither is that the intention of the NJDEP. Thus we anticipate that ADZ expansion will occur either between Green Creek and Norburys Landing or between Norburys Landing and Fishing Creek, but not both. In all scenarios, we assume full occupancy of aquaculture outside of Protected Areas from Lease A-173 to Green Creek, including the ADZ infill area. This assumption also includes aquaculture on the riparian grant south of the Cape Shore Lab, which is unlikely. Finally, we assume that all red knots exposed to aquaculture will experience some degree of non-lethal take, in the form of harm and/or harassment (see Effects to Individuals, above). With these assumptions, our final estimates of maximum annual incidental take (as a result of exposure to aquaculture) is shown in Table 13.

As shown in Table 13, projected annual levels of incidental take decrease after the Northern Segment sunset date. However, the decrease is more substantial if ADZ expansion occurs north instead of south of Norburys Landing. As discussed above, ADZ expansion south of Norburys Landing is not preferred. In addition to a higher expected level of incidental take due to higher levels of red knot use in survey segments 4 and 5 (relative to the southern half of segment 6; Tables 12 and 13), ADZ expansion south of Norburys Landing may further increase exposure of red knots to aquaculture (and therefore incidental take) because aquaculture would be dispersed over a larger area, resulting in greater total habitat loss (due to the perimeter-based "preclusion zone") and likely greater overall levels of disturbance. Proposals for ADZ expansion will be evaluated during the Tier 2 process, including site-specific estimates of incidental take.

**Table 13. Maximum estimated annual non-lethal incidental take of red knots, by action area survey segment**

| | 2016 to 2018 | | 2019 to 2025 - No ADZ south of Norburys | | 2019 to 2025 - ADZ south of Norburys | |
|---|---|---|---|---|---|---|
| Survey Segment | Minimum Estimate Incidental Take (# of Knots / Year) | Maximum Estimated Incidental Take (# of Knots/Year) | Minimum Estimate Incidental Take (# of Knots / Year) | Maximum Estimated Incidental Take (# of Knots/Year) | Minimum Estimate Incidental Take (# of Knots / Year) | Maximum Estimated Incidental Take (# of Knots/Year) |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 218 | 668 | 0 | 0 | 0 | 0 |
| 8 | 172 | 1,260 | 0 | 0 | 0 | 0 |
| 7 | 125 | 2,993 | 125 | 2,993 | 125 | 2,993 |
| 6 | 133 | 599 | 265 | 1,197 | 133 | 599 |
| 5 | 0 | 0 | 0 | 0 | 229 | 1,497 |
| 4 | 0 | 0 | 0 | 0 | 24 | 282 |
| **Totals** | **647** | **5,520** | **390** | **4,189** | **511** | **5,370** |

Notwithstanding some large-scale assumptions about the timing and location of aquaculture, specified above, we cannot fully anticipate the actual sequencing or final extent of aquaculture build-out across the action area. Thus, except for existing authorizations on Leases A-19 and A-28, we defer our estimates of incidental take at the scale of the individual aquaculture farm until the Tier 2 process (see Incidental Take Statement, below). The above estimates are only for the purpose of evaluating the proposed action for the "jeopardy" analysis. The Service's policy is to err in favor of the species when facing uncertainties in our analyses under Section 7 of the ESA. We note the above estimates err on the high end, because: (a) we included the single highest peak counts from 2009 to 2014 (Table 11); (b) these estimates do not account for the likely concentration of red knots within the Protected Areas; (c) most farms are unlikely to occupy the entire length of allowable (outside of Protected Areas) intertidal growing area (Table 10); and (d) we assume all red knots exposed to aquaculture will experience harm and/or harassment (*i.e.*, that the adverse effects experienced by all exposed birds will rise to the level of incidental take by impacting rates of weight gain).

*Effects to Populations*

As discussed under Effects to Individuals, we expect that incidental take will be non-lethal in most years (*i.e.*, we expect birds exposed to the combined effects of displacement [from disturbance], functional habitat loss [from gear], and/or behavioral changes [from disturbance] will forage in other portions of Delaware Bay—and will thereby be impacted by higher energy expenditures, lower food availability and/or higher competition—but will still be able to achieve the threshold weight of 6.3 oz [180 g]). However, we also project that, 3 years in 10, adverse weather conditions will be such that the combined effects of disturbance and habitat loss from aquaculture will impact survival and/or reproduction rates of exposed red knots because in such years conditions (mainly of food availability) will not be sufficient for the birds to compensate for the effects of aquaculture.

In adverse weather years, we do not expect all red knots exposed to aquaculture (*i.e.*, subject to incidental take) to die, but expect they will exhibit lower survival and/or reproductive rates during the next breeding season following the disturbance. The most likely mechanism for this to occur is if these birds do not achieve the target weight of 6.3 oz (180 g), and the best available estimates of how departure weight from Delaware Bay affects survival rates comes from McGowan *et al.* (2011a). Based on data from 1997 to 2008, these authors confirmed earlier work by Baker *et al.* (2004) that heavy birds (at least 6.3 oz [180 grams]) had a higher average survival probability than light birds, but the difference was small (0.918 versus 0.915). However, the average survival rate (1997 to 2008) can mask differences among years. The survival of light birds was lower than heavy birds in 6 of the 11 years analyzed. For example, the 1998 to 1999 survival rate estimate was 0.851 for heavy birds and only 0.832 for light birds (McGowan *et al.* 2011a). If we apply these survival differences between heavy and light birds, we get a rough 10-year mortality range of 3 red knots (1997 to 2008 survival difference of 0.003 times 390 exposed knots per year times three events) to 315 red knots (1998 to 1999 survival difference of 0.019 times 5,520 exposed knots per year times three events). This estimated mortality range (3 to 315 knots over the next 10 years) errs on the high side because it assumes all birds exposed to aquaculture will fail to achieve the target weight of 6.3 oz (180 g) in adverse weather years, and thus experience these lower survival rates (or possibly reduced reproductive success) over the following year.

We do not expect the direct effects of aquaculture to produce a measurable impact on the red knot population in Delaware Bay based on: (a) our projected levels of non-lethal incidental take (about 400 to 5,500 birds per year, Table 13) from harm and harassment; (b) our projection that reduced survival and/or reproduction of exposed birds will occur three times over the life of this PBO; (c) our projected 10-year total mortality of 3 to 315 red knots resulting from reduced survival rates in three “bad weather” years; and (d) the low end of estimated baywide annual stopover population size (about 43,000, Table 5). This conclusion may be reconsidered if baywide populations decline, and our conclusion is tightly linked to the framework of CMs, including, but not limited to the following.

- By eliminating the possibility of aquaculture expansion in the Northern Segment during the stopover period, CM 12 substantially limits exposure of red knots to adverse effects. The Northern Segment has supported 2.5 to 4 times more red knots than the Southern Segment since 1986 (Tables 9 and 12).

- CM 12 further limits exposure by capping the footprint of aquaculture in the Southern Segment, while allowing for industry growth. The NJDEP’s priorities for clustering aquaculture, and for promoting subtidal methods, are also key in limiting the extent of habitat loss and disturbance.

- By establishing Protected Areas, CM 10 ensures that the highest-value red knot habitats (*i.e.*, egg concentration areas) will be free of gear during the stopover period. CM 15 ensures that these high-value feeding areas will also be free of human activity during the important mid- and high-tide foraging periods.

- CM 15 also seeks to limit disturbance to those red knots that may forage near aquaculture farms around the lower tides.

- CMs 9 and 10 are expected to prevent all disturbance to red knots from subtidal aquaculture in the action area.

**Effects to Horseshoe Crabs (Indirect Effects)**

Indirect effects are defined as those effects that are caused by, or will result from, the proposed action and are later in time, but are still reasonably certain to occur (50 CFR 402.02). The only indirect effects to red knots from structural aquaculture are through potential effects, both beneficial and adverse, on horseshoe crabs. Effects to horseshoe crabs can indirectly affect red knots if they alter the availability of red knot food resources (crab eggs) at either the localized or baywide scale.

In evaluating the likely effects of structural aquaculture on horseshoe crabs, we must first consider the geographic location and extent that may be occupied by aquaculture over the life of this PBO. Because no aquaculture gear and minimal driving will occur in the Protected Areas during the red knot stopover period, we do not expect any direct preclusion, suppression, or interference with horseshoe crab mating or nesting activity, which is concentrated along the MHW line (Brockman in Shuster *et al*. 2003). Crabs can and do encounter gear farther out in the intertidal zone, and may encounter gear in the Protected Area after June 7; see Current and Future Extent of Aquaculture, above. We assess potential beneficial and adverse effects to horseshoe crabs in the sections that follow. Different from red knots, any effects to horseshoe crabs from gear and/or tending activities are not expected to extend beyond the footprint of the aquaculture operation.

***Beneficial Effects***

The eastern oyster serves as a key species in estuarine ecosystems, such as Delaware Bay, by providing various benefits and services (Dame 2012; Grabowski and Peterson in Cuddington *et al.* 2007; Prins *et al.* 1998). Oysters remove particles from the water column and provide three-dimensional relief on an otherwise flat seafloor. Due to their creation of topographic relief and suitable conditions for estuarine communities that would not otherwise exist in the area (Grabowski 2004), oysters are often referred to as ecosystem engineers (Forrest *et al.* 2009; Byers *et al.* 2006; Jones *et al.* 1997). An ecosystem engineer is a species that either morphologically or behaviorally create more complex habitat (Coleman and Williams 2002). Specific to the eastern oyster, its role as ecosystem engineer is both morphological (*e.g.*, development of reef habitat), as well as behavioral (*e.g.*, regulation of local water quality through high filtration efficiency) (Coen *et al.* 2007). In fact, the eastern oyster is often held up as a preeminent example of a marine ecosystem engineer since it serves multiple roles across diverse estuarine systems. These environmental benefits (*i.e.*, structure building and water filtration) are accomplished through both wild and cultured oysters. Along the Cape Shore region of the Delaware Bay, wild oyster populations are rare and ephemeral (mainly due to disease), so benefits from oysters are minimal unless enhanced by cultivated populations (see Background on Aquaculture) (NJDFW 2016; Taylor 2008; Taylor and Bushek 2008).

Although the ecosystem and societal benefits of oysters (*i.e.*, structure building and water filtration) are widely recognized (Grabowski and Peterson in Cuddington *et al.* 2007), oysters do not directly benefit the red knot. However, oysters may benefit horseshoe crabs. Regarding the introduction of structure, horseshoe crabs benefit from wave attenuation through both reductions in wave-induced erosion and increased availability of calm waters needed for spawning (Niles *et al.* 2013a). Aquaculture is unlikely to produce the same level of wave attenuation as a reef of wild, untended oysters. However, Niles *et al.* (2013a) found that a double row of oyster racks had a small but statistically significant wave attenuating effect during periods of rougher wave conditions.

Another potential benefit to horseshoe crabs from the introduction of structure (either natural reefs or through aquaculture) is a localized increase in the abundance and diversity of invertebrates, some of which are prey for various life stages of horseshoe crabs. Elevated shellfish aquaculture structures provide a novel habitat that can support a considerably greater biomass, richness and density of organisms than adjacent natural habitats, and can affect the wider ecosystem in a number of ways (Forrest *et al.* 2009). Researchers in other East coast states have found that a modified rack and bag system, comparable to racks used in the action area, creates habitat similar to that of submerged aquatic vegetation (Dealteris *et al.* 2004) and restored oyster reefs (Erbland and Ozbay 2008). The increase in species richness provided by oyster culture gear has been found significantly different from that of the unmodified seafloor (Dealteris *et al.* 2004). Structural aquaculture can also lead to organic enrichment of benthic sediments, which could increase the abundance of prey available to bottom-feeding horseshoe crabs. However, one study to date found no significant differences between the infaunal communities or sediment grain sizes between aquaculture gear and restored reefs in Delaware (Erbland and Ozbay 2008). Some researchers have cautioned that excessive culture of oysters can lead to organic over-enrichment of the surficial sediments (Mallet *et al.* 2006; Newell 2004), but the characteristics of Delaware Bay (*e.g.*, high energy, long fetch, fast turnover rate (*i.e.*, well-flushed), seasonal ice conditions) make over-enrichment unlikely (Forrest *et al.* 2009; Dumbauld *et al.* 2009; Mallet *et al.* 2006).

Based on a few studies, USFWS (2014) concluded that horseshoe crabs do not appear to be particularly sensitive to differences in water quality. Thus, the water quality benefits provided by oysters may be less important to horseshoe crabs than the topographic relief created by aquaculture structures. However, to the extent that all marine organisms and organisms benefit from clean water, we conclude the filtration services provided by oysters provide an indirect (if unmeasurable) benefit to horseshoe crabs and their prey species.

The benefits discussed above are specific to oysters and to off-bottom aquaculture gear, such as racks. Such benefits may apply, but not necessarily, to other native bivalves and other gear types that may be used in the action area over the life of this PBO.

We conclude that localized benefits to horseshoe crabs from structural aquaculture may occur, though this conclusion is associated with high uncertainty because we are not aware of any studies to date showing a beneficial effect of oyster farms on horseshoe crabs. Despite the lack of studies, we conclude that the magnitude of any beneficial effect (if measurable) are likely to be small, based on the size of the area that can be authorized for structural aquaculture under this PBO and the fact that crabs are likely to move in and out of the action area both within and between years (Swan 2005). Because we expect any beneficial effects to be both localized and small in magnitude, we do not anticipate any discernable localized or population-wide benefits to horseshoe crabs in Delaware Bay.

***Adverse Effects***

As discussed under Direct Effects, above, we expect functional loss of red knot foraging habitat consisting of all intertidal areas covered by gear during the red knot stopover season (including spaces and lanes), plus a "preclusion zone" extending some distance around the perimeter of each aquaculture operation. We expect these areas will be lost to red knot foraging during the lower part of the tidal cycle. Because no aquaculture will occur in the Protected Areas, and tending will be limited to the period around low tide, we do not expect any loss of foraging habitat or activity during higher tide. However, red knots feeding in the Protected Areas or other areas near a farm may be adversely affected if aquaculture gear and/or activity interfere with horseshoe crab activity such that localized densities of horseshoe crab eggs are reduced. Further, red knots could be impacted across Delaware Bay if aquaculture reduces the baywide crab population. Adverse effects to horseshoe crabs from aquaculture may potentially occur from: (a) blocking, slowing, or impeding crab movements, especially to and from spawning beaches; (b) entangling or entrapping crabs; (c) direct crab mortality from vehicle or pedestrian traffic; or (d) altering horseshoe crab foraging conditions.

*Interference with Horseshoe Crab Movement*

Horseshoe crabs scuttle on tip toes (Sekiguchi and Shuster in Tanacredi *et al.* 2009), with the body raised 1 to 2 inches (3 to 5 cm) above the sand to take advantage of bottom currents (NJDFW 2016, Supplement). Film footage of adult crabs, singly and coupled for mating (amplexus), and juvenile crabs indicate all life stages scuttle along the bottom in a similar manner (NJDFW 2016, Supplement). Beyond free-swimming larvae, horseshoe crabs are rarely observed swimming on or near the water surface (Shuster and Anderson in Shuster *et al.* 2003). The vast majority of horseshoe crab movement consists of crawling on the bottom. Though rare, adult horseshoe crabs can swim. However they typically swim only in a half loop when they encounter and start crawling over an obstruction (Wright *et al.* 2011). Thus, crabs are unlikely to swim over a submerged obstacle. In addition, horseshoe crabs are not known to climb up or rest on vertical surfaces such as bridge pilings (Wright *et al.* 2011).

A power plant in Maryland utilizes a fully submerged, 3-foot-high (1-m-high) fence to reduce impingement of horseshoe crabs at its cooling water intake (Wright *et al.* 2011). Prior to the 2012 spawn and each year since, this removable fencing was installed as a horseshoe crab barrier at the water intakes. Impingement was reduced from 1,755 horseshoe crabs in 2011 to 430 in 2012. Impingement results for 2013 were similar to those for 2012. In 2014 total horseshoe crab mortality due to impingement was 117 animals (MDDNR 2015). Based on this example, we conclude that a fully submerged vertical structure can be a substantial impediment to horseshoe crab movement. Of course, the power plant fence was deliberately designed to block horseshoe crabs, and is much taller than typical aquaculture gear currently used in the action area. The fence also lacks openings, such as the lanes required between gear under CM 8. Nonetheless, the fence does demonstrate that few crabs, in this case, swim over a submerged vertical obstruction.

An aquaculture operation lies somewhere on an obstruction continuum between a fully unobstructed beach and a substantial barrier such as the fence in Maryland. We have little data on which to evaluate where on the continuum aquaculture gear may lie. Although observations of horseshoe crab behavior suggest that the presence of structures might alter their movement patterns within the habitat, there are no studies directly demonstrating an impact to crab movement or spawning activities from aquaculture structures (NJDFW 2016). However, we are not aware of any studies looking at this question, so the lack of a demonstrated impact could be due to lack of study. Given the lack of directly relevant studies, we evaluate the potential for aquaculture to interfere with crab movement at the scale of both the gear and the farm. At both scales, we look at both physical as well as behavioral considerations likely affecting the relative level of crab obstruction caused by aquaculture.

At the scale of gear, we conclude horseshoe crabs will typically not swim over cages, racks, or other structures, even during high tide, as discussed above. However, crabs may be able to pass under some gear types. Up to 1,000 square feet (93 square m) of intertidal or shallow subtidal gear per farm will be allowed to rest directly on the bay bottom (CM 8); clearly, crabs cannot pass under such gear. The vast majority of gear, however, will be up on legs (CM 8), providing potential for crabs to pass underneath. We evaluate both the physical and behavioral ability of horseshoe crabs to pass under gear with 14-inch (36 cm) legs that is maintained, to the extent practicable, at least 12 inches (30 cm) above the bay bottom, as set forth under CM 8.

From 222 samples taken during an October 2015 ocean trawl survey, the average male crab height was 2.415 inches (6.1 cm) (largest 3.937 inches [10.0 cm]) and the average female height was 3.523 inches (8.9 cm) (largest 4.803 inches [12.2 cm]) (R. Babb pers. comm. November 13, 2015). During amplexus a male is positioned on top of a female, near the rear of her carapace (Brockman in Shuster *et al.* 2003), not directly on top of her tallest (anterior) part. But to err on the high side, a large male (3.9 inches [10.0 cm]) mated with (and fully on top of) a large female (4.8 inches [12.2]) scuttling 2 inches (5.1 cm) above the bay bottom would stand 10.7 inches (27.3 cm) high. Considering an average size male (2.4 inches [6.1 cm]) and female (3.5 inches [8.9 cm]), the pair would stand 7.9 inches (20.2 cm) high when scuttling 2 inches (5.1 cm) above the bottom. Especially considering this unrealistic mating position, we conclude that both individual crabs and mated pairs will be able to pass under gear with 14-inch (36-cm) legs that is maintained, to the extent practicable, 12 inches (30 cm) above the bay bottom. However, as crabs pack into the intertidal area, crab passage becomes a "laminar flow" problem, especially with many crabs in amplexus simultaneously. Thus, at very high crab densities, we find it is possible that some crabs may not be able to immediately pass under a particular rack if there are already many other crabs beneath that same rack.

In addition to whether horseshoe crabs can physically pass under racks is the separate question of whether they will do so based on available information regarding crab behavior. During the day and full moons, racks and other raised gear cast shadows on the bay bottom. The nighttime movement of crabs sharply away from overhead shadow has been documented, and is probably a response to the need for light to detect mates (Barlow in Tanacredi *et al.* 2009). This observation suggests that overhead shadows, such as those cast by gear, may discourage crabs from passing below gear or may interfere with locating mates. Crabs also use tidal surge and bottom currents as cues for directional movement, tending to go with tidal currents rather than buck them (Anderson and Shuster in Shuster *et al.* 2003). The placement of gear could locally alter currents, possibly interfering with normal crab movements (NJDFW 2016). We have no information to indicate whether shadows and/or currents are influencing crab passage under gear. Anecdotal reports from growers indicate that horseshoe crabs are routinely observed under racks during the day, often partially burrowed in the sediment beneath racks around low tide (NJDFW 2016). Such observations indicate that, to at least some degree, crabs will utilize the space under gear despite possible shadow and/or current effects. We conclude that crabs may be discouraged from passing under gear, but neither their physical size nor behavior fully prevents horseshoe crabs from moving under gear. The extent to which crabs are reluctant to travel under gear, if at all, is unknown.

At the scale of the farm, CM 8 limits the footprint of gear that can rest directly on the bottom, and requires 4 to 6-foot-wide (1.2 to 1.8-m) lanes between each 6-foot-wide (1.8-m-wide) linear array of gear. CM 8 also encourages, to the extent practicable, shore-perpendicular arrangements of gear arrays. We note both the lanes and the shore-perpendicular configuration are already standard industry practice even before this PBO takes effect. Upon encountering an obstruction (*e.g.*, a bottom cage, a rack blocked by other crabs), crabs would have to navigate a maximum of 3 feet (1 m) to the nearest lane (as per CM 8, arrays will be a maximum of 6 feet (2 m) wide). We conclude that horseshoe crabs are physically able to navigate around an obstruction to a nearby lane. Behaviorally, it is possible that crabs could be dissuaded from spawning as a result of encountering an obstruction, or due a general reluctance to travel under gear (*e.g.*, due to shadows or currents). Although we lack data directly relevant to crab behavioral responses upon encountering gear, we doubt such encounters would substantially deter crabs from continuing on to a spawning beach due their mobility and the biological drive to reproduce. Anecdotally, one expert who studied horseshoe crab spawning at the Cape Shore Lab when large numbers of oyster trays were aligned in multiple rows parallel to the beach reported that no impacts of oyster cultivation were observed, and crabs moved around the structures to access the beach (NJDFW 2016).

The effects of aquaculture on horseshoe crab movement remain highly uncertain. Further research in this area would help inform the adaptive management process (CM 6). Based on best information currently available, we conclude a highly atypical arrangement involving long arrays of contiguous, shore-parallel, bottom-resting gear would present a substantial barrier to horseshoe crab movement. However, no such arrangements are currently present in the action area, and would be prevented by CM 8, as well as the adaptive management and Tier 2 processes. Based on the provisions of CM 8 for shore-perpendicular arrays of mainly raised gear, separated by lanes roughly as wide as each array, we conclude aquaculture conducted under this PBO will not present a substantial barrier to horseshoe crab movement. That said, at some unknown densities of gear and crabs, we would expect even raised gear with lanes to possibly interfere with large-scale crab movements to the beach, for example in circumstances when hundreds of crabs encounter hundreds of rack legs. We do not anticipate such circumstances, should they arise, will impact the localized density of crab eggs available to red knots over the life of this PBO—in part because under such circumstances, crab density would be so high as to ensure a large number of crabs would still make it to the beach (*i.e.*, through the lanes) and spawn. However, we reiterate high uncertainty and the need for future study and adaptive management.

Growers may deploy or relocate gear to Protected Areas after June 7, which is still during the peak of the spawning season. As discussed under Current and Future Extent of Aquaculture, above, we do not expect gear will extend all the way to the MHW line, because when oysters spend too much time exposed to the air their growth rates are typically slowed (Oesterling and Petrone 2012). However, encroachment of gear into the Protected Areas after June 7 would incrementally increase the risk of these structures interfering with horseshoe crab spawning since crab density is theoretically highest in the narrow strip of beach at and just below the MLW line.

Although some crabs are likely to remain in the action area after July 31, when CM 8 is no longer in effect, the density of crabs during this period is expected to be low, substantially reducing the potential for blockage, which we consider density-dependent (*e.g.*, based on laminar flow dynamics). Further, we do not expect widespread conversion of gear (*e.g.*, narrowing of lanes, lowering of racks) even after July 31 (see Current and Future Extent of Aquaculture, above).

Because red knots will have left the bay before June 7 and well before July 31, any impediments to crab spawning or movement during this period would only affect red knots if they contribute to a reduction in the baywide horseshoe crab population, because crabs take about 10 to mature (ASMFC 2004) and female crabs do not appear to exhibit high fidelity to the same spawning beach between years (Swan 2005). The potential for effects to the baywide crab population is discussed below.

*Entanglement and Entrapment*

Numerous segmented appendages, attached ventrally at a central location, a hinged body, and a rigid, flattened carapace make horseshoe crabs susceptible to entanglement and entrapment (NJDFW 2016). Segmented horseshoe crab legs are commonly entangled in fine-gauge and fibrous materials prone to fraying, including but not limited to monofilament fishing line, jute, frayed rope (*e.g.*, lost from boats or blue crab pots), abandoned fishing nets, and electrical wires in construction debris (NJDFW 2016). Horseshoe crabs have been observed entangled in frayed silt fence (K. Conrad personal communication, October 28, 2015). Regarding entrapment, crab appendages can become wedged in wire mesh of gabion baskets used for coastal hardening, and crabs have also become wedged in structures and debris including rip-rap, derelict bulkheads, and debris from razed or damaged homes (NJDFW 2016). Horseshoe crab have also been observed trapped behind silt fence (K. Conrad personal communication, October 28, 2015).

Although horseshoe crabs are known to become entangled in certain types of fishing gear, there are no directed studies and little other evidence specifically related to the types of gear used for aquaculture (NJDFW 2016). Aquaculture structures are markedly different from the types of fishing gear where entanglement and entrapment have been observed (NJDFW 2016). In a literature review of bird (not horseshoe crab) entanglement, Forrest *et al.* (2009) reported that, though an important issue for some forms of aquaculture or fishing practice, entanglement is unlikely to be an important consideration for intertidal oyster culture where primarily rigid structures are used. We are not aware of any documented instances of horseshoe crab entanglement or entrapment at oyster farms. Horseshoe crabs have not been observed entangled or trapped within shellfish aquaculture racks at the Atlantic Cape Fisheries, Inc. farm. In 15 years of experience working at the Cape Shore flats, BSF biologists have not encountered horseshoe crabs trapped in or under racks or other aquaculture structures (NJDFW 2016).

CM 8 would prohibit use of material types known to cause horseshoe crab entanglement, and we note that such materials are not commonly in use for aquaculture in the action area at the time of this PBO. CM 8 also reduces entrapment risk by ensuring wide, shore-parallel travel lanes, and by prohibiting gear (to the extent practicable) with ground clearance between 1 and 12 inches (between 3 and 30 cm) under which a crab could theoretically become wedged. New gear types, materials, and/or configurations with higher entanglement/entrapment risks could potentially be developed in the future; these would be reviewed during both the Tier 2 and adaptive management processes.

Based on the above information, and CMs 6 and 8, we expect a negligible number of crabs to become entangled or entrapped during the red knot stopover period. We also expect that growers would generally free any entangled or entrapped crabs they may encounter during their 4-hour tending period around low tide 5 days per week. However, recognizing uncertainty due to the lack of research directed at this issue, we consider a range of 1 to 10 crabs per acre per year possibly becoming entangled or entrapped at aquaculture farms. We further consider an extreme scenario in which all entangled or entrapped crabs did not survive. At maximum build-out of 150 acres (61 ha) of aquaculture (including lanes), this would correspond to 150 to 1,500 crabs entangled or entrapped per year. For context, a volunteer program in New Jersey dedicated 1,270 volunteer hours rescuing entrapped crabs in 2015. State-wide, those volunteers rescued 4,288 crabs entrapped by anthropogenic hazards structures, and 1,345 entrapped by natural hazards (reTURN the Favor 2016), or 5,633 total crabs. Because this volunteer program cannot operate every night on every beach, the rescued crabs must represent only a percentage (unknown) of total crabs entrapped by non-aquaculture hazards. The size of the baywide crab population was estimated at 9.3 to 32.2 million crabs, averaging around 19 million, from 2002 to 2014 (ASMFC 2015; USFWS 2014). Given that the volume of horseshoe crabs eggs in the action area currently appears sufficient for the current red knot population (see Environmental Baseline), we conclude that a very high estimate of 1,500 additional lethal crab entanglements or entrapments per year would not appreciably reduce localized egg densities available to red knots. However, we reiterate moderate uncertainty and the need for horseshoe crab monitoring at oyster farms, and for adaptive management.

Although growers may deploy or relocate gear to Protected Areas after June 7, the provisions of CM 8 intended to minimize entanglement and entrapment risks remain in effect through July 31. Although horseshoe some crabs are likely to remain in the action area after July 31, when CM 8 is no longer in effect, the density of crabs during this period is expected to be low, reducing the potential for entrapment and entanglement. Further, we do not expect widespread use of entangling materials even after July 31, nor widespread deployment of shorter-leg gear that theoretically presents a higher entrapment risk. In addition, because red knots will have left the bay well before July 31, crab entanglement and/or entrapment during this period would only affect red knots if they contribute to a reduction in the baywide horseshoe crab population, because crabs take about 10 years to mature (ASMFC 2004) and female crabs do not appear to exhibit high fidelity to the same spawning beach between years (Swan 2005). The potential for effects to the baywide crab population is discussed below.

*Mortality from Vehicle and Foot Traffic*

Unlike the potential for obstruction and entanglement/entrapment, discussed above, direct mortality from vehicle and foot traffic could impact all life stages of horseshoe crabs, not just adults. Intensive, unrestricted motor vehicle use in the action area would be expected to crush considerable numbers of adult horseshoe crabs and larvae, and to crush or compact nests. Intensive foot traffic might have similar, but far lesser, effects. To evaluate this potential effect of aquaculture on horseshoe crabs, we consider the timing and distribution of crabs in the action area.

Horseshoe crabs of all life stages use the intertidal zone of Delaware Bay (NJDFW 2016, Supplement). Adult crabs move into shallower areas of the bay to spawn during spring (ASMFC 2004) and may be present in shallow waters from April through October (NJDFW 2016, Supplement). Horseshoe crab spawning generally occurs from March through July, with the peak spawning activity occurring around the evening new and full moon high tides in May and June (Smith and Michels 2006; Shuster and Botton 1985). In Delaware Bay, spawning may commence as early as April and end as late as August (Shuster and Sekiguchi in Shuster *et al.* 2003), though in most years spawning activity in April and August is minimal. After spawning, adult horseshoe crabs begin to move into the deeper waters of Delaware Bay and to the continental shelf (Anderson and Shuster in Shuster *et al.* 2003). Eggs develop within beach sediments, typically hatching into larvae about 24 to 28 days after fertilization (Botton and Loveland 2003), though embryo development may be as short as two weeks or as long as several months in Delaware Bay (Brockman in Shuster *et al.* 2003; Botton *et al.* 1992). Most larvae emerge from beach sediments shortly after hatching, although they have the potential to overwinter as discussed further below (Botton and Loveland 2003; Botton *et al.* 1992). By July, adult abundance has normally declined and most eggs have hatched into larvae (Botton 1984). Within a few days after the first molt, the initially free-swimming larvae settle on the nearshore sand flats adjacent to spawning beaches, where they may remain for up to a year (Brockman in Shuster *et al.* 2003). Young horseshoe crabs remain in the intertidal zone for one to three years (Shuster and Sekiguchi in Tanacredi *et al.* 2009; Botton *et al.* in Shuster *et al.* 2003), foraging from April through October and possibly overwintering between November and March (Anderson and Shuster in Shuster *et al.* 2003).

Most larvae emerge from the sediment during the summer. However, Botton *et al.* (1992) found that a smaller component of the larval population at the Cape Shore Lab delayed emergence, and remained alive within the sediments until the following spring. Overwintering larvae were distributed in a 10-foot-wide (3-m-wide) band in the mid-tide region, at sediment depths greater than 6 inches (15 cm). Between 90 and 900 live larvae per square foot (1,000 and 10,000 per square m) were found throughout the winter and into early spring. This phenomenon may be ecologically significant, since emergence of overwintering larvae in early spring occurs at a time when predation by birds is minimal. Sediment disturbance by winter storms may be the major factor limiting the survivorship of overwintering cohorts (Botton *et al.* 1992).

The Delaware Bay is a horseshoe crab nursery area with beaches and extensive intertidal zones that favor crab breeding, egg hatching, and juvenile crab foraging. The bay's intertidal zone is contiguous with abundant food resources on the Continental Shelf (Anderson and Schuster in Shuster *et al.* 2003). Studies in Delaware Bay and elsewhere have found that larval and juvenile horseshoe crabs remain in and near the intertidal zone year round (NJDFW 2016, Supplement) and are abundant in shallow, nearshore areas (NJDFW 2016; Shuster and Anderson in Shuster *et al.* 2003). Young-of-year (Brockman in Shuster *et al.* 2003) and juvenile horseshoe crabs (Anderson and Schuster in Shuster *et al.* 2003) are found in the intertidal zone adjacent to breeding beaches.

In the Southern Segment, driving will occur year round, but will be limited to 5 days per week between May 1 and June 7. In the Northern Segment, driving will be restricted as follows.

- Leases A-19 and A-28 (CMs 20 and 21)
  - 2016 to 2018: No driving May 1 to August 31 (Appendices C and D)
  - After 2018: No driving May 1 to June 7 (CM 9)

- All other leases/grants: No driving May 1 to June 7 (CM 9)

Conservation Measure (CM) 9 requires Vehicle Use Plans for any allowable beach driving between May 1 and September 15, encompassing the entire spawning and egg development season, as well as the emergence season for the majority of larvae. The Vehicle Use Plans must: (a) designate and consistently use approved beach entry and exit points, and driving routes, preferentially selecting routes already in use for aquaculture and avoiding undisturbed stretches of beach; (b) minimize the amount of driving on the beach parallel to the shoreline; (c) when driving parallel to the shoreline cannot be avoided, drive as far seaward of the high water line as practical; (d) avoid driving through concentrations of crabs and in the wrack line. Each Vehicle Use Plan will be approved during the Tier 2 process.

Combined with adaptive management (CM 6), we expect the Vehicle Use Plans will virtually eliminate direct adult crab mortality from vehicles. Based on CMs 6 and 9, and the Tier 2 process, we expect minimal crushing of adult horseshoe crabs from vehicle use over the life of this PBO. Thus, we do not anticipate any appreciable reductions in localized egg densities available to red knots due to direct vehicle-induce crab mortality. However, any large-scale impacts to other life stages have the potential to reduce the baywide crab population.

Combined with adaptive management (CM 6), we expect the Vehicle Use Plans will substantially limit crushing or compaction of nests and emerging larvae, which are concentrated within the Protected Areas. Through July 31, crushing of larvae and juveniles outside of Protected Areas will be limited by CM 8 (*i.e.*, with lanes about as wide as the arrays of gear, roughly half of the area of each typical farm will not be accessible to vehicles). Through September 15, crushing of larvae and juveniles within and outside of the Protected areas will also be limited by the requirement that the Vehicle Use Plans specify approved driving routes.

However, some growers may increase the intensity of vehicle use after September 15; for example they may stop following designated travel routes. Juvenile crabs likely inhabit intertidal portions of the action area during this time, probably active through October, and are potentially susceptible to crushing (NJDFW 2016) by vehicles and (to a much lesser degree) foot traffic. Intensified vehicle use after September 15 could also potentially crush overwintering larvae. We expect this effect to be minor because these larvae are buried more than 6 inches (15 cm) deep (Botton *et al.* 1992); notwithstanding, where deep rutting occurs, it may be possible for vehicles to expose and possibly kill buried, overwintering larvae.

Because horseshoe crabs take about 10 years to mature (ASFMC 2004), any vehicle impacts to larvae or juveniles would not affect localized egg densities available to red knots in the action area over the life of this PBO. Impacts to early horseshoe crab life stages would need to translate into crab spawning population-level impacts to result in diminished food availability for red knots (NJDFW 2016). The possibility for effects to the baywide horseshoe crab population are considered below.

*Impacts to Horseshoe Crab Foraging Conditions*

Potential exists for aquaculture to alter foraging conditions for all life stages of horseshoe crabs. Horseshoe crabs are opportunistic foragers that can take advantage of a wide range of locally available prey, but primarily eat bivalves and marine worms. Due to the crab's generalist feeding strategy, horseshoe crab prey on the continental shelf have been shown to include 50 taxa. Documented prey species include blue mussels (*Mytilus edulis*), surf clams (*Spisula solidissima*), nut clams (*Nucula proxima*), razor clams (*Ensis directus*), tellinids, small brachyuran crabs, and polycheates. Bivalves have been found to comprise the vast majority of the ingested food during all seasons. Horseshoe crabs have been shown to exhibit a clear preference for thinner-shell prey such as dwarf surf clams (*Mulinia lateralis*) and soft-shell clams (*Mya arenaria*) over the thicker-shelled *Gemma* clams and quahogs (also called hard clams) (*Mercenaria mercenaria*) (Botton *et al.* in Shuster *et al.* 2003).

Studies from the United States and other parts of the world have documented recreational impacts to beach invertebrates, primarily from the use of motor vehicles, but even heavy pedestrian traffic can have effects (USFWS 2014). Studies have demonstrated that off-road driving and foot traffic in supratidal and intertidal habitats can cause direct mortality to invertebrates, alter their habitats, and cause shifts in community composition depending on ground pressure, extent of rutting, and the scale and intensity of activity (NJDFW 2016). Some early studies found minimal impacts to intertidal beach invertebrates from vehicle use (USFWS 2014). Based on a review of the literature through 1999, Stephenson (1999) concluded that daytime vehicle impacts on the biota of the foreshore (intertidal zone) of sandy beaches appeared to be minimal; however, very few elements of the foreshore biota had been examined. Other studies have found higher impacts to benthic invertebrates from driving (USFWS 2014; Sheppard *et al.* 2009). Due to the compactness of sediments low on the beach profile, driving in this zone is thought to minimize impacts to the overall beach invertebrate community. However, intertidal beaches and surf zones can be impacted by vehicles (Schlacher *et al.* 2008a). The relative vulnerability of species in this zone is not well known. The severity of direct impacts (*e.g.*, crushing) depends on the compactness of the sand, the sensitivity of individual species, and the depth at which they are buried (Schlacher *et al.* 2008b; Schlacher *et al.* 2008c). Study results involving thicker-shelled bivalves may not be applicable to thinner-shelled bivalves (such as those preferred by horseshoe crabs), which may be more vulnerable to crushing (NJDFW 2016; Sheppard *et al.* 2009). Further, it is not clear if the vehicles considered in beach driving studies are of similar weights (and exert similar ground pressures) to those typically used in aquaculture (NJDFW 2016).

We assume at least some benthic invertebrates are crushed by vehicle and (possibly) foot traffic in the action area. The limited extent of driving in the Northern Section is detailed under Mortality from Vehicle and Foot Traffic, above. Looking only at the Southern Segment, full build-out would be capped at 150 intertidal acres (including lanes) (61 ha), as per CM 12, or about 43 percent of the intertidal area outside of Protected Areas (Table 3). From May 1 to September 15, CM 9 will limit vehicle travel to specified routes approved during the Tier 2 process. Assuming a typical farm set-up would be comprised of roughly half gear and half lanes, by area (as per CM 8), and assuming that driving in every lane was approved, roughly 22 percent of the intertidal area (outside of Protected Areas) would be potentially subject to invertebrate crushing. Based on this maximum level of crab prey exposure to driving, we do not expect adult horseshoe crabs to starve or exhibit suppressed spawning activity due to vehicle-induced reductions in food availability considering that: (a) invertebrate mortality in the driving lanes would not be 100 percent; (b) horseshoe crab mobility is probably adequate to move out of any driving lanes exhibiting depressed prey densities; and (c) horseshoe crabs also forage in subtidal areas. We would expect even less impact from foot traffic, particularly considering CM 15.

In addition to crushing prey species, vehicle use could compact the sediments. Horseshoe crabs forage on the intertidal bay bottom by churning sediment to find prey (Botton *et al.* in Shuster *et al.* 2003). Benthic substrate compaction could interfere with this crab foraging strategy (NJDFW 2016). However, studies have found the foreshore more resilient to physical disturbance (*e.g.*, sand displacement, compaction) from vehicles than the upper beach, due to the high substrate compaction and moisture content in this zone (Hatch Mott MacDonald 2011; Schlacher and Thompson 2008; Anders and Leatherman 1987). Anders and Leatherman (1987) reported that the foreshore, with its high degree of compaction and high moisture content, was the least susceptible zone to physical disturbance by vehicles, especially where gently sloping (such as in flats in the action area). Compaction from vehicles in the foreshore is limited because this zone is already rather compacted, resulting in small average track size and less sand displacement on the foreshore relative to the upper beach. The naturally compact substrate of the foreshore is correlated with high moisture content (Hatch Mott MacDonald 2011; Anders and Leatherman 1987). In a consultation involving beach driving on the Atlantic coast of New Jersey, USFWS (2011) assessed 90 to 130 trips per day by trucks weighing 62,000 pounds (empty) to 132,000 pounds (loaded) (*i.e.*, far heavier than vehicles used in aquaculture). That consultation concluded that, in the swash zone, the continual saturation of the haul route was expected to offset the compaction of the sand resulting from the truck loads (USFWS 2011). The amount of compaction that occurs as a result of vehicle passes in the intertidal zone was thought to be minimal in relation to the natural physical wave and swash processes, which act to flatten and compact the sand (Hatch Mott MacDonald 2011).

Notwithstanding our above conclusions regarding invertebrate crushing and sediment compaction, we recognize high uncertainty around the effects of aquaculture tending on benthic communities, such as those that support horseshoe crabs. Forrest *et al.* (2009) reported that impacts to seabed communities from disturbance associated with elevated (off-bottom) bivalve culture are not well known. In addition to prey crushing and sediment compaction, other impacts to horseshoe crab foraging conditions are possible. For example:

- Crabs could potentially be affected by reduced accessibility to prey under raised gear if they exhibit any reluctance to use the spaces under gear (*e.g.*, due to shadow and/or current effects, as discussed under Blockage of Horseshoe Crab Movement, above). However, the preponderance of raised gear (*i.e.*, limits on bottom-resting gear) gear, as per CM 8, leaves open the possibility for crabs to forage under the gear for nearly the entire spawning season (April 15 to July 31).

- It is possible that the presence of the gear itself (*e.g.*, shading, altered currents), as well as the farmed bivalves and/or their associated fauna such as mudworms, could influence benthic invertebrate abundance and/or species composition (Forrest *et al.* 2009). Any such changes could be adverse or, as discussed above, beneficial to horseshoe crab foraging conditions.

Although these potential effects are associated with high uncertainty, we find that any such effects to horseshoe crab foraging conditions cannot—based on best information currently available—be shown to influence localized horseshoe crab egg densities available to red knots. Considering all of the possible effects discussed above, we conclude that potential exists for aquaculture to alter foraging conditions for adult horseshoe crabs, but we have no information regarding the relative magnitude of any beneficial versus adverse effects. Even if adverse effects predominate, we consider the size and location of authorized aquaculture areas relative to available horseshoe crab spawning and foraging habitats, and find that even moderately degraded foraging conditions in these locations are unlikely to impact localized egg densities available to red knots. This is because we consider adult crabs to be sufficiently mobile to spawn in areas of high-suitability beach habitat even if the immediately adjacent foraging habitat is suboptimal (*e.g.*, crabs can probably tolerate some moderate distance between optimal foraging habitats and optimal spawning habitats).

Although growers may deploy or relocate gear to Protected Areas after June 7, the Protected Areas are mainly important for horseshoe crab spawning, not foraging (*i.e.*, we do not consider Protected Areas to be important horseshoe crab foraging habitats). The provisions of CM 8 intended to preserve crab access to their benthic foraging habitats (*i.e.*, a preponderance of raised gear) remain in effect through July 31. After July 31, when CM 8 is lifted, growers could increase the area covered by bottom-resting gear, thereby blocking crab access to a greater area of bay bottom. Growers may also alter the spacing and/or configuration of gear. However, most adult crabs have left the shallows by then, and we do not expect widespread conversion of gear types after July 31 (see Current and Future Extent of Aquaculture). Further, since red knots would have departed before July 31, such effects (if any) would only affect red knots though impacts to the baywide crab population.

Altered foraging conditions could also affect larval and juvenile horseshoe crabs. Because crabs take 10 to 12 years to mature (USFWS 2014), any impacts to larvae or juveniles would not affect localized egg densities available to red knots. Impacts to early horseshoe crab life stages would need to translate to crab spawning population-level impacts to result in diminished food availability for red knots (NJDFW 2016). Possible effects to the baywide horseshoe crab population are considered below.

***Consequences***

<u>Localized Effects to Egg Densities</u>

As shown in Table 13, we have calculated a rough projection that 390 to 5,520 red knots per year will be exposed to aquaculture across the action area. We have concluded that all these birds will experience annual non-lethal incidental take (harm and/or harassment) from habitat loss and disturbance, and we have projected that 3 years in 10 exposed birds will experience reduced survival and/or reproductive rates due to that habitat loss and disturbance. Based on the preceding review of best available information, we do not expect any incremental increase in the magnitude (*e.g.*, number of birds) or severity (*e.g.*, degree of effects to energy budgets) of the previously calculated incidental take as a result of locally depressed horseshoe crab egg densities due to potential aquaculture effects on adult crabs. Though there is high uncertainty regarding aquaculture effects on adult horseshoe crabs, we have concluded that none of the possible effects reviewed above (blockage of movement, entanglement/entrapment, impacts from vehicle use, impacts to foraging conditions) are likely, singly or collectively, to appreciably reduce the localized densities of horseshoe crab eggs available to red knots foraging in and near aquaculture operations. This conclusion is based on our above analysis, which considered the CMs an integral part of the proposed action.

<u>Baywide Effects</u>

Red knots could be impacted within and outside of the action area if aquaculture activities cause a substantial reduction in the baywide horseshoe crab population. Rangewide red knot declines have been tied to previous drops in horseshoe crab abundance in Delaware Bay (*i.e.*, as a result of crab overharvest) (USFWS 2014).

In the BA, NJDFW (2016) assessed data in Lathrop *et al.* 2006 and 2013 and concluded that suitable horseshoe crab spawning habitat is more prevalent, and relatively more stable, in the lower Delaware Bay than the northern portion of the bay; thus, the action area may include a disproportionate percentage of suitable spawning habitat on a State-wide basis. On a baywide scale, however, 52 to 58 percent of mapped suitable habitat is in Delaware (Lathrop *et al.* 2013; Lathrop *et al.* 2006). In addition, Lathrop *et al.* (2013) found that Reed's Beach to Norburys was a major hotspot of declining spawning habitat suitability between 2002 and 2010, though this trend may have been locally reversed by restoration projects since 2013. Lathrop *et al.* (2006) also reported that horseshoe crabs did not appear to show a strong preference among the various classes (*e.g.*, optimal/suitable, less suitable, avoided, disturbed) of mapped sand beach habitat for their spawning activity. This may be due to differences in beach morphology, which are presumably due to differences in wave energy regimes (Lathrop *et al.* 2006). Based on these considerations, we do not conclude that the action area supports a disproportionate amount of the baywide horseshoe crab spawning activity, but this is a pertinent question to be addressed during the adaptive management process.

Of the possible effects considered above, we expect no adult crab mortality from blockage of movement or altered foraging conditions, concluding that if crabs found a farm too difficult to navigate and/or depauperate in prey, they can and would relocate to another area rather than starve. We expect that any adults avoiding farms for any reason (*e.g.*, obstructed movement, altered foraging conditions) will experience minor effects to their energy budgets. We do not believe the level of farm avoidance by adult crabs will rise to the level of functional habitat loss for foraging, as is the case for red knots. However, even if degraded foraging conditions exist, most crabs would be physically and behaviorally able to transit through the farms to access high-quality spawning beaches, if present. We consider 1,500 adult crabs per year a very high end estimate of adult mortality from entanglement/entrapment. We expect negligible adult crab mortality from vehicle use and other human activities associated with aquaculture, based on Conservations Measures 9 and 15. We expect minimal impacts to developing nests and larvae near the MHW line, based on CMs 9, 10, and 15. We do not expect this level of impacts to adult crabs (including their reproductive capacity), from all these potential effects combined, will affect baywide horseshoe crab populations.

Between May 1 and September 15, we expect some unknown percentage of larval and juvenile crabs to be crushed within approved driving routes. Between September 15 and April 30, the extent of area impacted by driving may increase in fall and spring, but less winter driving is expected. We have no basis to conclude what effects (beneficial or adverse) larvae and juveniles may experience as a result of potentially altered foraging conditions in and around farms. In order to result in spawning population-level impacts, early life stage crab mortality associated with aquaculture activities would need to be additive to other sources of early life stage mortality and not subject to density dependent compensation (*e.g.*, such morality mortality would not be compensated by increased survival of non-impacted individuals, increased survival at later life stages, or increased fecundity) (NJDFW 2016). Although information is lacking to be able to predict such impacts, NJDFW (2016) speculated that early life stage mortality associated with aquaculture practices would likely be indiscernible from typical variability in early life stage mortality of natural populations. Based on the above information, we do not expect impacts to larvae or juveniles to affect baywide horseshoe crab populations.

Our conclusion regarding lack of an impact on the baywide horseshoe crab population is further supported by the following:

- The size of the baywide crab population was estimated at 9.3 to 32.2 million crabs, averaging around 19 million, from 2002 to 2014 (ASMFC 2015; USFWS 2014).

- Even if some combination of the above possible factors depressed spawning near farms, we expect those crabs would spawn elsewhere rather than forgo spawning. Further, density-dependent responses by crab populations might compensate for any local reductions in spawning activity.

- Aquaculture is expected to occupy a small percent of available horseshoe crab habitat in the bay. From April 15 to June 7, intertidal aquaculture will not exceed 150 acres (61 ha) (including spaces and lanes), out of about 800 total intertidal acres (324 ha) in the action area (about 19 percent) and out of about 1,800 total intertidal acres (728 ha) on New

> Jersey's side of the bay (about 8 percent). Additional intertidal habitat is available in Delaware. After June 7, intertidal aquaculture may expand into the Northern Segment and into Protected Areas; however, that is past the peak of horseshoe crab spawning in most years, and we do not expect this practice to be widespread. Unlike red knots, crabs use subtidal as well as intertidal areas, so New Jersey's estimated 1,800 intertidal acres (728 ha) represent only a small portion of the habitats used by horseshoe crabs during the spawning season. Subtidal aquaculture is expected to cover no more than about 20 acres. (See Current and Future Extent of Aquaculture.)

Likewise, any benefits to horseshoe crabs from aquaculture in the action area (*e.g.*, from improved foraging conditions and/or water quality) are unlikely to affect the baywide horseshoe crab population, and are therefore unlikely to produce any measurable benefits to the red knot. This conclusion is based on: (1) high uncertainty about how aquaculture may affect horseshoe crab foraging conditions in the action area (beneficial and/or adverse), and the magnitude of any such effects; and (2) the tenuous connection (currently unmeasurable) between any such effects on horseshoe crabs and the crab egg densities available to red knots. Any new information that becomes available regarding the potential for aquaculture to affect the baywide horseshoe crab population will be considered as part of the adaptive management process (CM 6).

### Aggregate Effects

Prior to initiation of this programmatic consultation, applications to the Corps for structural aquaculture were handled on a case-by-case basis. Even with permit conditions recommended by the Service to minimize red knot impacts at each farm, potential existed for aggregate effects of aquaculture spread across the action area. For example, without a coordinated access schedule, birds could be disturbed by growers on one farm one day, and on an adjacent farm the next day. Further, for a given footprint of intertidal aquaculture, the total area of functional habitat loss would be greater if farms were spread out rather than clustered, due to the "preclusion zone" that is related to the total perimeter of aquaculture operations. In addition, for a given footprint of intertidal aquaculture, exposure of red knots to adverse effects from habitat loss and disturbance would be far greater in the Northern Zone than in the Southern Zone based on bird distribution across the action area (Tables 9 and 10). We conclude that the potential for these and other aggregate effects are minimized by the framework of CMs in this PBO including, but not limited to, CMs 6 (adaptive management), 7 (phased build-out), 9 (vehicle use), 12 (clustering and acreage cap), 15 (coordinated access schedules), and 22 through 24 (Tier 2 process).

## CUMULATIVE EFFECTS

As used in the context of consultations under Section 7 of the ESA, cumulative effects are those effects of future State or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation (50 CFR 402.02).

Future habitat restoration efforts, such as those discussed under Environmental Baseline, are expected to benefit red knots, but are not considered here because they all require Corps authorizations, which are Federal actions. Likewise, any proposals to harden the shoreline for erosion control or storm protection would involve a Federal action (Corps permit), though we note we are not aware of any such proposals at this time. Potential non-Federal actions affecting red knot habitat would include expansion of residential or commercial development or other infrastructure—we are not aware of any such proposals and consider development pressure in the action area low.

Regulation of the horseshoe crab harvest, which affects red knot food availability in the action area, is implemented by a non-Federal entity, the Atlantic States Marine Fisheries Commission (ASMFC). We expect the ASMFC's current management framework will remain in place over the life of this PBO. Under the current management framework, known as the ARM, the present horseshoe crab harvest is not considered a threat to the red knot because harvest levels are tied to red knot populations via scientific modeling (USFWS 2014).

Management of disturbance to red knots from human activities is primarily non-Federal. Human activity on action area beaches (unrelated to aquaculture) is currently low, and we expect it will remain effectively managed by State and local governments and non-governmental organizations. Though low-flying aircraft have been identified as causing disturbance, we expect impacts from aircraft to decrease over the life of this PBO based on the recent efforts of the State and the recent listing of the red knot under the ESA (Section 9 of which prohibits harassment (take) of listed wildlife by both Federal and non-Federal entities).

Based on the above, we do not expect cumulative adverse effects to red knots in the action area over the life of this PBO.

### CONCLUSION

"Jeopardize the continued existence" of a species, as defined in regulations implementing the ESA, means to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both survival and recovery in the wild by reducing the reproduction, numbers, and distribution of that species (50 CFR 402.02). After reviewing the current status of the red knot, the environmental baseline for the action area, the effects of the proposed action, and cumulative effects, the Service's Biological Opinion is that the proposed action is not likely to jeopardize the continued existence of the red knot. At the time of this PBO, no critical habitat has been designated for these species; therefore, no critical habitat will be affected.

## INCIDENTAL TAKE STATEMENT

### DEFINITION OF INCIDENTAL TAKE

Section 9 of the ESA and the federal regulation pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without special exemption. *Take* is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct. *Harm* is further defined by the Service to include significant habitat modification or degradation that results in the death or injury to listed species by significantly impairing essential behavioral patterns such as breeding, feeding, or sheltering. *Harass* is defined by the Service as intentional or negligent actions that create the likelihood of injury to a listed species by annoying it to such an extent as to significantly disrupt normal behavior patterns, which include, but are not limited to, breeding, feeding, or sheltering. *Incidental take* is defined as take that is incidental to, and not the purpose of carrying out an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to, and not intended as part of, the agency action is not considered a prohibited taking under the ESA, provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement.

## EXTENT OF ANTICIPATED TAKE

Final regulations published on May 11, 2015 (*Federal Register* Vol. 80, No. 90, p. 26845) define *framework programmatic action*, for purposes of an incidental take statement, as a Federal action that approves a framework for the development of future action(s) that are authorized, funded, or carried out at a later time, and any take of a listed species would not occur unless and until those future action(s) are authorized, funded, or carried out and subject to further section 7 consultation. These regulations define *mixed programmatic action*, for purposes of an incidental take statement, as a Federal action that approves action(s) that will not be subject to further section 7 consultation, and also approves a framework for the development of future action(s) that are authorized, funded, or carried out at a later time and any take of a listed species would not occur unless and until those future action(s) are authorized, funded, or carried out and subject to further section 7 consultation. Under these regulations, for a framework programmatic action, an Incidental Take Statement is not required at the programmatic level; any incidental take resulting from any action subsequently authorized, funded, or carried out under the program will be addressed in subsequent (Tier 2) section 7 consultation, as appropriate. For a mixed programmatic action, an Incidental Take Statement is required at the programmatic level only for those program actions that are reasonably certain to cause take and are not subject to further section 7 consultation.

This PBO constitutes consultation on a mixed programmatic action. As such, this Incidental Take Statement <u>does not</u> authorize any take for future Corps authorizations, including new, or modified, or renewed authorizations, for existing aquaculture that is in place at the time of this PBO. Incidental take from the authorization of these existing aquaculture operations, and from any new, modified or expanded operations over the 10-year life of this PBO, will be assessed during the Tier 2 process.

The only incidental take authorized in this PBO is as follows.

1. Mortality of up to **315** red knots over the 10-year life of this PBO as a result of harassment (disturbance) and harm (functional habitat loss) that cause reduced survival rates during the 3 of the 10 years. This is a maximum cumulative mortality total expected to result from all structural aquaculture in the action area over the next 10 years. We will not attempt to apportion this estimated maximum mortality total of 315 red knots among various individual aquaculture operations during the Tier 2 process because we do not believe it can be reasonably assessed at the scale of individual farms.

2. For the operation of Dias Creek Oyster Company (CENAP-OP-R-2012-798-24) on Lease A-19 in accordance with the provisions (permit conditions) specified in Appendix C from the effective date of this PBO through March 18, 2017, non-lethal incidental take of up to **644** red knots from the combined effects of: (a) harassment from disturbance caused by aquaculture activities; and (b) functional habitat loss of up to 7.3 acres (3.0 ha) of intertidal foraging habitat (but outside of the highest-value habitats, *i.e.*, Protected Areas). The calculations supporting this projection of incidental take are shown in Table 14. From the range shown in the table of 266 to 1,021 red knots shown in Table 14, we find a mid-point of 644 is more appropriate than the maximum of 1,021, because low-tide access will occur only twice per week during the red knot stopover season, there will be no driving or crossing of the Protected Areas during the stopover season, and the footprint of gear (not counting spaces and lanes) is small (1,800 square feet [0.04 acre, 167 square m]). (We do not anticipate any harassment of red knots as a result of high-tide access, based on the buffer distance that will be maintained from the water's edge.) Any impacts to the survival of these 644 birds as a result of this incidental take was accounted for in #1, above.

**Table 14. Possible range of incidental take from operations on Lease A-19 through March 18, 2017**

| Survey Segment | Length of Intertidal Aquaculture in Segment (feet) | Length of Intertidal Aquaculture on Lease A-19 (feet) | Segment-wide Range of Incidental Take | Range of Incidental Take attributed to Lease A-19 |
|---|---|---|---|---|
| 9 | 990 | 990 (100%) | 218 to 668 | 218 to 668 |
| 8 | 1,520 | 420 (28%) | 172 to 1,260 | 48 to 353 |
| **Total** | | | | **266 to 1,021** |

As per CMs 20 and 21, this permittee may continue to operate on Lease A-19 under the provisions of Appendix C until one year after this permittee has been offered an intertidal growing area within an ADZ, or on June 8, 2018, whichever comes first. If no ADZ intertidal growing area has been offered and if this grower wishes to renew the existing Corps authorization under NWP-48 (conditioned as per Appendix C), a Tier 2 consultation will be necessary and any further incidental take will be assessed at that time.

3. For the operation of Sweet Amalia Oyster Farm (CENAP-OP-R-2014-970-24) on Lease A-28 in accordance with the provisions (permit conditions) specified in Appendix D from the effective date of this PBO through March 18, 2017, non-lethal incidental take of up to **641** red knots from the combined effects of: (a) harassment from disturbance caused by aquaculture activities; and (b) functional habitat loss of up to 7.3 acres (3.0 ha) of intertidal foraging habitat (but outside of the highest-value habitats, *i.e.*, Protected Areas). The calculations supporting this projection of incidental take are shown in Table 15. From the range of 124 to 907 red knots shown in Table 15, we find a somewhat higher than mid-point (641) is more appropriate than the maximum of 907, because access is only twice per week during the red knot stopover season and there will be no driving

during the stopover season. Any impacts to the survival of these birds as a result of this incidental take was accounted for in #1, above.

**Table 15. Possible range of incidental take from operations on Lease A-28 through March 18, 2017**

| Survey Segment | Length of Intertidal Aquaculture in Segment (feet) | Length of Intertidal Aquaculture on Lease A-28 (feet) | Segment-wide Range of Incidental Take | Range of Incidental Take attributed to Lease A-28 |
|---:|---:|---:|---:|---:|
| 8 | 1,520 | 1,100 (72%) | 172 to 1,260 | 124 to 907 |

As per CMs 20 and 21, this permittee may continue to operate on Lease A-28 under the provisions of Appendix D until one year after this grower has been offered an intertidal growing area within an ADZ, or on June 8, 2018, whichever comes first. If no ADZ intertidal growing area has been offered and if this permittee wishes to renew the existing Corps authorization under NWP-48 (conditioned as per Appendix D), a Tier 2 consultation will be necessary and any further incidental take assessed at that time.

## EFFECT OF THE TAKE

The Service has determined that the level of take anticipated, as described above, from the Corps Program is not likely to result in jeopardy to the species or destruction or adverse modification of critical habitat.

## REASONABLE AND PRUDENT MEASURES

Reasonable and Prudent Measures (RPMs) are measures considered necessary or appropriate to minimize the amount or extent of anticipated incidental take of the species. The Service has concluded that the below RPMs are necessary and appropriate to minimize take of red knots. In order to be exempt from the prohibitions of Section 9 of the ESA, the Corps and its permittees must comply with the below terms and conditions, which implement the RPMs and outline monitoring and reporting requirements. The RPMs and associated terms and conditions are nondiscretionary, and must be implemented by the Corps.

The Corps has a continuing duty to regulate the activity covered by this incidental take statement. If the Corps: (1) fails to demonstrate clear compliance with the RPMs and their implementing terms and conditions in this PBO; or (2) fails to require Corps staff or permittees to adhere to the terms and conditions of the incidental take statement; and/or (3) fails to retain oversight to ensure compliance with these terms and conditions, the protective coverage of section 7(o)(2) may lapse.

**RPM 1:** Ensure that all growers are fully informed and compliant with all CMs contained in this BPO.

**RPM 2:** Ensure that all State agencies and organizations involved in any aspect of aquaculture are fully informed of the CMs contained in this PBO.

**RPM 3:** Follow all Federal, regional, and State requirements and guidelines, and industry best practices, to avoid the introduction or spread of non-native organisms.

**RMP 4:** Follow best practices to avoid spills or leaks of oil and gas within the action area.

**RPM 5:** Report on the progress of the action and its impact on the species, as required pursuant to 50 CFR 402.14(i)(3).

## TERMS AND CONDITIONS

RPM 1: Terms and Conditions

1.1 The Corps or its designated non-Federal representative (*i.e.*, NJDFW) shall distribute a full copy of the CMs to all existing growers (both authorized and unauthorized) within 30 days of the effective date of this PBO.

1.2 The Corps or its designated non-Federal representative (*i.e.*, NJDFW) shall promptly provide a full copy of the CMs to any future prospective growers upon inquiry or application for a shellfish lease or authorization.

1.3 Following each annual adaptive management meeting (CM 6), the NJDFW will communicate an update to all growers regarding any pertinent new information reviewed by the agencies and any modifications to the CMs agreed upon by the agencies. This may be accomplished through an in-person and/or web based information session, but must also be accompanied by written communication via U.S. mail or electronic mail to each authorized grower within 60 days.

1.4 The NJDFW shall ensure, through lease agreements or other means, that all growers in an ADZ comply with all provisions of this PBO. The NJDFW shall work with other State agencies and organizations (see RPM 2) to ensure that all non-ADZ growers comply with all provisions of this PBO within the limits of each agency/organization's purview and authority. (Of course, the applicable CMs will also be conditions of each Corps authorization, following the Tier 2 consultation process.)

RPM 2: Terms and Conditions

2.1 The Corps or its designated non-Federal representative (*i.e.*, NJDFW) shall distribute a full copy of the CMs to all agencies and organizations listed under Action Implementation within 60 days of the effective date of this PBO.

2.2 Following each annual adaptive management meeting (CM 6), the NJDFW will communicate an update to all agencies and organizations listed under Action Implementation regarding any pertinent new information and any modifications to the CMs within 60 days.

RPM 3: Terms and Conditions

3.1 At or before the first annual adaptive management meeting (CM 6), the Corps or its designated non-Federal representative (*i.e.*, NJDFW) shall circulate to the Service and to all agencies and organizations listed under Action Implementation draft Best Practices Guidelines for growers to minimize the risk of introducing or spreading non-native organisms, including but not limited to invasive beach vegetation, non-native invertebrates, parasites, pathogens, and hitchhikers. The Best Practices Guidelines shall be based on best available commercial and scientific data, including any applicable industry standards and regulations. The Best Practices Guidelines shall be finalized within one year of the effective date of this PBO, and shall be reviewed during each annual adaptive management meeting. The Best Practices Guidelines shall be attached to the CMs that are periodically distributed to all growers, agencies, and organization under RPMs 1 and 2.

3.2 The NJDEP will use its existing authorities and industry best practices to avoid the introduction or spread of non-native organisms, including implementation of the Best Practices Guidelines by all growers. State law at N.J.S.A. Title 50 requires approval from NJDEP before any shellfish can be planted within the waters of the State. "The commissioner may issue such permission after due inspection and examination of the nature, species, quantity, source, location of proposed planting or lodging, and the condition of the shellfish and after the commissioner's determination that the same will not be detrimental to the native shellfish or to the shellfish industry of this State. The permission shall specify the nature, species, quantity and proposed location of planting or lodgment of the shellfish." (50:1-35).

RPM 4: Terms and Conditions

4.1 The Corps or its designated non-Federal representative (*i.e.*, NJDFW) shall ensure that growers conduct all fueling and servicing of power washers, ATVs, and any other powered equipment in uplands outside of the action area.

4.2 The Corps or its designated non-Federal representative (*i.e.*, NJDFW) shall ensure that growers maintain all power washers, ATVs, and any other powered equipment in good condition. Under no circumstances will equipment be permitted in the action area with visible signs of a gas or oil leak.

RPM 5: Terms and Conditions

5.1 Exercise care in handling any specimens of dead or injured red knots to preserve biological material in the best possible state. In conjunction with the preservation of any specimens, the finder has the responsibility to ensure that evidence intrinsic to determining the cause of death of the specimen is not unnecessarily disturbed. The finding of dead or non-viable specimens does not imply enforcement proceedings pursuant to the ESA. The reporting of dead specimens is required to enable the Service to determine if take is reached or exceeded and to ensure that the terms and conditions are appropriate and effective.

The discovery of a dead bird must be reported to the following Service Law Enforcement office:

Senior Resident Agent
U.S. Fish and Wildlife Service
Division of Law Enforcement
Sea Land Building, 2nd Floor
1210 Corbin Street
Elizabeth, New Jersey 07201
(973) 645-5910

## COORDINATION OF INCIDENTAL TAKE STATEMENT WITH OTHER LAWS, REGULATIONS, AND POLICIES

The Service will not refer the incidental take of any migratory bird for prosecution under the Migratory Bird Treaty Act of 1918, as amended (16 U.S.C. S 703-712), if such take is in compliance with the Terms and Conditions specified herein. Take resulting from activities that are not in conformance with this PBO (*e.g.*, deliberate harassment of wildlife) are not considered part of the proposed action and are not covered by this Incidental Take Statement and may be subject to enforcement action against the individual responsible for the act.

## CONSERVATION RECOMMENDATIONS

Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information. The Service recommends the Corps or its designated non-Federal representative (*i.e.*, NJDFW) carry out the following actions to further red knot recovery.

1. Continue the Rutgers study to investigate both displacement and behavioral changes of red knots due to human activities associated with aquaculture, as well as functional habitat loss as result of the gear itself. Seek to determine threshold distances at which red knots react to various types of human activity and various types of gear, and other information useful to the adaptive management process.

2. Conduct targeted annual red knot surveys at all stages of the tidal cycle covering the entire the intertidal zone from Green Creek to West Miami Avenue, in order to inform future management decisions regarding possible ADZ expansion.

3. Research the potential effects, both beneficial and adverse, of structural aquaculture on horseshoe crabs, with the objective of informing the adaptive management process.

4. Maintain favorable conditions for red knots in the action area, as described under Environmental Baseline, through habitat maintenance/restoration and management of recreational and other non-aquaculture human activities.

5. Continue annual baywide red knot surveys, monitoring, research, and management to provide the agencies with current high-quality information on which to base management decisions, and supply the Service with such information for use in our evaluation of individual Corps actions during the Tier 2 process (including assessment of incidental take).

6. Develop rigorous adaptive management practices to address recurrent decisions about siting and managing oyster culture within the action area. Adaptive management incorporates clearly articulated hypotheses about specific effects (or lack thereof), as well as commitments to monitor and to evaluate the monitoring results relative to the hypotheses (Williams *et al*. 2009). The Service's National Conservation Training Center offers Structured Decision Making workshops that provide support and expertise to natural resource managers facing real-world decisions that are well-suited to this issue.

## REINITIATION – CLOSING STATEMENT

This concludes formal consultation on the action outlined in the request. As provided in 50 CFR 402.16, re-initiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action that may affect listed species in a manner or to an extent not considered in this opinion or the project has not been completed within five years of the issuance of this biological opinion; (3) the agency action is subsequently modified in a manner that causes an effect to the listed species not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action. In instances where the amount or extent of incidental take is exceeded, any operations causing such take must cease pending re-initiation.

For this PBO, the incidental take will be exceeded when total mortality, mainly expected to occur through reduced survival rates and estimated by best available science, exceeds 315 red knots (over the 10-year life of this PBO, not per year or per farm).

For Corps permittees operating on Leases A-19 and A-28 through March 18, 2017, the incidental take will be exceeded when non-lethal incidental take, estimated by best available science, exceeds 644 and 641 red knots, respectively, and/or when the intertidal area impacted by gear exceeds 7.3 acres (3.0 ha) per farm.

# REFERENCES CITED

## LITERATURE CITED


Anders, F.J., and S.P. Leatherman. 1987. Disturbance of beach sediment by off-road vehicles. Environmental Geology and Water Sciences 9:183-189.

Andres, B.A. 2009. Analysis of shorebird population trend datasets. Unpublished report by the U.S. Fish and Wildlife Service, Denver, Colorado.

Atkinson, P.W., A.J. Baker, K.A. Bennett, N.A. Clark, J.A. Clark, K.B. Cole, A. Dekinga, A. Dey, S. Gillings, P.M. González, K. Kalasz, C.D.T. Minton, J. Newton, L.J. Niles, T. Piersma, R.A. Robinson, and H. Sitters. 2007. Rates of mass gain and energy deposition in red knot on their final spring staging site is both time- and condition-dependent. Journal of Applied Ecology 44:885-895.

Atkinson, P.W., A.J. Baker, K.A. Bennett, N.A. Clark, J.A. Clark, K.B. Cole, A. Dey, S. Gillings, P.M. González, B.A. Harrington, C.D.T. Minton, I. de Lima Serrano, J. Newton, L.J. Niles, R.A. Robinson, and H.P. Sitters. 2006. Hard or soft-shelled? Migration strategy determines resource use by red knot on their final stopover in Delaware Bay. Pages 41 *In* International Wader Study Group Annual Conference, October 13-17, 2006, Wader Study Group.

Atkinson, P.W., G.F. Appleton, J.A. Clark, N.A. Clark, S. Gillings, I.G. Henderson, R.A. Robinson, and R.A. Stillman. 2003. Red Knots *Calidris canutus* in Delaware Bay 2002. Survival, foraging and marking strategy. Research report no. 308. British Trust for Ornithology, Norfolk, United Kingdom.

Atkinson, P.W., I.G. Henderson, and N.A. Clark. 2002. A preliminary analysis of the survival rates of red knots *Calidris canutus rufa* passing through the State of Delaware 1997-2001. British Trust for Ornithology, Norfolk, United Kingdom.

Atlantic States Marine Fisheries Commission [ASMFC]. 2015. ASMFC horseshoe crab and Delaware Bay ecosystem Technical Committees meeting summary. Arlington, Virginia. 11 pp.

Atlantic States Marine Fisheries Commission [ASMFC]. 2013. September 24, 2013 meeting summary. ASMFC, Horseshoe Crab Delaware Bay Ecosystem Technical Committee. Arlington, Virginia. 12 pp.

Atlantic States Marine Fisheries Commission [ASMFC]. 2012. Delaware Bay Ecosystem Technical Committee report – species reports September 5 – 6, 2012. Unpublished report to the ASMFC.

Atlantic States Marine Fisheries Commission [ASMFC]. 2004. Horseshoe crab 2004 stock assessment report. ASMFC, Washington, DC. 87 pp.

Babb, R.M. 2005. Newsletter of the Partnership for the Delaware Estuary: A National Estuary Program. Estuary News 15(3):4-6. https://s3.amazonaws.com/delawareestuary/pdf/EstuaryNews/2005/ENSpring05.pdf

Baker, A.J., P.M. González, T. Piersma, L.J. Niles, d.N. de Lima Serrano, P.W. Atkinson, N.A. Clark, C.D.T. Minton, M.K. Peck, and G. Aarts. 2004. Rapid population decline in red knots: Fitness consequences of decreased refuelling rates and late arrival in Delaware Bay. Proceedings of the Royal Society Biological Sciences Series B 271(1541):875-882.

Berkson, J., and C.N.J. Shuster. 1999. The horseshoe crab: The battle for a true multiple-use resource. Fisheries Management 24(11):6-10.

Bimbi, M., F. Sanders, J. Thibault, D. Catlin, M. Freidrich, and K. Hunt. 2014. Ongoing conservation efforts for shorebirds in South Carolina. Unpublished PowerPoint presentation. USWFS South Carolina Field Office, Charleston, South Carolina.

Botton, M.L. 1984. Effects of laughing gulls and shorebird predation on the intertidal fauna at Cape May, New Jersey. Estuarine Coastal Shelf Science 18:209-220.

Botton, M.L. and R.E. Loveland. 2003. Abundance and dispersal potential of horseshoe crab (*Limulus polyphemus*) Larvae in the Delaware Estuary. Estuaries 26(6):1472–1479.

Botton, M.L., R.E. Loveland, and T.R. Jacobsen. 1994. Site selection by migratory shorebirds in Delaware Bay, and its relationship to beach characteristics and abundance of horseshoe crab (*Limulus polyphemus*) eggs. The Auk 111(3):605-616.

Botton, M.L., R.E. Loveland, and T.R. Jacobsen. 1992. Overwintering by trilobite larvae of the horseshoe crab *Limulus polyppemus* on a sandy beach of Delaware Bay (New Jersey USA). Mar. Ecol. Prog. Ser. 88:289-292.

Botton, M.L., R.E. Loveland, and T.R. Jacobsen. 1988. Beach erosion and geochemical factors: Influence on spawning success of horseshoe crabs (*Limulus polyphemus*) in Delaware Bay. Marine Biology 99(3):325-332.

Botton, M.L., and J.W. Ropes. 1987. Populations of horseshoe crabs, *Limulus polyphemus*, on the northwestern Atlantic continental shelf. Fishery Bulletin 85(4):805-812.

Brown, S.W. 2012. Salinity tolerance of the oyster mudworm *Polydora websteri*. Honors Thesis, University of Maine. 33 pp. http://digitalcommons.library.umaine.edu/cgi/viewcontent.cgi?article=1040&context=honors

Brown, S., C. Hickey, B. Harrington, and R. Gill editors. 2001. The U.S. shorebird conservation plan, 2nd edition. Manomet Center for Conservation Sciences, Manomet, Massachusetts.

Buehler, D.M., and T. Piersma. 2008. Travelling on a budget: Predictions and ecological evidence for bottlenecks in the annual cycle of long-distance migrants. Phil. Trans. R. Soc. B 363:247-266.

Burger, J. 1986. The effect of human activities on shorebirds in two coastal bays in the Northeastern United States. Environmental Conservation 13:123-130.

Burger, J. L., J. Niles, A.D. Dey, T. Dillingham, A.S. Gates, J. Smith. 2015. An experiment to examine how red knots *Calidris canutus rufa* and other shorebirds respond to oyster culture at Reed's Beach, Delaware Bay, New Jersey. Wader Study Group 122(2): 89–98.

Burger, J., and L.J. Niles. 2014. Effects on five species of shorebirds of experimental closure of a beach in New Jersey: implications for severe storms and sea-level rise. Journal of Toxicology and Environmental Health, Part A, 77:1102–1113.

Burger, J., and L.J. Niles. 2013a. Closure versus voluntary avoidance as a method of protecting migratory shorebirds on beaches in New Jersey. Wader Study Group Bulletin 120(1):20-25.

Burger, J., and L.J. Niles. 2013b. Shorebirds and stakeholders: Effects of beach closure and human activities on shorebirds at a New Jersey coastal beach. Urban Ecosystems 16:657-673.

Burger, J., S.A. Carlucci, C.W. Jeitner, and L. Niles. 2007. Habitat choice, disturbance, and management of foraging shorebirds and gulls at a migratory stopover. Journal of Coastal Research 23(5):1159-1166.

Burger, J., C. Jeitner, K. Clark, and K.J. Niles. 2004. The effect of human activities on migrant shorebirds: Successful adaptive management. Environmental Conservation 31(4):283-288.

Burger, J., K.L. Clark, and L. Niles. 1997. Importance of beach, mudflat and marsh for migrant shorebirds on Delaware Bay. Biological Conservation 79:283-292.

Burger, J., and M. Gochfeld. 1991. Human activity influence and diurnal and nocturnal foraging of sanderlings (*Calidris alba*). The Condor 93:259-265.

Burger, J., M. Gochfeld, and L. Niles. 1995. Ecotourism and birds in coastal New Jersey: Contrasting responses of birds, tourists and managers. Environmental Conservation 22:56-64.

Byers, J.E., K. Cuddington, C.G. Jones, T.S. Talley, A. Hastings, J.G. Lambrinos, J.A. Crooks and W.G. Wilson. 2006. Using ecosystem engineers to restore ecological systems. TRENDS in Ecology and Evolution. 21(9): 493-500.

Carmichael, R.H., M.L. Botton, P.K.S. Shin, S.G. Cheung, eds. 2015. Changing Global Perspectives on Horseshoe Crab Biology, Conservation and Management. Springer, New York. 619 pp.

Clark, K.E., R.R. Porter, and J.D. Dowdell. 2009. The shorebird migration in Delaware Bay. New Jersey Birds 35(4):85-92.

Clark, K.E., L.J. Niles, and J. Burger. 1993. Abundance and distribution of migrant shorebirds in Delaware Bay The Condor 95:694-705.

Coen L.D., R.D. Brumbaugh, D. Bushek, R. Grizzle, M. Luckenbach, M.H. Posey, S.P. Powers, and S.G. Tolley. 2007. Ecosystem services related to oyster restoration. Mar Ecol Prog Ser 341: 303-307.

Cohen, J.B., S.M. Karpanty, J.D. Fraser, and B.R. Truitt. 2010. The effect of benthic prey abundance and size on red knot (*Calidris canutus*) distribution at an alternative migratory stopover site on the US Atlantic Coast. Journal of Ornithology 151:355-364.

Cohen, J.B., S.M. Karpanty, J.D. Fraser, B.D. Watts, and B.R. Truitt. 2009. Residence probability and population size of red knots during spring stopover in the mid-Atlantic region of the United States. Journal of Wildlife Management 73(6):939-945.

Coleman, F.C. and S.L. Williams. 2002. Overexploiting ecosystem engineers: potential consequences for biodiversity. Trends in Ecology and Evolution. 17(1): 40-44.

Conseil Scientifique Régional du Patrimoine Naturel [CSRPN]. 2013. Public comments of November 29, 2013. CSRPN. Cayenne, French Guiana.

Committee on the Status of Endangered Wildlife in Canada [COSEWIC]. 2007. COSEWIC assessment and status report on the red knot *Calidris canutus* in Canada. COSEWIC, Gatineau, Quebec.

Connolly and L.M. and M.A. Colwell. 2005. Comparative use of longline oysterbeds and adjacent tidal flats by waterbirds. Bird Conservation International 15(03): 237-255.

Cuddington, K., J. E. Byers, W. G. Wilson, A. Hastings, eds. 2007. Ecosystem engineers, first edition, plants to protists. Elsevier Academic Press, Burlington, Massachusetts. 432 pp.

Dame, R.F. 2012. Ecology of marine bivalves: an ecosystem approach. Second edition. CRC Press, Boca Raton. 283 pp.

Dealteris, J.T., B.D. Kilpatrick, and R.B. Rheault. 2004. A comparative evaluation of the habitat value of shellfish aquaculture gear, submerged aquatic vegetation and a non-vegetated seabed. Journal of Shellfish Research. 23(3): 867–874.

Dey, A., L. Niles, H. Sitters, K. Kalasz, and R.I.G. Morrison. 2011a. Update to the status of the red knot *Calidris canutus* in the Western Hemisphere, April, 2011, with revisions to July 14, 2011. Unpublished report to the New Jersey Department of Environmental Protection, Division of Fish and Wildlife, Endangered and Nongame Species Program.

Dey, A., K. Kalasz, and D. Hernandez. 2011b. Delaware Bay egg survey: 2005-2010. Unpublished report to the ASMFC. 27 pp.

Duerr, A.E., B.D. Watts, and F.M. Smith. 2011. Population dynamics of red knots stopping over in Virginia during spring migration. Center for Conservation Biology technical report series. College of William and Mary and Virginia Commonwealth University, CCBTR-11-04, Williamsburg, Virginia.

Dumbauld, B.R., J.L. Ruesink, S.S. Rumrill. 2009. The ecological role of bivalve shellfish aquaculture in the estuarine environment: A review with application to oyster and clam culture in West Coast (USA) estuaries. Aquaculture 290(3-4):196-223.

Dunne, P., D. Sibley, C. Sutton, and W. Wander. 1982. 1982 aerial shorebird survey of the Delaware Bay endangered species. New Jersey Birds 9:68-74.

Erbland, P.J. and G. Ozbay. 2008. A comparison of the macrofaunal communities inhabiting a *Crassostrea virginica* oyster reef and oyster aquaculture gear in Indian River Bay, Delaware. Journal of Shellfish Research. 27(4): 757–768.

Escudero, G., J.G. Navedo, T. Piersma, P. De Goeij, and P. Edelaar. 2012. Foraging conditions ‘at the end of the world’ in the context of long-distance migration and population declines in red knots. Austral Ecology 37:355-364.

Farrell, J.G., and C.S. Martin. 1997. Proceedings of the Horseshoe Crab Forum: Status of the resource. University of Delaware, Sea Grant College Program, Newark, Delaware.

Forgues, K. 2010. The effects of off-road vehicles on migrating shorebirds in Maryland and Virginia barrier islands. Trent University, Peterborough, Ontario, Canada. 92 pp.

Food and Agriculture Organization of the United Nations [FAO] and World Bank Group [WBG]. 2015. Aquaculture zoning, site selection and area management under the ecosystem approach to aquaculture. Policy brief. Rome, Italy. 4 pp. http://www.fao.org/3/a-i5004e.pdf

Ford, S.E. 1997. History and present status of molluscan shellfisheries from Barnegat Bay to Delaware Bay. In: C.L. MacKenzie Jr., V.G. Burrell Jr., A. Rosenfield and W.L. Hobart, editors. The history, present condition, and future of the molluscan fisheries of North and Central America and Europe. Vol. 1. North America: U.S. Department of Commerce. pp.119-140.

Forrest, B.M., N.B. Keeley, G.A. Hopkins, S.C. Webb, and D.M. Clement. 2009. Bivalve aquaculture in estuaries: Review and synthesis of oyster cultivation effects. Aquaculture 298: 1–15.

Foster, C., A. Amos, and L. Fuiman. 2009. Trends in abundance of coastal birds and human activity on a Texas barrier island over three decades. Estuaries and Coasts 32:1079-1089.

Fraser, J.D., S.M. Karpanty, and J.B. Cohen. 2010. Shorebirds forage disproportionately in horseshoe crab nest depressions. Waterbirds 33(1):96-100.

Gaine, N. 2012. Spraying Deterrent Stimuli as a Treatment Method For The Prevention of Biofouling Caused By the Mudworm *Polydora ligni* Webster On New Jersey Oyster Farms. MS Thesis, Rutgers Graduate School. Camden, New Jersey. 81 pp. https://rucore.libraries.rutgers.edu/rutgers-lib/37290/

Galbraith, H., D.W. DesRochers, S. Brown, and J.M. Reed. 2014. Predicting the vulnerabilities of North American shorebirds to climate change.

Galbraith, H., R. Jones, R.A. Park, J.S. Clough, S. Herrod-Julius, B. Harrington, and G. Page. 2002. Global climate change and sea level rise: Potential losses of intertidal habitat for shorebirds. Waterbirds 25:173-183.

Gerasimov, K.B. 2009. Functional morphology of the feeding apparatus of red knot *Calidris canutus*, great knot *C. tenuirostris* and surfbird *Aphriza virgate*. *In* International Wader Study Group Annual Conference, September 18-21, 2009, International Wader Study Group, Norfolk, United Kingdom.

Gerhart, S.D. 2007. A review of the biology and management of horseshoe crabs, with emphasis on Florida populations. Fish and Wildlife Research Institute Technical Report TR-12. Florida Fish and Wildlife Conservation Commission, St. Petersburg, Florida.

Gill, J.A., K. Norris, and W.J. Sutherland. 2001. Why behavioural responses may not reflect the population consequences of human disturbance. Biological Conservation 97:265-268.

Gillings, S., P.W. Atkinson, A.J. Baker, K.A. Bennett, N.A. Clark, K.B. Cole, P.M. González, K.S. Kalasz, C.D.T. Minton, N.J. Niles, and et al. 2009. Staging behaviour in red knot (*Calidris canutus*) in Delaware Bay: Implications for monitoring mass and population size. The Auk 126:54-63.

Gittings, T. and P. O'Donoghue. 2014. Dungarvan Harbour Special Protection Area: appropriate assessment of intertidal oyster cultivation [including consideration of Helvick Head to Ballyquin SPA and Mid-Waterford Coast SPA]. Unpublished Report prepared by Atkins for the Marine Institute. http://www.agriculture.gov.ie/media/migration/fisheries/aquacultureforeshoremanagement/aquaculturelicensing/appropriateassessments/DungarvanHarbourAA240314.pdf

Goss-Custard, J.D., P. Triplet, F. Sueur, and A.D. West. 2006. Critical thresholds of disturbance by people and raptors in foraging wading birds. Biological Conservation 127:88-97.

Grabowski, J.H. 2004. Habitat complexity disrupts predator-prey interactions but not the trophic cascade on oyster reefs. Ecology. 85(4): 995-1004.

Guilfoyle, M.P., R.A. Fischer, D.N. Pashley, and C.A. Lott editors. 2007. Summary of second regional workshop on dredging, beach nourishment, and birds on the north Atlantic coast. ERDC/EL TR-07-26. U.S. Army Corps of Engineers, Washington, DC. http://el.erdc.usace.army.mil/elpubs/pdf/trel07-26.pdf

Guilfoyle, M.P., R.A. Fischer, D.N. Pashley, and C.A. Lott editors. 2006. Summary of first regional workshop on dredging, beach nourishment, and birds on the south Atlantic coast. ERDC/EL TR-06-10. U.S. Army Corps of Engineers, Washington, DC. http://www.fws.gov/raleigh/pdfs/ES/trel06-10.pdf

Guo, X., Y. Wang, G. DeBrosse, D. Bushek, and S. Ford. 2008. Building a Superior Oyster for Aquaculture. The Jersey Shoreline 25(1):7-9. http://hsrl.rutgers.edu/services/JerseyShorelineWinter2008.pdf

Harrington, B.A. 2008. Coastal inlets as strategic habitat for shorebirds in the southeastern United States. DOER technical notes collection. ERDC TN-DOER-E25. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.

Harrington, B.A. 2005. Studies of disturbance to migratory shorebirds with a focus on Delaware Bay during north migration. Unpublished report by the Manomet Center for Conservation Sciences, Manomet, Massachusetts. 23 pp.

Harrington, B.A. 2001. Red knot (*Calidris canutus*). *In* A. Poole, and F. Gill, eds. The birds of North America, No. 563, The Birds of North America, Inc., Philadelphia, Pennsylvania.

Harrington, B.A. 1999. Shorebird migrations; fundamentals for land managers in the United States. An overview of North America's most intriguing migratory birds and the diversity of habits on which they depend. Ducks Unlimited, Memphis, Tennessee. 44 pp.

Harrington, B.A. 1996. The flight of the red knot: A natural history account of a small bird's annual migration from the Arctic Circle to the tip of South America and back. W. W. Norton & Company, New York.

Haskin, E. 2014. Identification of methods to control bio-fouling of cultured eastern oysters, *Crassostrea virginica*, by the tube-building polychaete worm, *Polydora cornuta*. Final Report. Northeast SARE Program. 9 pages. Sustainable Agriculture Research and Education. Cape May Court House, New Jersey. http://mysare.sare.org/sare_project/fne13-780/?page=final

Haskin Shellfish Research Laboratory [Haskin Lab]. 2015. Rutgers Disease Resistant (MSX, Dermo), Cultchless, *C. virginica* price list. 1 p. http://hsrl.rutgers.edu/services/HSRL2015SeedPrices.pdf

Hatch Mott McDonald. 2011. Biological assessment of the effects of sand scraping on piping plover (*Charadrius melodus*) and seabeach amaranth (*Amaranthus pumilus*). Borough of Avalon, Cape May County, New Jersey. 71 pp.

Hilgerloh, G., J. O'Halloran, T.C. Kelly, G.M. Burnell. 2001. A preliminary study on the effects of oyster culturing structures on birds in a sheltered Irish estuary. Hydrobiologia 465:175–180.

Jones, C.G., J.H. Lawton, and M. Shachak. 1997. Positive and negative effects of organisms as physical ecosystem engineers. Ecology 78(7): 1946–1957.

Kalasz, K. 2008. Delaware shorebird conservation plan. Version 1.0. Delaware Natural Heritage and Endangered Species Program Division of Fish and Wildlife, Delaware Department of Natural Resources and Environmental Control, Smyrna, Delaware.

Karpanty, S.M., J. Cohen, J.D. Fraser, and J. Berkson. 2011. Sufficiency of horseshoe crab eggs for red knots during spring migration stopover in Delaware Bay USA Journal of Wildlife Management 75(5):984-994.

Karpanty, S.M., J.D. Fraser, J. Berkson, L. Niles, A. Dey, and E.P. Smith. 2006. Horseshoe crab eggs determine distribution of red knots in the Delaware Bay. Journal of Wildlife Management (70):1704-1710.

Kelly, J.P., J.G. Evans, R.W. Stallcup, D. Wimpfheimer. 1996. Effects of aquaculture on habitat use by wintering shorebirds in Tomales Bay, California. California Fish and Game 82(4)160-174.

Koch, S.L. and P.W.C. Paton. 2014. Assessing anthropogenic disturbances to develop buffer zones for shorebirds using a stopover site. The Journal of Wildlife Management 78(1):58–67.

Kochenberger, R. 1983. Survey of shorebird concentrations along the Delaware bayshore. Peregrine Observer spring 1983. New Jersey Audubon Publications.

Kvist, A., Å. Lindström, M. Green, T. Piersma, and G.H. Visser. 2001. Carrying large fuel loads during sustained bird flight is cheaper than expected. Nature 413:730-732.

Laursen, K., J. Frikke, and J. Kahlert. 2008. Accuracy of 'total counts' of waterbirds from aircraft in coastal waters. Wildlife Biology 14:165-175.

Lathrop, R.G., Jr., L. Niles, D. Merchant, T. Farrell, and C. Licitra. 2013. Mapping the critical horseshoe crab spawning habitats of Delaware Bay. Rutgers Center for Remote Sensing & Spatial Analysis, New Brunswick, New Jersey.

Lathrop, R. G., M. Allen, and A. Love. 2006. Mapping and Assessing Critical Horseshoe Crab Spawning Habitats of Delaware Bay. 38 pp. http://crssa.rutgers.edu/projects/delbay/hcrab/ALS_DelBay_hcrab_report_20060718.pdf

Lathrop, R.G., Jr. 2005. Red knot habitat in Delaware Bay: Status and trends. Unpublished report by the Department of Ecology, Evolution and Natural Resources, Center for Remote Sensing and Spatial Analysis, Rutgers University, New Brunswick, New Jersey.

Lott, C.A., C.S. Ewell Jr., and K.L. Volansky. 2009. Habitat associations of shoreline-dependent birds in barrier island ecosystems during fall migration in Lee County, Florida. U.S. Army Corps of Engineers, ERDC/EL TR-09-14, Washington, DC.

Luckenbach, M. 2007. Potential interactions between clam aquaculture and shorebird foraging in Virginia, U.S.A. Unpublished report by the Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia.

Lyons, J.E. 2015. Red knot stopover population size and stopover ecology at Delaware Bay in 2015. Report to the Delaware Bay ARM Workgroup. Laurel, Maryland. 12 pp.

Mallet, A.L., C.E. Carver, and T. Landry. 2006. Impact of suspended and off-bottom Eastern oyster culture on the benthic environment in eastern Canada. Aquaculture. 255: 362-373.

Manomet. 2008. ISS New Jersey Focal Site Report: Delaware Bay Shoreline of NJ Coast - Fortescue/Egg Island, Reeds Beach to Pierces Point, Thompsons and Moores Beaches. https://www.manomet.org/publications-tools/shorebird-recovery-project/iss-new-jersey-focal-site-report-delaware-bay

Maryland Department of Natural Resources [MDDNR]. 2015. 2014 Fishery Management Plans report to the Legislative Committees. Prepared by MDDNR Fisheries Service, Annapolis, Maryland. MSAR # 8160. 262 pp. http://dnr2.maryland.gov/fisheries/Documents/Full_FMP_2015.pdf

Maslo, B., J.L. Lockwood, D. Bushek, J. Burger. 2016. Effects of oyster aquaculture on foraging shorebirds on Delaware Bay. Preliminary results report—2016 findings for red knots. Rutgers University Department of Ecology, Evolution, and Natural Resources, New Brunswick, New Jersey. 6 pp.

McGowan, C.P. 2015. Comparing models of Red Knot population dynamics. The Condor Ornithological Applications 115: 494–502.

McGowan, C.P., J.E. Hines, J.D. Nichols, J.E. Lyons, D.R. Smith, K.S. Kalasz, L.J. Niles, A.D. Dey, N.A. Clark, P.W. Atkinson, and et al. 2011a. Demographic consequences of migratory stopover: Linking red knot survival to horseshoe crab spawning abundance. Ecosphere 2(6):1-22.

McGowan, C.P., D.R. Smith, J.A. Sweka, J. Martin, J.D. Nichols, R. Wong, J.E. Lyons, L.J. Niles, K. Kalasz, and J. Brust. 2011b. Multi-species modeling for adaptive management of horseshoe crabs and red knots in the Delaware Bay. Natural Resource Modeling 24:117-156.

Mizrahi, D.S. 2002. Shorebird distribution along New Jersey's southern Atlantic Coast: Temporal patterns and effects of human disturbance. Unpublished report to the Edwin B. Forsythe National Wildlife Refuge. 23 pp.

Morrison, R.I.G. 2006. Body transformations, condition, and survival in red knots *Calidris canutus* travelling to breed at Alert, Ellesmere Island, Canada. Ardea 94(3):607-618.

Morrison, R.I.G, B.J. McCaffery, R.E. Gill, S.K. Skagen, S.L. Jones, W. Gary, C.L. Gratto-Trevor, and B.A. Andres. 2006. Population estimates of North American shorebirds Wader Study Group Bull. 111:67-85.

Morrison, R.I.G., N.C. Davidson, and T. Piersma. 2005. Transformations at high latitudes: Why do red knots bring body stores to the breeding grounds? The Condor 107:449-457.

Morrison, R.I.G., K. Ross, and L.J. Niles. 2004. Declines in wintering populations of red knots in southern South America. The Condor 106:60-70.

Morrison, R.I.G., and B.A. Harrington. 1992. The migration system of the red knot *Calidris canutus* in the New World. Wader Study Group Bulletin 64:71-84.

Morrison, R.I.G., and R.K. Ross. 1989. Atlas of Nearctic shorebirds on the coast of South America in two volumes. Canadian Wildlife Service, Ottawa, Canada.

Newell, R.I.E. 2004. Ecosystem influences of natural and cultivated populations of suspension-feeding bivalve mollusks: a review. Journal of Shellfish Research. 23: 51-61.

New Jersey Division of Fish and Wildlife [NJDFW]. 2016. Programmatic Biological Assessment for structural shellfish aquaculture projects for red knot (*Calidris canutus rufa*), Lower Delaware Bay, NJ. Trenton, New Jersey. 106 pp. + Appendices (including Supplement).

New Jersey Division of Fish and Wildlife [NJDFW]. 2013. Seasonal Delaware Bay and Atlantic Coast beach closure location map. http://www.state.nj.us/dep/fgw/ensp/beachclozmap.htm

National Park Service [NPS]. 2013. Public comments of November 21, 2013. NPS, Biological Resource Management Division. Fort Collins, Colorado.

Niles, L.J., J.A.M. Smith, D.F. Daly, T. Dillingham, W. Shadel, A.D. Dey, M.S. Danihel, S. Hafner, and D. Wheeler. 2013a. Restoration of Horseshoe Crab and Migratory Shorebird Habitat on Five Delaware Bay Beaches Damaged by Superstorm Sandy. 22 pp. http://www.smithjam.com/wp-content/uploads/2014/03/RestorationReport_112213.pdf

Niles, L., T. Dillingham, D. Daly, J. Smith, A. Dey, and S. Hafner. 2013b. DRAFT: Creating Resilient Beach and Marsh on Delaware Bay for Shorebirds and Horseshoe Crabs: Seven Restoration Projects for the Future. 41 pp.

Niles, L.J., J. Burger, R.R. Porter, A.D. Dey, S. Koch, B. Harrington, K. Iaquinto, and M. Boarman. 2012a. Migration pathways, migration speeds and non-breeding areas used by northern hemisphere wintering Red Knots *Calidris canutus* of the subspecies *rufa*. Wader Study Group Bulletin 119(2):195-203.

Niles, L., A. Dey, D. Mizrahi, L. Tedesco, and K. Sellers. 2012b. Second report: Damage from Superstorm Sandy to horseshoe crab breeding and shorebird stopover habitat on Delaware Bay. Wetlands Institute, Stone Harbor, New Jersey.

Niles, L.J., J. Burger, R.R. Porter, A.D. Dey, C.D.T. Minton, P.M. González, A.J. Baker, J.W. Fox, and C. Gordon. 2010a. First results using light level geolocators to track red knots in the Western Hemisphere show rapid and long intercontinental flights and new details of migration pathways. Wader Study Group Bulletin 117(2):123-130.

Niles, L.J., H.P. Sitters, A.D. Dey, N. Arce, P.W. Atkinson, V. Ayala-Perez, A.J. Baker, J.B. Buchanan, R. Carmona, N.A. Clark, and et al. 2010b. Update to the status of the red knot *Calidris canutus* in the Western Hemisphere, April 2010. NJDEP, Division of Fish and Wildlife, Endangered and Nongame Species Program.

Niles, L.J., H.P. Sitters, A.D. Dey, P.W. Atkinson, A.J. Baker, K.A. Bennett, R. Carmona, K.E. Clark, N.A. Clark, and C. Espoz. 2008. Status of the red knot (*Calidris canutus rufa*) in the Western Hemisphere. Studies in Avian Biology 36:1-185.

Nordstrom, K.F., N.L. Jackson, D.R. Smith, and R.G. Weber. 2006. Transport of horseshoe crab eggs by waves and swash on an estuarine beach: Implications for foraging shorebirds. Estuarine, Coastal and Shelf Science 70:438-448.

North Carolina Wildlife Resources Commission [NCWRC]. 2013. Public comments of November 27, 2013. NCWRC. Raleigh, North Carolina.

Oesterling M. and C. Petrone. 2012. Non-Commercial oyster culture, or oyster gardening. Southern Regional Aquaculture Center Publication No. 4307. VIMS Marine Resource Report No. 2011-13, VSG-11-12. 12 pp. http://web.vims.edu/library/GreyLit/VIMS/mrr11-13.pdf

Pfister, C., B.A. Harrington, and M. Lavine. 1992. The impact of human disturbance on shorebirds at a migration staging area. Biological Conservation 60(2):115-126.

Piersma, T., and J.A. van Gils. 2011. The flexible phenotype. A body-centred integration of ecology, physiology, and behavior. Oxford University Press Inc., New York.

Piersma, T., D.I. Rogers, P.M. González, L. Zwarts, L.J. Niles, de Lima S. do Nascimento, I., C.D.T. Minton, and A.J. Baker. 2005. Fuel storage rates before northward flights in red knots worldwide: Facing the severest ecological constraints in tropical intertidal environments? Pages 262–273 *In* R. Greenberg, and P.P. Marra, eds. Birds of two worlds: The ecology and evolution of migration, Johns Hopkins University Press, Baltimore, Maryland.

Piersma, T., G.A. Gudmundsson, and K. Lilliendahl. 1999. Rapid changes in the size of different functional organ and muscle groups during refueling in a long-distance migrating shorebird. Physiological and Biochemical Zoology 72(4):405-415.

Piersma, T., R. Hoekstra, A. Dekinga, A. Koolhaas, P. Wolf, P. Battley, and P. Wiersma. 1993. Scale and intensity of intertidal habitat use by knots *Calidris canutus* in the western Wadden Sea in relation to food, friends and foes. Netherlands Journal of Sea Research 31(4):331-357.

Pooler, P.S., D.R. Smith, R.E. Loveland, M.L. Botton, and S.F. Michels. 2003. Assessment of sampling methods to estimate horseshoe crab (*Limulus polyphemus* L.) egg density in Delaware Bay. Fisheries Bulletin 101(3):698-703.

Prins, T.C., A.C. Smaal, and R.F. Dame. 1998. A review of the feedbacks between bivalve grazing and ecosystem processes. Aquatic Ecology. 31: 349-359.

reTURN the Favor. 2016. Rescue stranded horseshoe crabs. http://returnthefavornj.org/

Robinson, R.A., P.W. Atkinson, and N.A. Clark. 2003. Arrival and weight gain of Red Knot *Calidris canutus*, Ruddy Turnstone *Arenaria interpres* and Sanderling *Calidris alba* staging in Delaware Bay in spring. British Trust for Ornithology, BTO Research Report No. 307, Norfolk, United Kingdom.

Rogers, D.I., T. Piersma, and C.J. Hassell. 2006. Roost availability may constrain shorebird distribution: Exploring the energetic costs of roosting and disturbance around a tropical bay. Biological Conservation 133:225-235.

Schlacher, T.A., and L.M.C. Thompson. 2008. Exposure of fauna to off-road vehicle (ORV) traffic on sandy beaches. Coastal Management 35:567-583.

Schlacher, T.A., D.S. Schoeman, J. Dugan, M. Lastra, A. Jones, F. Scapini, and A. McLachlan. 2008a. Sandy beach ecosystems: Key features, sampling issues, management challenges and climate change impacts. Marine Ecology 29((Suppl. 1)):70-90.

Schlacher, T.A., L.M.C. Thompson, and S.J. Walker. 2008b. Mortalities caused by off-road vehicles (ORVs) to a key member of sandy beach assemblages, the surf clam *Donax deltoids*. Hydrobiologia 610:345-350.

Schlacher, T.A., D. Richardson, and I. McLean. 2008c. Impacts of off-road vehicles (ORVs) on macrobenthic assemblages on sandy beaches. Environmental Management 41:878-892.

Sheppard, N., K.A. Pitt, and T.A. Schlacher. 2009. Sub-lethal effects of off-road vehicles (ORVs) on surf clams on sandy beaches. Journal of Experimental Marine Biology and Ecology 380:113-118.

Shuster, C.N., Jr., R.B. Barlow, and J.H. Brockmann editors. 2003. The American horseshoe crab. Harvard University Press, Cambridge, Massachusetts.

Shuster, C.N., and M.L. Botton. 1985. A contribution to the population biology of horseshoe crabs, *Limulus polyphemus* (L), in Delaware Bay. Estuaries 8(4):363-372.

Smith, D.R. 2007. Effect of horseshoe crab spawning density on nest disturbance and exhumation of eggs: A simulation study. Estuaries and Coasts 30(2):287-295.

Smith, D.R. and T.J. Robinson. 2015. Horseshoe crab spawning activity in Delaware Bay, USA, after harvest reduction: a mixed-model analysis. Estuaries and Coasts 36(6): 2345-2354.

Smith, D.R., N.L. Jackson, K.F. Nordstrom, and R.G. Weber. 2011. Beach characteristics mitigate effects of onshore wind on horseshoe crab spawning: Implications for matching with shorebird migration in Delaware Bay. Animal Conservation 14:575-584.

Smith, D.R., and S.F. Michels. 2006. Seeing the elephant: Importance of spatial and temporal coverage in a large-scale volunteer-based program to monitor horseshoe crabs. Fisheries 31(10):485-491.

Smith, D.R., P.S. Pooler, R.E. Loveland, M.L. Botton, S.F. Michels, R.G. Weber, and D.B. Carter. 2002. Horseshoe crab (*Limulus polyphemus*) reproductive activity on Delaware Bay beaches: Interactions with beach characteristics. Journal of Coastal Research 18(4):730-740.

Stephenson, G. 1999. Vehicle impacts on the biota of sandy beaches and coastal dunes: A review from a New Zealand perspective. Department of Conservation, Wellington, New Zealand. 44 pp. + Appendices. http://www.doc.govt.nz/Documents/science-and-technical/sfc121.pdf

Stern, L. 2009. Impact of sea level rise on foraging habitats for migratory shorebirds in Cape May County, New Jersey. Unpublished report by Rutgers University, New Brunswick, New Jersey.

Stillman, R.A., A.D. West, R.W.G. Caldow, and Durell, S. E. A. le V. dit. 2007. Predicting the effect of disturbance on coastal birds. Ibis 149(Suppl. 1):73-81.

Swan, B.L. 2005. Migrations of adult horseshoe crabs, *Limulus polyphemus*, in the Middle Atlantic Bight: A 17-year tagging study. Estuaries (28):28-40.

Tanacredi, J.T., M.L. Botton, and D. Smith. 2009. Biology and conservation of horseshoe crabs. Springer, New York.

Tarr, N.M. 2008. Fall migration and vehicle disturbance of shorebirds at South Core Banks, North Carolina. North Carolina State University, Raleigh, North Carolina. 185 pp.

Taylor J. 2008. Evaluation of the ecological value of constructed intertidal oyster reefs and aquaculture structures in Delaware Bay. MS Thesis, Rutgers University Graduate School, New Brunswick, New Jersey. 77 pp. https://rucore.libraries.rutgers.edu/rutgers-lib/24969/

Taylor, J. and D. Bushek. 2008. Intertidal oyster reefs can persist and function in a temperate North American Atlantic estuary. Mar Ecol Prog Ser 361: 301–306.

U.S. Fish and Wildlife Service [USFWS]. 2016a. Hurricane Sandy Recovery, Building a Stronger Coast. Increase Resilience of Delaware Bay Beach Habitat. http://www.fws.gov/hurricane/sandy/projects/DEBayBeachHabitat.html

U.S. Fish and Wildlife Service [USFWS]. 2016b. Letter to New Jersey Division of Land Use Management regarding Federal Consistency Determination for Cooks and Kimbles Beaches, Cape May County, New Jersey. Galloway, New Jersey. 5 pp. + Appendices.

U.S. Fish and Wildlife Service [USFWS]. 2015. Intra-Service Section 7 Biological Evaluation Form, Reeds Beach Oyster Reef. Pleasantville, New Jersey. 10 pp.

U.S. Fish and Wildlife Service [USFWS]. 2014. Rufa red knot background information and threats assessment. Supplement to Endangered and Threatened Wildlife and Plants; Final Threatened Status for the Rufa Red Knot (*Calidris canutus rufa*) [Docket No. FWS–R5–ES–2013–0097; RIN AY17]. Pleasantville, New Jersey. 376 pp. + Appendices. http://www.fws.gov/northeast/redknot/pdf/20141125_REKN_FL_supplemental_doc_FINAL.pdf

U.S. Fish and Wildlife Service [USFWS]. 2011. Draft biological opinion on the effects of backpassing on the federally listed (threatened) piping plover (*Charadruis melodus*) and sea-beach amaranth (*Amaranthus pumilus*) in Avalon Borough, Cape May County, New Jersey, 2011 to 2017. USFWS New Jersey Field Office, Pleasantville, New Jersey.

U.S. Fish and Wildlife Service [USFWS]. 2003. Delaware Bay shorebird-horseshoe crab assessment report and peer review. ASMFC, Arlington, Virginia.

U.S. Fish and Wildlife Service [USFWS] and National Marine Fisheries Service [NMFS]. 1998. Endangered Species Consultation Handbook, Procedures for conducting consultation and conference activities under Section 7 of the Endangered Species Act. https://www.fws.gov/ENDANGERED/esa-library/pdf/esa_section7_handbook.pdf

van Gils, J.A., P.F. Battley, T. Piersma, and R. Drent. 2005a. Reinterpretation of gizzard sizes of red knots world-wide emphasis overriding importance of prey quality at migratory stopover sites. Proceedings of the Royal Society of London, Series B 272:2609-2618.

van Gils, J.A., A. Dekinga, B. Spaans, W.K. Vahl, and T. Piersma. 2005b. Digestive bottleneck affects foraging decisions in red knots (*Calidris canutus*). II. Patch choice and length of working day. Journal of Animal Ecology 74:120-130.

Walls, E.A., J. Berkson, and S.A. Smith. 2002. The Horseshoe Crab, *Limulus polyphemus*: 200 Million Years of Existence, 100 Years of Study. Reviews in Fisheries Science 10(1):39-73.

Walton, B., J.E. Davis, G. Chaplin, F.S. Rikard, D.L. Swann, and T. Hanson. 2012. Bottom oyster farming gear types fact sheets. Mississippi – Alabama Sea Grant Program and Alabama Cooperative Extension Service, MASGP Publication Nos. 12-013-01 through 04. http://masgc.org/publications/details/off-bottom-oyster-farming-gear-types

Watts, B. 2009. Red knot resight data indicates flux between two migration staging areas. Available at http://www.ccb-wm.org/news/2009_SeptDec/redKnot_resights.html.

Wander, W., and P. Dunne. 1982. Species and numbers of shorebirds on the Delaware bayshore of New Jersey - spring 1981, Occasional Paper Number 140. Records of N.J. Birds 7(4):59-64.

West, A.D., J.D. Goss-Custard, R.A. Stillman, Caldow, Richard W. G. S., Dit Durell, S. E. A. Le V., and S. McGrorty. 2002. Predicting the impacts of disturbance on shorebird mortality using a behaviour-based model. Biological Conservation 106(3):319-328.

Williams, B.K., R.C. Szaro, and C. D. Shapiro. 2009. Adaptive Management: The U.S. Department of the Interior Technical Guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC. 72 pp. https://www.usgs.gov/sdc/doc/DOI-%20Adaptive%20ManagementTechGuide.pdf

Wright, B.R., B. Nuse, J. Burkman. 2011. Horseshoe crab impingement reduction at Calvert Cliffs Power Plant Unit 1 and Unit 2 Presented to JEC, March 23, 2011. http://pbadupws.nrc.gov/docs/ML1109/ML110970435.pdf

Zimmerman, J. E. Hale, D. Smith, S. Bennett. 2015. Horseshoe crab spawning activity in Delaware Bay: 1999 – 2014. Report to the Atlantic States Marine Fisheries Commission's Horseshoe Crab Technical Committee. 15 pp.

Zwarts, L., and A.M. Blomert. 1992. Why knot *Calidris canutus* take medium-sized *Macoma balthica* when six prey species are available. Marine Ecology Progress Series 83:113-128.

## PERSONAL COMMUNICATIONS

Babb, R. 2016. Supervising Fisheries Biologist. Email of November 13, 2015. Marine Fisheries Administration, Bureau of Shellfisheries. Port Republic, New Jersey.

Burger, J. 2016. Professor. E-mails of February 29, 2016 and March 15, 2016. Rutgers University, Division of Life Sciences. Piscataway, New Jersey.

Burger, J. 2014. Professor. E-mail of September 28, 2014. Rutgers University, Division of Life Sciences. Piscataway, New Jersey.

Conrad, K. 2015. Fish and Wildlife Biologist. Email of October 28, 2015. U.S. Fish and Wildlife Service, New Jersey Field Office, Pleasantville, New Jersey.

Harrington, B. 2013. Senior Scientist Emeritus. Public comments of November 14, 2013. Manomet Center for Conservation Sciences, Plymouth, Massachusetts

Kalasz, K. 2012. Biologist. E-mail of November 26, 2012. Delaware Department of Natural Resources and Environmental Control, Delaware Shorebird Project. Dover, Delaware.

Niles, L. 2015. LJ Niles Associates LLC. E-mail of August 26, 2015. Greenwich, New Jersey.

Niles, L. 2012. Consulting Biologist/Leader. E-mails of November 19 and 20, 2012. International Shorebird Project, Conserve Wildlife Foundation of New Jersey. Greenwich, New Jersey.

Wenczel, A. 2016. Aquacultural Development Specialist. Email dated March 15, 2016. New Jersey Department of Agriculture, Trenton, New Jersey.

## APPENDIX A. DEFINITIONS

action area = all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR 402.02)

adaptive management = a flexible decision making process that can be adjusted as outcomes from management actions and other events become better understood

amplexus = a type of mating behavior exhibited by some externally fertilizing species in which a male grasps a female with his front legs and fertilizes the eggs as they are released from the female's body. In horseshoe crabs, the male grasps with his first pair of legs a pair of projections at the posterior end of the female's carapace.

aquaculture = the farming of aquatic organisms such as fish, crustaceans, molluscs and aquatic plants

aquaculture development zone (ADZ) = an aquaculture area where farms share a common waterbody or water source and that benefit from a common management system aimed at minimizing environmental, social and animal health risks. In New Jersey, the shellfish ADZs in Delaware Bay have been identified for structural aquaculture development and are managed to minimize environmental, social and user group conflicts while streamlining the permitting process that growers are must navigate.

aquaponics = systems that combine conventional finfish aquaculture with the hydroponic cultivation of plants

area occupied by the species at the time it is listed on which are found those physical or biological features that are essential to the conservation of the species and that which may require special management considerations or protection; and (2) specific areas outside the geographical area occupied by the species at the time it is listed upon a determination that such areas are essential for the conservation of the species. (50 CFR 17 and 226)

array = specific to this PBO, a configuration or arrangement of gear into groups or units

arthropod = an invertebrate animal having an exoskeleton (external skeleton), a segmented body, and jointed appendages (phylum Arthropoda)

biofouling = the accumulation of microorganisms, plants, algae, or animals on wetted surfaces

bivalve = a class of marine and freshwater molluscs that have laterally compressed bodies enclosed by a shell consisting of two hinged parts (phylum Mollusca, class Bivalvia)

Cape Shore = the Delaware Bay shoreline of New Jersey's Cape May peninsula

carapace = a dorsal (upper) section of the exoskeleton or shell in a number of animal groups, including arthropods (*e.g.*, arachnids, crustaceans, horseshoe crabs) as well as vertebrates such as turtles and tortoises

Clam Line = a legal boundary established in New Jersey State law (N.J.S.A. Title 50) that separates three open access shellfish harvesting areas from traditional shellfish lease areas

conservation measures = actions to benefit or promote the recovery of listed species that are included by the Federal agency as an integral part of the proposed action. These actions will be taken by the Federal agency or applicant (*i.e.*, once adopted, Conservation Measures are non-discretionary), and serve to minimize or compensate for project effects on the species under review. These may include actions taken prior to the initiation of consultation, or actions that the Federal agency or applicant have committed to complete in a BA or similar document.

critical habitat = for species listed under the ESA: (1) the specific areas within the geographical

cumulative effects = as used in the context of consultations under Section 7 of the ESA, those effects of future State or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation (50 CFR 402.02)

dermo = a disease causing high mortality in oyster populations, caused by a pathogenic species of protest (*Perkinsus marinus*) belonging to the phylum Perkinsozoa.

emergency = a situation involving an act of God, disasters, casualties, national defense or security emergencies, etc. (*e.g.*, hurricane), and includes response activities that must be taken to prevent imminent loss of human life or property environmental baseline = in the context of consultations under Section7 of the ESA, the past and present impacts of all Federal, State, or private actions and other human activities in an action area, the anticipated impacts of all proposed Federal projects in an action area that have already undergone Section 7 consultation, and the impact of State or private actions that are contemporaneous with the consultation in process (50 CFR 402.02)

harass = intentional or negligent actions that create the likelihood of injury to a listed species by annoying it to such an extent as to significantly disrupt normal behavior patterns, which include, but are not limited to, breeding, feeding, or sheltering

harm = significant habitat modification or degradation that results in the death or injury to listed species by significantly impairing essential behavioral patterns such as breeding, feeding, or sheltering

husbandry = any activity related to the cultivation and management of shellfish on a leased or granted ground

incidental take = take that is incidental to, and not the purpose of carrying out an otherwise lawful activity

intertidal = the part of the littoral zone between the mean higher high water (MHHW) and mean lower low water (MLLW) lines that is alternately flooded and exposed by tides

intertidal aquaculture = for purposes of this PBO, structural aquaculture of native bivalve species in the intertidal zone such that gear is exposed at Mean Low Water (MLW)

jeopardize the continued existence of a listed species = under ESA, to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species (50 CFR 402.02)

littoral = of, relating to, or situated on the shore of the sea

Mean High Water (MHW) = the average of all the high water heights observed over the National Tidal Datum Epoch (NTDE). The NTDE is the specific 19-year period adopted by the National Ocean Service as the official time segment over which tide observations are taken. The present NTDE is 1983 through 2001.

Mean Higher High Water (MHHW) = the average of the higher high water height of each tidal day observed over the NTDE

Mean Low Water (MLW) = the average of all the low water heights observed over the NTDE

Mean Lower Low Water (MLLW) = the average of the lower low water height of each tidal day observed over the NTDE

mollusk = an animal belonging to the invertebrate phylum Mollusca, characterized by a fleshy mantle and often a shell (*e.g.*, clams, mussels, snails)

precluded zone = for the purposes of this PBO, a threshold distance around the perimeter of a structural aquaculture farm in which red knots' habitat use is suppressed by visual effects of the gear, habitual human presence in the area, and/or other factors still to be determined.

Protected Areas = for the purposes of this PBO, the most important red knot foraging habitats within the action area, including all areas within 300 feet (91 m) of the MHW line (both seaward and landward of MHW), as well a 500-foot (152-m) buffer around all creek mouth shoals. The Protected Areas include all lands and waters (subtidal, intertidal, and supratidal) within these buffers.

red knot habitat = for the purposes of this PBO, all beaches, marsh, tidal flats, and creek mouth shoals in the action area from the landward limit of the beach/dune to the MLLW line.

riparian grant = a deed from the State of New Jersey for the sale of its tidelands interest, also known as riparian lands. Riparian grants are no longer available for land that is currently flowed by mean high tide (*e.g.*, covered with water during high tide). All valid riparian grants for these areas were deeded in the early to mid-1900s.

seed (oyster) = an oyster that is transplanted to another location for the purposes of commercial grow-out or restoration. Seed can be produced from a hatchery or harvested from the wild.

shell planting = the placement of shell for wild oyster recruitment shellfish = for purposes of this PBO, any bivalve species native to the action area. Note this definition differs from that found in State law at N.J.S.A. Title 50.

shellfish lease = for the purposes of this PBO, a one-year, renewable agreement for a specific parcel of State-owned land under the tidally flowed waters of the Delaware Bay, to be exclusively used and enjoyed for planting and cultivating shellfish, by the leaseholder. All leases must be granted by the New Jersey Shellfisheries Council, upon approval of the Commissioner of the NJDEP.

slough = within the intertidal zone, low areas (often linear) that hold water for a greater portion of the tidal cycle than adjacent ridges or flats. Also called “runnels” or “troughs.”

spat = small, juvenile stages of bivalve species

structural aquaculture = for purposes of this PBO, the tending and harvesting of native bivalves in bags, cages, or other structures, with the exception of marker buoys or poles

subtidal = the part of the littoral zone seaward of the MLLW line that is nearly always submerged

subtidal aquaculture = for purposes of this PBO, structural aquaculture of native bivalve species in the subtidal zone such that no gear is exposed at Mean Low Water (MLW)

supratidal = the part of the littoral zone landward of the MHHW line that is almost never inundated

take = under the ESA, to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct

traditional aquaculture = non-structural aquaculture, which typically involves moving naturally occurring oysters (*i.e.*, not from hatchery-produced seed) to favorable growing locations and/or the placement of shell for wild oyster recruitment (“shell planting”)

triploid = a cell or organism containing three sets of chromosomes

*Vibrio parahaemolyticus* = an organism that occurs naturally in coastal waters that is not related to pollution. Consumption of raw or undercooked shellfish, usually oysters, with high levels of *V. parahaemolyticus* may result in gastrointestinal illness in humans.

## APPENDIX B. ACRONYMS

AAC = Aquaculture Advisory Council
ADZ = Aquaculture Development Zone
ARM = Adaptive Resource Management
ASMFC = Atlantic States Marine Fisheries Commission
ATV = all-terrain vehicle
BA = Biological Assessment
BLE = Bureau of Law Enforcement
BMWM = Bureau of Marine Water Monitoring
BSF = Bureau of Shellfisheries
BTM = Bureau of Tidelands Management
CCA = copper–chromium–arsenic
CFR = Code of Federal Regulations
CM = Conservation Measure
CMNWR = Cape May National Wildlife Refuge
Corps = U.S. Army Corps of Engineers
COSEWIC = Committee on the Status of Endangered Wildlife in Canada
CSRPN = Conseil Scientifique Régional du Patrimoine Naturel (French Guiana Regional Scientific Council for Natural Heritage)
DBC = Delaware Bayshore Council
DLUR = Division of Land Use Regulation
ENSAC = Endangered and Nongame Species Advisory Committee
ENSP = Endangered and Nongame Species Program
EQIP = Environmental Quality Incentives Program (administered by NRCS)
ESA = Endangered Species Act
ESRI = Environmental Systems Research Institute (makers of GIS software)
FAO = Food and Agriculture Organization of the United Nations
GIS = Geographic Information System
MDDNR = Maryland Department of Natural Resources
MHHW = Mean Higher High Water
MHW = Mean High Water
MLLW = Mean Lower Low Water
MLW = Mean Low Water
NCWRC = North Carolina Wildlife Resources Commission
NJDA = New Jersey Department of Agriculture
NJDEP = New Jersey Department of Environmental Protection
NJDFW = New Jersey Division of Fish and Wildlife
NJDOH = New Jersey Department of Health
NMFS = National Marine Fisheries Service (within the U.S. Department of Commerce)
NPS = National Park Service
NRCS = National Resource Conservation Service (within the U.S. Department of Agriculture)
NSSP = National Shellfish Sanitation Program
NTDE = National Tidal Datum Epoch
NWP = Nationwide Permit
PBO = Programmatic Biological Opinion
PVC = polyvinyl chloride (a type of plastic)
RPM = Reasonable and Prudent Measure
Service or USFWS = U.S. Fish and Wildlife Service
SFC = Shellfisheries Council
SLAMM = Sea Level Affecting Marsh Modeling
TC = Terms and Conditions
TRC = Tidelands Resource Council
U.S.C. = U.S. Code
WBG = World Bank Group

## APPENDIX C. DIAS CREEK OYSTER COMPANY

During a transitional period, the Dias Creek Oyster Farm may continue to operate on Lease A-19, in accordance with the following Special Conditions that will be included in a forthcoming modification to Corps authorization CENAP-OP-R-2012-798-24. The transitional period will end 1 year after this grower has been offered an intertidal growing area within an ADZ, or on June 8, 2018, whichever comes first. After the transitional period ends, Dias Creek Oyster Company must cease operations, relocate, or adopt all provisions of the PBO that apply to the Northern Segment. The Corps will reflect this transitioning requirement in all future modifications and authorizations for Dias Creek Oyster Company, including renewal of the NWPs in March 2017. During the transitional period, certain levels and types of incidental take that may occur due to operation of the Dias Creek Oyster Company on Lease A-19 are accounted for in this PBO and authorized through March 2017 in the accompanying Incidental Take Statement.

**Project Specific Special Conditions:**

1. All work performed in association with the above noted project shall be conducted within the 97-acre New Jersey Bureau of Shellfisheries lease identified as A-19, as shown on the attached maps/plans labeled E-1 through E-3. The work authorized by this NWP verification is the placement of aquaculture structures (i.e. floating bags on long-lines and racks with bags; also called “gear”) within Delaware Bay, off-shore from the area between the Pierces Point and Kimbles Beach sections of Middle Township, Cape May County, New Jersey. The authorized work is described as placement of a maximum total of 13 floating lines, 100’ long, approximately 20 feet apart, secured by steel augers or 50-pound cement anchor. Each line would have up to 20 floating bags (2x3’), spaced 5’ apart (on center), for a maximum total of 250 bags. All structures shall be in the location and arrangement as shown on the approved plans. Phase 1 of this total would be a maximum of 6 floating lines, with up to 120 total floating bags. In addition, an area is authorized for up to 10 racks with bags, each one 10x3’and spaced at least 5 feet apart as shown on the authorized plans. No work beyond Phase 1 (i.e. the remaining 7 of the 13 floating lines) shall take place until 2017. During the period from April 15 through August 31, inclusive, of any year, all access for construction and maintenance shall be by the route shown on the authorized plan and in accordance with other special conditions of this authorization.

2. Construction activities shall not result in the disturbance or alteration of greater than <u>0.041 acre</u> (1,800 square feet) of Delaware Bay from the total coverage by aquaculture structures (i.e. floating bags and racks with bags), and shall be limited to the approximate 7.3-acre designated growing area (i.e. outside the identified red knot buffer area) within the inter-tidal portion of the of the 97-acre lease (A-19).

3. Any deviation in construction methodology or project design from that shown on the above noted drawings or repair plan must be approved by this office, in writing, prior to performance of the work. All modifications to the above noted project plans shall be approved, in writing, by this office. No work shall be performed prior to written approval of this office.

4. This office shall be notified prior to the commencement of authorized work by completing and signing the enclosed Notification/ Certification of Work Commencement Form (Enclosure 3). This office shall also be notified within 10 days of the completion of the authorized work by completing and signing the enclosed Notification/Certification of Work Completion/Compliance Form (Enclosure 4). All notifications required by this condition shall be in writing. The Notification of Commencement of work may be sent to this office by facsimile or other electronic means; all other notification shall be transmitted to this office by registered mail. Oral notifications are not acceptable. Similar notification is required each time maintenance work is to be done under the terms of this Corps of Engineers permit.

5. The permittee understands and agrees that, if future operations by the United States require the removal, relocation, or other alteration, of the structure or work herein authorized, or if, in the opinion of the Secretary of the Army or his authorized representative, said structure or work shall cause unreasonable obstruction to the free navigation of the navigable waters, the permittee will be required, upon due notice from the Corps of Engineers, to remove, relocate, or alter the structural work or obstructions caused thereby, without expense to the United States. No claim shall be made against the United States on account of any such removal or alteration.

6. Representatives of the U.S. Army Corps of Engineers shall be permitted to inspect the project site, and to collect any samples, or to conduct any tests deemed necessary.

7. The permittee is responsible for ensuring that the contractor and/or workers executing the activity(s) authorized by this permit have knowledge of the terms and conditions of the authorization.

8. The authorized structures shall be marked in accordance with U.S. Coast Guard requirements in order to protect navigation. The permittee shall contact the U.S. Coast Guard at the following address to determine such requirements, and shall comply with such requirements as directed by the U.S. Coast Guard: Commander (oan), Fifth Coast Guard District; 431 Crawford Street; Portsmouth, VA 23704. All authorized structures shall be securely anchored and marked.

9. The permittee shall notify the National Oceanic Service within 60 days of the date of this permit regarding any required marking of the structures on navigational charts. Their address is: Chief, Nautical Data Branch; Code C5261; National Ocean Service; 1315 East-West Highway; Silver Spring, Maryland 20910-3282.

10. In order to ensure that aquaculture structures do not impede the nearshore horseshoe crab activity (which includes crab foraging, spawning, and passage) that supports red knot foraging, all aquaculture structures and activities shall adhere to the following conservation measures for gear located in the nearshore (water less than 5 feet deep and/or within 2,000 feet of the shoreline) between April 15 and August 31:

a. Cables or ropes used for any purpose shall be at least 0.5 inch (rope) or 0.25 inch (stiff cable) in diameter, made of materials resistant to fraying, maintained in good condition, and configured in way to avoid crab entanglement. Neither monofilament line nor fibrous materials (*e.g.*, jute cloths) shall be used for any purpose.
b. For all gear types, structures shall be arranged in linear, shore-perpendicular configurations, and not in shore-parallel or grid arrangements. Lanes at least 5 feet

wide shall be maintained between each shore-perpendicular linear array of gear, to facilitate crab passage.

c. Raised structures (*e.g.*, racks) shall be maintained at least 1 foot off the bottom, to allow crab passage.
d. For intertidal aquaculture, floating structures shall be spaced at least 5 feet apart within rows (on center) with a minimum spacing of 20 feet between rows (on center) to allow crab passage when the gear is resting on the bottom.

11. The permittee shall adhere to the access route as shown on the approved plan during the period from June 15 through August 31, inclusive, of any year, for all ingress/egress associated with construction and maintenance activities to minimize impacts on late-season spawning crabs and developing crab eggs and larvae. As per Special Condition 16, below, no land-based motorized vehicles shall be used.

12. The permittee shall coordinate and cooperate with the U.S. Fish and Wildlife Service (USFWS) and NJDEP, Division of Fish and Wildlife (NJDFW), with regard to those agencies' red knot and horseshoe crab monitoring efforts. A part of that cooperation shall be adaptive management for the aquaculture operations based on research and monitoring results (i.e. potential modification of operations, including special conditions of this permit). As a part of this, the permittee shall submit a report to this office, and to the USFWS and NJDFW, outlining horseshoe crab and red knot observations for that year, particularly noting any instances of horseshoe crab impingement, and any recommended adaptive management measures to offer further protection. This report shall be submitted by August 31 of each year. The USFWS, NJDFW, or their partners may provide a standardized data sheet for horseshoe crab observations.

13. There shall be no activities (other than access as per Special Conditions 16 and 17, below) within the identified red knot buffer area during the period April 15 through June 15, inclusive, of any year. As per this seasonal restriction, there shall be no use, construction, installation or stockpiling of aquaculture gear or associated materials within the red knot buffer area during the restricted period.

a. As shown on the approved plans, the identified red knot buffer area includes: (a) all areas within 300 feet of the mean high water line (MHWL); (b) all creek mouth shoals that are exposed at low tide; and (c) areas within a 500 foot buffer around the creek mouth shoals.
b. If any bags or other gear break away from their tethers within the designated growing area (e.g. during a storm) and are deposited within the identified red knot buffer area, the permittee shall immediately notify the Corps and USFWS, and shall submit via facsimile or electronic mail a proposal for retrieving such gear within 24 hours. Retrieval shall occur within one of the low-tide or high-tide access periods described in Special Conditions 16 and 17 below, and shall be planned and carried out to minimize disturbance of red knots. The USFWS and/or the NJDFW may elect to monitor the retrieval.

14. From April 15 to June 15, inclusive, of any year: (a) there shall be no installation of new structures or gear; and (b) to the extent practicable, intertidal gear shall be located in troughs that retain water throughout the tidal cycle.

15. For the year 2016, gear shall not cover more than 0.12 percent of the identified inter-tidal red knot habitat within Lease A-19 (0.023 out of 19.5 acres as shown on the authorized plan) during the period from April 15 through June 15, inclusive, of any year. Beginning in the year 2017, allowable coverage shall be 0.21 percent (0.041 out of 19.5 acres as shown on the authorized plan).

16. The permittee shall adhere to the following limitations when accessing the operation for the purpose of maintenance (including power-washing) and counting/sorting/harvesting during the period May 1 to June 15, inclusive, of any year: (a) access shall be only by boat, with a maximum of two (2) boats per visit; (b) access shall be limited to either the 2 hours before and 2 hours after low tide ("low-tide access") OR the 2 hours before and 2 hours after high tide ("high-tide access"); (c) the permittee shall ensure that all boats and any associated equipment enter and exit the lease area together and minimize the time spent crossing the Dias Creek shoals area and identified red knot buffer area (i.e. no stopping or anchoring in these areas except in an emergency), but all boats shall pass through the Dias Creek shoal areas at low speeds that do not produce wake; (d) the permittee shall ensure consistent use of designated entry and exit points and travel routes as shown on the approved plans; (e) there shall be no driving of land-based motorized vehicles within the identified red knot habitat shown on the approved plans or on the adjacent shoals; (f) the permittee shall minimize walking parallel to the shoreline; (g) the permittee shall minimize the duration of each visit; and (h) notwithstanding the need to keep visits short as per item (g), the permittee shall minimize the number of personnel at each visit, and shall not exceed 4 people per visit. Limitations on access frequency, duration and number of people shall not be changed except by specific written modification of this condition by this office.

17. Frequency of access.

a. Low-tide access (maintenance, harvest and other operations) between May 1 and June 15, inclusive, of any year (see 16 above) shall be limited to no more than 2 days per week (for all purposes, including power-washing).
b. High-tide access (maintenance, harvest and other operations) between May 1 and June 15, inclusive, of any year (see 16 above) shall be limited to no more than 2 days per week (for all purposes, including power-washing). The permittee shall ensure that a minimum of 500 feet is maintained between any such activities and the water's edge.
c. On a year-by-year basis, access and other restrictions during June may be lifted if specifically notified by this office with the concurrence of the USFWS. This notification may be by electronic mail.

18. Any incidental take of red knots (e.g. harm and/or harassment) that may occur under this Nationwide Permit (NWP) authorization (until the NWPs expire on March 18, 2017) will be authorized under a Programmatic Biological Opinion (PBO) to be issued by the U.S. FWS in April 2016. The PBO will allow for continued operation of the Dias Creek Oyster Farm on Lease A-19 in accordance with the Special Conditions listed above for a duration of a specified transitional period. The transitional period will end 1 year after this permittee has been offered an intertidal growing area within a State-run Aquaculture Development Zone, or on June 8, 2018, whichever comes first. After the transitional period ends, Dias Creek Oyster Company

must cease operations, relocate, or adopt all provisions of the PBO that apply to the Northern Segment in which Lease A-19 is located.  The Corps will reflect this transitioning requirement in all future modifications and authorizations for Dias Creek Oyster Company, including renewal of the NWPs in March 2017.  Any future modifications or authorizations (including renewal of the NWPs) will require a “Tier 2” consultation between the Corps and the USFWS.

## APPENDIX D. SWEET AMALIA OYSTER FARM

During a transitional period, the Sweet Amalia Oyster Farm may operate on Lease A-28, in accordance with the Special Conditions included in existing Corps authorization CENAP-OP-R-2014-970-24 (dated April 6, 2015). The transitional period will end 1 year after this grower has been offered an intertidal growing area within an ADZ, or on June 8, 2018, whichever comes first. After the transitional period ends, Sweet Amalia Oyster Farm must cease operations, relocate, or adopt all provisions of the PBO that apply to the Northern Segment. The Corps will reflect this transitioning requirement in all future modifications and authorizations for Sweet Amalia Oyster Farm, including renewal of the NWPs in March 2017. During the transitional period, certain levels and types of incidental take that may occur due to operation of the Sweet Amalia Oyster Farm on Lease A-28 are accounted for in this PBO and authorized through March 2017 in the accompanying Incidental Take Statement.

**Project Specific Special Conditions:**

1. All work performed in association with the above noted project shall be conducted within the permittee's New Jersey Bureau of Shellfisheries lease identified as A-28, in accordance with the Bureau's "Permission" form issued (signed) September 23, 2014, and as shown on the enclosed plan sheet dated February 24, 2015, prepared by Bosco Architects, entitled "Sweet Amalia Oyster Farm Shellfish Lease A28 Analysis - Pierces Point, Cape May NJ Preliminary Build-Out Plan.01b" (labeled E-1). The work authorized by this NWP verification is the placement of aquaculture structures (i.e. racks with bags, floating bags on long-lines and bottom cages; also called "gear") within Delaware Bay, off-shore from (and immediately north of) the Pierces Point area of Middle Township, Cape May County, New Jersey. The authorized work is described as placement of a maximum total of 723 (10x3') racks (with bags), 34 floating arrays (ten 20"x3' floating bags each), and 10 bottom cages (4x3') to be placed in the arrangement as shown on the plan referenced above. Phase 1 of this total would be 195 racks, 10 floating arrays, and 10 bottom cages (as identified on the authorized plan). The cages would be in place of 5 of the racks identified on the plan in the southern segment of Phase 1. No work beyond Phase 1 shall take place until 2017. During the period from April 15 through August 31, inclusive, of any year, all access for construction and maintenance shall be by the route shown on the authorized plan and in accordance with other special conditions of this authorization.

2. Construction activities shall not result in the disturbance or alteration of greater than <u>0.54 acre</u> of Delaware Bay from the total coverage by aquaculture structures, and shall be limited to the 7.3-acre inter-tidal portion of the 23.3-acre lease (A-28) that is outside the identified red knot buffer area.

3. Any deviation in construction methodology or project design from that shown on the above noted drawings or repair plan must be approved by this office, in writing, prior to performance of the work. All modifications to the above noted project plans shall be approved, in writing, by this office. No work shall be performed prior to written approval of this office.

4. This office shall be notified prior to the commencement of authorized work by completing and signing the enclosed Notification/ Certification of Work Commencement Form (Enclosure

3). This office shall also be notified within 10 days of the completion of the authorized work by completing and signing the enclosed Notification/Certification of Work Completion/Compliance Form (Enclosure 4). All notifications required by this condition shall be in writing. The Notification of Commencement of work may be sent to this office by facsimile or other electronic means; all other notification shall be transmitted to this office by registered mail. Oral notifications are not acceptable. Similar notification is required each time maintenance work is to be done under the terms of this Corps of Engineers permit.

5. The permittee understands and agrees that, if future operations by the United States require the removal, relocation, or other alteration, of the structure or work herein authorized, or if, in the opinion of the Secretary of the Army or his authorized representative, said structure or work shall cause unreasonable obstruction to the free navigation of the navigable waters, the permittee will be required, upon due notice from the Corps of Engineers, to remove, relocate, or alter the structural work or obstructions caused thereby, without expense to the United States. No claim shall be made against the United States on account of any such removal or alteration.

6. Representatives of the U.S. Army Corps of Engineers shall be permitted to inspect the project site, and to collect any samples, or to conduct any tests deemed necessary.

7. The permittee is responsible for ensuring that the contractor and/or workers executing the activity(s) authorized by this permit have knowledge of the terms and conditions of the authorization.

8. The authorized structures shall be marked in accordance with U.S. Coast Guard requirements in order to protect navigation. The permittee shall contact the U.S. Coast Guard at the following address to determine such requirements, and shall comply with such requirements as directed by the U.S. Coast Guard: Commander (oan), Fifth Coast Guard District; 431 Crawford Street; Portsmouth, VA 23704. All authorized structures shall be securely anchored and marked.

9. The permittee shall notify the National Oceanic Service within 60 days of the date of this permit regarding any required marking of the structures on navigational charts. Their address is: Chief, Nautical Data Branch; Code C5261; National Ocean Service; 1315 East-West Highway; Silver Spring, Maryland 20910-3282.

10. In order to ensure that aquaculture structures do not impede the nearshore horseshoe crab activity (which includes crab foraging, spawning, and passage) that supports red knot foraging, all aquaculture structures and activities shall adhere to the following conservation measures for gear located in the nearshore (water less than 5 feet deep and/or within 2,000 feet of the shoreline) between April 15 and August 31:

a. Cables or ropes used for any purpose shall be at least 0.5 inch (rope) or 0.25 inch (stiff cable) in diameter, made of materials resistant to fraying, maintained in good condition, and configured in way to avoid crab entanglement. Neither monofilament line nor fibrous materials (*e.g.*, jute cloths) shall be used for any purpose.
b. For all gear types, structures shall be arranged in linear, shore-perpendicular configurations, and not in shore-parallel or grid arrangements. Lanes at least 5

feet wide shall be maintained between each shore-perpendicular linear array of gear, to facilitate crab passage.

c. Raised structures (*e.g.*, racks) shall be maintained at least 1 foot off the bottom, to allow crab passage. The only exception to this requirement shall be any existing shorter racks owned by the permittee, which are to be relocated from another lease to the Phase 1 portion of this operation. This exception shall not apply to any new racks. All such shorter racks shall be phased out so that all racks on this lease meet the one-foot requirement of this condition by 2017 season.

d. For intertidal aquaculture, floating structures shall be spaced at least 5 feet apart in all directions to allow crab passage when the gear is resting on the bottom.

e. Bottom cages shall rest firmly on the bottom or the main bottom of the cage (not counting feet) shall be no more than 1 inch off the bottom to avoid crab impingement. Bottom cages shall be spaced at least 5 feet apart in all directions to avoid impingement and allow crab passage.

11. The permittee shall adhere to the access route as shown on the approved plan during the period from June 15 through August 31, inclusive, of any year, for all ingress/egress associated with construction and maintenance activities to minimize impacts on late-season spawning crabs and developing crab eggs and larvae. As per Special Condition 16, below, no motorized vehicles shall be used from May 1 through June 15, inclusive, of any year. If motorized vehicles are used after June 15, such vehicles shall: (a) consistently use the designated beach entry and exit points and travel routes shown on the approved plan; (b) minimize the amount of driving parallel to the shoreline; (c) when driving parallel to the shoreline cannot be avoided, drive as far seaward of the mean high water line as practical (minimum 100 feet); and (d) avoid driving through concentrations of crabs and in the wrack line.

12. The permittee shall coordinate and cooperate with the U.S. Fish and Wildlife Service (USFWS) and NJDEP, Division of Fish and Wildlife (NJDFW), with regard to those agencies' red knot and horseshoe crab monitoring efforts. A part of that cooperation shall be adaptive management for the aquaculture operations based on research and monitoring results (i.e. potential modification of operations, including special conditions of this permit). As a part of this, the permittee shall submit a report to this office, and to the USFWS and NJDFW, outlining horseshoe crab and red knot observations for that year, particularly noting any instances of horseshoe crab impingement, and any recommended adaptive management measures to offer further protection. This report shall be submitted by August 31 of each year.

13. There shall be no activities (other than access as per Special Conditions 16 and 17, below) within the identified red knot buffer area during the period April 15 through June 15, inclusive, of any year. As per this seasonal restriction, there shall be no use, construction, installation or stockpiling of aquaculture gear or associated materials within the red knot buffer area during the restricted period. As shown on the approved plans, the identified red knot buffer area includes: (a) all areas within 300 feet of the mean high water line (MHWL); (b) all creek mouth shoals that are exposed at low tide; and (c) areas within a 500 foot buffer around the creek mouth shoals.

14. From April 15 to June 15, inclusive, of any year: (a) there shall be no installation of new structures or gear; and (b) to the extent practicable, intertidal gear shall be located in troughs that retain water throughout the tidal cycle.

15. For the years 2015 and 2016, gear shall not cover more than 0.82 percent of the identified inter-tidal red knot habitat within Lease A-28 (0.15 out of 18.3 acres as shown on the authorized plan) during the period from April 15 through June 15, inclusive, of any year. Beginning in the year 2017, allowable coverage shall be 2.95 percent (0.54 out of 18.3 acres as shown on the authorized plan).

16. The permittee shall adhere to the following limitations when accessing the operation for the purpose of maintenance (including power-washing) and counting/sorting/harvesting during the period May 1 to June 15, inclusive, of any year: (a) access shall be by foot and non-motorized (i.e. human-powered) vehicle, subject to the frequency limitations outlined in Special Condition 17 below; (b) access shall be limited to the 2 hours before and 2 hours after low tide; (c) the permittee shall ensure that all personnel enter and exit the lease area together and minimize the time spent crossing the identified red knot buffer area; (d) the permittee shall ensure consistent use of designated beach entry and exist points and travel routes as shown on the approved plans, with preferential use of the more seaward travel routes to the extent practicable; (e) there shall be no driving of motorized vehicles; (f) the permittee shall minimize walking parallel to the shoreline; (g) the permittee shall minimize the duration of each visit; and (h) notwithstanding the need to keep visits short as per item (g), the permittee shall minimize the number of personnel at each visit, and shall not exceed 3 people during one of the two weekly visits and shall not exceed 4 people during the other weekly visit. Limitations on access frequency, duration and number of people shall not be changed except by specific written modification of this condition by this office.

17. Frequency of access for maintenance and other operations between May 1 and June 15, inclusive, of any year (see 16-a above) shall be limited to no more than 2 day per week (for all purposes, including power-washing). On a year-by-year basis, access and other restrictions during June may be lifted if specifically notified by this office with the concurrence of the USFWS. This notification may be by electronic mail.

## APPENDIX E. SUMMARY OF RED KNOT BIOLOGY AND THREATS

The following summary is taken from USFWS 2014, Rufa Red Knot Background Information and Threats Assessment, Supplement to Endangered and Threatened Wildlife and Plants; Final Threatened Status for the Rufa Red Knot (*Calidris canutus rufa*) [Docket No. FWS–R5–ES–2013–0097; RIN AY17]. For a list of literature cited in this excerpt, consult the full Supplemental Document, which is available online at http://www.fws.gov/northeast/redknot/pdf/20141125_REKN_FL_supplemental_doc_FINAL.pdf

**Terminology:** Throughout this document, "rufa red knot," "red knot," and "knot" are used interchangeably to refer to the subspecies *Calidris canutus rufa*. "*Calidris canutus*" and "*C. canutus*" are used to refer to the species as a whole or to birds of unknown subspecies. References to other particular subspecies are so indicated by use of the Latin name. "Winter" is consistently used to refer to the nonbreeding period of the red knot life cycle when the birds are not undertaking migratory movements, typically December to February, although this period is actually summer in the Southern Hemisphere. Likewise, although the seasons are reversed in the Southern Hemisphere, "spring" is used throughout to refer to the nonbreeding period of the red knot life cycle when the birds are undertaking northbound migratory movements and "fall" is used to refer to the nonbreeding period when the birds are undertaking southbound migratory movements.

**Introduction:** The rufa red knot (*Calidris canutus rufa*) is a medium-sized shorebird that migrates annually between its breeding grounds in the central Canadian Arctic and several wintering regions, including the Southeast United States (Southeast), the Northeast Gulf of Mexico, northern Brazil, and Tierra del Fuego at the southern tip of South America. During both the northbound (spring) and southbound (fall) migrations, red knots use key staging and stopover areas to rest and feed. Another subspecies, *Calidris canutus roselaari*, breeds in western Alaska and on Wrangel Island in eastern Russia (Carmona *et al.* 2013, p. 169; Buehler and Baker 2005, p. 498) and winters on the Pacific coast from northern Mexico through Panama and possibly farther south (D. Newstead pers. comm. February 13, 2014; Carmona *et al.* 2013, pp. 171, 175). The nonbreeding ranges of these two subspecies are known to overlap in a few locations, and may overlap more broadly. However, geolocator data confirm the existence of distinct breeding areas for the *rufa* and *roselaari* subspecies (D. Newstead pers. comm. February 13, 2014; L. Niles pers. comm. January 4, 2013; Newstead *et al.* 2013, p. 56; Niles *et al.* 2012a, pp. 197–200; Niles *et al.* 2010a, pp. 125–126). The rufa red knot's typical life span is at least 7 years (J. Parvin pers. comm. March 14, 2014; Niles *et al.* 2008, p. 28), with the oldest known wild bird at least 21 years old as of 2014 (Bauers 2014; Jordan 2014). Age of first breeding is at least 2 years (S. Koch, L. Niles, and R. Porter pers. comm. August 12, 2014; Harrington 2001, p. 21).

**Breeding:** The red knot breeds in the central Canadian Arctic, from the islands of northern Hudson Bay to the Foxe Basin shoreline of Baffin Island, and west to Victoria Island (Niles *et al.* 2008, pp. 15–16; Morrison and Harrington 1992, p. 73). Potential breeding habitat extends farther north the southern Queen Elizabeth Islands (Niles *et al.* 2008, p. 16). The extent to which rufa red knots from different wintering areas mix on the breeding grounds, and therefore potentially interbreed, is poorly known (Harrington *et al.* 1988, p. 443). Red knots generally nest in dry, slightly elevated tundra locations, often on windswept slopes with little vegetation. Breeding areas are located inland, but near arctic coasts. Nests may be scraped into patches of mountain avens (*Dryas octopetala*) plants, or in low spreading vegetation on hummocky (characterized by knolls or mounds) ground containing lichens, leaves, and moss. After the eggs hatch, red knot chicks and adults quickly move away from high nesting terrain to lower, freshwater wetland habitats. On the breeding grounds, the red knot's diet consists mostly of terrestrial invertebrates such as insects and other arthropods (Niles *et al.* 2008, p. 27; Harrington 2001, p. 11).

Pair bonds form soon after the birds arrive on breeding grounds, in late May or early June, and remain intact until shortly after the eggs hatch (Niles *et al.* 2008, p. 25–26; Harrington 2001, p. 16). Female rufa red knots lay only one clutch (group of eggs) per season, and, as far as is known, do not lay a replacement clutch if the first is lost. The usual clutch size is four eggs, though three-egg clutches have been recorded. The incubation period lasts approximately 22 days from the last egg laid to the last egg hatched, and both sexes participate equally in egg incubation. Young are precocial, leaving the nest within 24 hours of hatching and foraging for themselves (Niles *et al.* 2008, p. 27). Females are thought to leave the breeding grounds and start moving south soon after the chicks hatch in mid-July. Thereafter, parental care is provided solely by the males, but about 25 days later (around August 10) males also abandon the newly fledged juveniles and move south. Not long after, they are followed by the juveniles (Niles *et al.* 2008, p. 14). Breeding success of High Arctic shorebirds such as *Calidris canutus* varies dramatically among years in a somewhat cyclical manner. Two main factors seem to be responsible for this annual variation: abundance of arctic lemmings (*Dicrostonyx torquatus* and *Lemmus sibericus*) (by indirectly affecting predation pressure on shorebirds) and weather (Piersma and Lindström 2004, pp. 63–64; Blomqvist *et al*. 2002, p. 149; Summers and Underhill 1987, p. 169). Growth rate of *C. canutus* chicks is very high compared to similarly sized shorebirds nesting in more temperate climates and is strongly correlated with weather-induced and seasonal variation in availability of invertebrate prey (Schekkerman *et al*. 2003, p. 332).

**Nonbreeding Range:** Geolocator and resightings data show definitively that the *rufa* nonbreeding range includes the entire Atlantic and Caribbean coasts of South America and the Caribbean islands; Chiloé Island on the central Pacific coast of Chile; the Pacific coast of Panama; the North American Gulf and Atlantic coasts from Tamaulipas, Mexico through Quebec, Canada; the interior of South America; and the interior of the United States and Canada west at least as far as the Great Plains (Bimbi *et al.* 2014, pp. 29–31; S. Koch, L. Niles, R. Porter, and F. Sanders pers. comm. August 8 and 12, 2014; Newstead 2014a, p. 19; D. Newstead pers. comm. May 8, 2014; Niles 2014; J. Parvin pers. comm. March 13, 2014; Newstead *et al.* 2013, pp. 55–57; Burger *et al.* 2012b, p. 107; Niles 2012a; Niles *et al.* 2012a, entire; Niles 2011a; Niles 2011b; Niles *et al.* 2010a, entire; Niles *et al.* 2008, p. 19; B. Paxton pers. comm. November 9, 2008; Buehler 2002, p. 42; Morrison and Harrington 1992, p. 77). *Calidris canutus roselaari* also occurs in certain parts of this established *rufa* nonbreeding range. Best available data are limited but suggest that the nonbreeding ranges of *C.c. roselaari* and *C.c. rufa* overlap, at least in Texas during spring and in Panama during winter (D. Newstead pers. comm. May 13, 2014; D. Newstead pers. comm. February 13, 2014; D. Newstead pers. comm. February 11, 2014; D. Newstead pers. comm. August 20, 2012). However, geolocator and resightings data provide strong evidence that *Calidris cantus* on the Pacific coast from northeastern Russia to Las Garzas, Mexico are the *roselaari* subspecies, and we conclude from the best available data that the rufa red knot does not occur in this region of the Pacific (D. Newstead pers. comm. February 13, 2014; Carmona *et al.* 2013, entire; J. Buchanan pers. comm. January 9, 2013).

**Wintering:** Wintering areas for the rufa red knot include the Atlantic coasts of Argentina and Chile (particularly the island of Tierra del Fuego that spans both countries), the north coast of Brazil (particularly in the State of Maranhão), the Northwest Gulf of Mexico from the Mexican State of Tamaulipas through Texas (particularly at Laguna Madre) to Louisiana, and the Southeast United States from Florida (particularly the central Gulf coast) to North Carolina (Newstead 2014a, p. 19; Newstead *et al.* 2013, p. 55; L. Patrick pers. comm. August 31, 2012; Niles *et al.* 2008, p 17). Smaller numbers of knots winter in the Caribbean, and along the central Gulf coast (Alabama, Mississippi), the mid-Atlantic, and the Northeast United States (eBird.org 2014; Russell 2014, p. 4; Burger *et al.* 2012b, p. 6; A. Dey pers. comm. November 19, 2012; H. Hanlon pers. comm. November 22, 2012; Niles *et al.* 2012a, entire; L. Patrick pers. comm. August 31, 2012; Morrison and Harrington 1992, p. 77). *Calidris canutus* is also known to winter in Central America, northwest South America, and along the Pacific coast of South America, but it is not yet clear if all these birds are the *rufa* subspecies (Carmona *et al.* 2013, entire). Winter area fidelity appears to be high, with minimal movement of birds among wintering regions (Georgia Department of Natural Resources (GDNR) 2013; BandedBirds.org 2012; Schwarzer *et al.* 2012, p. 729; Niles *et al.* 2008, pp. 9, 55; Harrington *et al.* 1988, p. 441). Researchers often distinguish between those rufa red knots that winter the farthest south (in Argentina and Chile) and therefore undertake the longest-distance migrations ("southern-wintering"), from those that winter farther north in northern Brazil and the Southeast ("northern-wintering"), with some notable physiological and ecological differences between the two groups (B. Harrington pers. comm. November 14, 2013).

**Migration Biology:** Each year some red knots make one of the longest distance migrations known in the animal kingdom, traveling up to 19,000 mi (30,000 km) annually. Red knots undertake long flights that may span thousands of miles without stopping. As *Calidris canutus* prepare to depart on long migratory flights, they undergo several physiological changes. Before takeoff, the birds accumulate and store large amounts of fat to fuel migration and undergo substantial changes in metabolic rates. In addition, the leg muscles, gizzard (a muscular organ used for grinding food), stomach, intestines, and liver all decrease in size, while the pectoral (chest) muscles and heart increase in size. Due to these physiological changes, *C. canutus* arriving from lengthy migrations are not able to feed maximally until their digestive systems regenerate, a process that may take several days. Because stopovers are time-constrained, *C. canutus* requires stopovers rich in easily digested food to achieve adequate weight gain (Niles *et al.* 2008, pp. 28–29; van Gils *et al.* 2005a, p. 2609; van Gils *et al.* 2005b, pp. 126–127; Piersma *et al*. 1999, pp. 405; 412) that fuels the next migratory flight and, upon arrival in the Arctic, also fuels a body transformation to breeding condition (Morrison 2006, pp. 610–612). At some stages of migration, very high proportions of entire shorebird populations may use a single migration staging site to prepare for long flights. High fractions of the red knot's rangewide population can occur together at a small number of nonbreeding locations, leaving populations vulnerable to loss of key resources (Harrington 2001, p 22). For example, Delaware Bay provides the final Atlantic coast stopover for a significant majority (50 to 80 percent) of the red knot population making its way to the arctic breeding grounds each spring (Clark *et al*. 2009, p. 90; Brown *et al.* 2001, p. 10). Individual red knots show moderate fidelity to particular migration staging areas between years (French Guiana Regional Scientific Council for Natural Heritage (CSRPN) 2013; Duerr *et al.* 2011, p. 16; Watts 2009a; Harrington 2001, pp. 21–22).

**Spring Migration:** Well-known spring stopover areas along the Atlantic coast include Río Gallegos, Península Valdés, and San Antonio Oeste (Patagonia, Argentina); Lagoa do Peixe (eastern Brazil, State of Rio Grande do Sul); Maranhão (northern Brazil); the Southeast United States (e.g., the Carolinas to Florida); the Virginia barrier islands (United States); and Delaware Bay (Delaware and New Jersey, United States) (A. Dey pers. comm. April 21, 2014; Wallover *et al.* 2014, p. 6; GDNR 2013; South Carolina Department of Natural Resources (SCDNR) 2013, p. 36; Cohen *et al.* 2009, p. 939; Niles *et al.* 2008, p. 19; González 2005, p. 14). However, large and small groups of red knots, sometimes numbering in the thousands, may occur in suitable habitats all along the Atlantic and Gulf coasts from Argentina to Massachusetts (Niles *et al.* 2008, p. 29).

Although a few birds may depart before the end of January, the main red knot movement north from Tierra del Fuego occurs in February. The northward migration through South America is typically rapid, with only brief stopovers (Niles *et al*. 2008, p. 15), although longer stops in Argentina (17 to 22 days) have been reported (Musmeci *et al.* 2012, pp. 359–360). Birds moving north from Argentina typically arrive in Brazil in April (Scherer and Petry 2012, p. 46; Niles *et al.* 2008, p. 29). Departure from Brazil tends to occur in the first half of May (Niles *et al.* 2010a, p. 126; Niles *et al*. 2008, pp. 15, 29). Many knots marked in Argentina and Chile are seen on the Atlantic coasts of Florida, Georgia, South Carolina, and North Carolina during, but not before, May (B. Harrington pers. comm. November 14, 2013; GDNR 2013; SCDNR 2013, p. 31). Available data indicate that red knots wintering in the Southeast use at least two different spring migration routes—coastal (moving north along the coast to the mid-Atlantic before departing for the Arctic) and inland (departing overland for the Arctic directly from the Southeast coast) (Bimbi *et al.* 2014, pp. 29–30; SCDNR 2013, p. 38; Niles *et al.* 2012a, pp. 197–200; Harrington 2005a, p. 1; Morrison and Harrington 1992, p. 77).

**Fall Migration:** Departure from the breeding grounds begins in mid-July and continues through August. Females are thought to leave first, followed by males and then juveniles (Niles *et al.* 2008, pp. 14–15; Harrington 2001, p. 6). Adult *Calidris canutus* pass through stopover sites along the migratory route earlier in years with low reproductive success than in years with high reproductive success (Blomqvist *et al*. 2002, p. 149). Along the U.S. Atlantic coast, southbound red knots start arriving in July. Numbers of adults peak in mid-August and most depart by late September, although geolocators and resightings have shown some birds (especially northern-wintering knots) stay through November (Wallover *et al.* 2014, p. 6; Niles *et al.* 2012a, pp. 197–200; Harrington *et al.* 2010b, p. 357; Harrington 2001, p. 2). Well-known fall stopover sites include southwest Hudson Bay (including the Nelson River delta), James Bay, the north shore of the St. Lawrence River, the Mingan Archipelago, and the Bay of Fundy in Canada; the coasts of Massachusetts and New Jersey and the mouth of the Altamaha River in Georgia in the United States; the Caribbean (especially Puerto Rico and the Lesser Antilles); and the northern coast of South America from Brazil to Guyana (eBird.org 2014; Autoridad de Energía Eléctrica (Electric Energy Authority, or (AEE) 2013; Newstead *et al.* 2013, p. 57; Niles 2012a; D. Mizrahi pers. comm. October 16, 2011; Niles *et al.* 2010a, pp. 125–136; Schneider and Winn 2010, p. 3; Niles *et al.* 2008, pp. 30, 75, 94; B. Harrington pers. comm. March 31, 2006; Antas and Nascimento 1996, p. 66; Morrison and Harrington 1992, p. 74; Spaans 1978, p. 72). However, birds can occur all along the coasts in suitable habitats. In one study of northern-wintering red knots, the total time spent along the U.S. Atlantic coast (including spring, fall, and for some birds winter) averaged 218 days (range 121 to 269 days) (Burger *et al.* 2012b, p. 1), or about 60 percent of the calendar year.

**Midcontinental Migration:** Geolocator results from red knots wintering in Texas have shown that these birds typically use a central, overland flyway across the midcontinental United States, with birds departing Texas between May 16 and May 21 and using stopover areas in the Northern Great Plains and along southern Hudson Bay (Newstead *et al.* 2013, p. 58). Texas-wintering birds typically use a similar and direct interior flyway across the midcontinental United States during the southbound migration, using a southbound stopover site on the south shore of Hudson Bay (Nelson River Delta to James Bay). Geolocator results (Bimbi *et al.* 2014, pp. 29–31; Niles 2014; Newstead *et al.* 2013; Niles *et al.* 2012a, p. 197-200; Niles 2011a; Niles 2011b; Niles *et al.* 2010a, pp. 125–128) have suggested that rufa red knots exhibit strong flyway fidelity (Newstead *et al.* 2013, p. 58) (i.e., not switching between Atlantic coast and midcontinental routes). However, newer geolocator data, as yet unpublished, do show some switching between these two flyways. Several Texas-wintering birds have been shown to use the "typical" midcontinental flyway in spring, but then follow a fall migration route along the U.S. Atlantic coast before returning Texas via the Gulf coast. To date, no known geolocator tracks from Texas birds have shown use of the Atlantic coast during spring migration, but some resighting data suggest that this may also occur (D. Newstead pers. comm. May 8, 2014). Even for the same individual bird, the actual routes and number of stopovers can vary considerably from year to year (D. Newstead pers. comm. May 8, 2014). In one study, red knots wintering in the Northwest Gulf of Mexico spent nearly the entire nonbreeding phase of their annual cycle (286 days, or 78.4 percent of the calendar year) on the Texas coast (Newstead *et al.* 2013, p. 55).

**Nonbreeding Habitat:** Coastal habitats used by red knots in migration and wintering areas are similar in character (Harrington 2001, p. 9), generally coastal marine and estuarine (partially enclosed tidal area where fresh and salt water mixes) habitats with large areas of exposed intertidal sediments. Migration and wintering habitats include both high-energy ocean- or bay-front areas, as well as tidal flats in more sheltered bays and lagoons (Harrington 2001, p. 9). Preferred wintering and migration microhabitats are muddy or sandy coastal areas, specifically, the mouths of bays and estuaries, tidal flats, and unimproved tidal inlets (North Carolina Wildlife Resources Commission (NCWRC) 2013; Lott *et al.* 2009, pp. 18–19; Niles *et al.* 2008, p. 30; Harrington 2001, p. 8). Along the U.S. Atlantic coast, dynamic and ephemeral (lasting only briefly) features are important red knot habitats, including sand spits, islets, shoals, and sandbars, features often associated with inlets (Harrington 2008, p. 2; Harrington in Guilfoyle *et al.* 2007, pp. 18–19; Winn and Harrington in Guilfoyle *et al.* 2006, pp. 8–10). In many wintering and stopover areas, quality high-tide roosting habitat (i.e., close to feeding areas, protected from predators, with sufficient space during the highest tides, free from excessive human disturbance) is limited (CSRPN 2013; K. Kalasz pers. comm. November 26, 2012; L. Niles pers. comm. November 19 and 20, 2012; Kalasz 2008, p. 9). In nonbreeding habitats, *Calidris canutus* require sparse vegetation to avoid predation (Niles *et al.* 2008, p. 44; Piersma *et al.* 1993, pp. 338–339, 349).

Available information suggests that red knots use inland saline lakes as stopover habitat in the Northern Great Plains (Newstead *et al.* 2013, p. 57; North Dakota Game and Fish Department (NDGFD) 2013; Western Hemisphere Shorebird Reserve Network (WHSRN) 2012; Skagen *et al.* 1999). We have little information to indicate whether or not red knots may also utilize inland freshwater habitats during migration, but data suggest that certain freshwater areas may warrant further study as potential stopover habitats (C. Dovichin pers. comm. May 6, 2014; eBird.org 2014; Russell 2014, entire). Best available data indicate that small numbers of red knots sometimes use manmade freshwater habitats (e.g., impoundments) along inland migration routes (eBird.org 2014; Russell 2014, entire; Central Flyway Council 2013; NDGFD 2013; Oklahoma Department of Wildlife Conservation (ODWC) 2013; A. Simnor pers. comm. October 15, 2012).

**Nonbreeding Food:** Across all (six) subspecies, *Calidris canutus* is a specialized molluscivore, eating hard-shelled mollusks, sometimes supplemented with easily accessed softer invertebrate prey, such as shrimp- and crab-like organisms, marine worms, and horseshoe crab eggs (Piersma and van Gils 2011, p. 9; Harrington 2001, pp. 9–11). The mollusk prey is swallowed whole and crushed in the gizzard, which in *C. canutus* is the largest (relative to body size) among any shorebird species evaluated (Piersma and van Gils 2011, pp. 9–11). Large gizzards are among this species’ adaptations to a mollusk diet, allowing *C. canutus* to grind the hard shells of its prey. *Calidris canutus* prefer thin-shelled to thick-shelled prey species because they are easier to digest and provide a more favorable meat to mass ratio (higher prey quality) (van Gils *et al.* 2005a, p. 2611; Harrington 2001, p. 11; Zwarts and Blomert 1992, p. 113). From studies of other subspecies, Zwarts and Blomert (1992, p. 113) concluded that *C. canutus* cannot ingest prey with a circumference greater than 1.2 in (30 millimeters (mm)). For rufa red knots, prey lengths of 0.16 to 0.79 in (4 to 20 mm) have been observed (Cohen *et al.* 2010b, pp. 359–360; González *et al.* 1996, p. 575). Foraging activity is largely dictated by tidal conditions, as *C. canutus* rarely wade in water more than 0.8 to 1.2 in (2 to 3 cm) deep (Harrington 2001, p. 10). Due to bill morphology, *C. canutus* is limited to foraging on only shallow-buried prey, within the top 0.8 to 1.2 in (2 to 3 cm) of sediment (Gerasimov 2009, p. 227; Zwarts and Blomert 1992, p. 113). Along the U.S. coast, *Donax* and *Mulinia* clams and blue mussel (*Mytilus edulis*) spat are key prey items. A prominent departure from typical prey items occurs each spring when red knots feed on the eggs of horseshoe crabs (*Limulus polyphemus*), particularly during the key migration stopover within the Delaware Bay. Delaware Bay serves as the principal spring migration staging area for the red knot because of the abundance and availability of horseshoe crab eggs (Clark *et al.* 2009, p. 85; Harrington 2001, pp. 2, 7; Harrington 1996, pp. 76–77; Morrison and Harrington 1992, pp. 76–77). In Delaware Bay, horseshoe crab eggs are a superabundant source of easily digestible food.

**Population Trends:** After a thorough review of the best available population data, we conclude that we do not have sufficient reliable data on which to derive a precise rangewide population estimate for the rufa red knot. For example, there are no rangewide population estimates for fall migration or breeding areas because birds are too dispersed. However, we can reliably infer population trend information from some areas. We have high confidence in long-term survey data from two key red knot areas, Tierra del Fuego (wintering) and Delaware Bay (spring), showing declines of 70 to 75 percent over roughly the same period, since about 2000 (Dey *et al.* 2014, p. 2; Dey *et al.* 2011a, p. 2; Clark *et al.* 2009, p. 88; Morrison *et al*. 2004, p. 65;

Morrison and Ross 1989, Vol. 2, pp. 226, 252; Kochenberger 1983, p. 1; Dunne *et al.* 1982, p. 67; Wander and Dunne 1982, p. 60). Data sets associated with lower confidence, from the Brazil wintering region and three South American spring stopovers, also suggest declines roughly over this same timeframe (Niles *et al.* 2008, pp. 58, 134; Baker *et al.* 2005, p. 12; González 2005, p. 14; Morrison and Ross 1989, Vol. 2, p. 183; Harrington *et al.* 1986, p. 50), however, more recently a substantial increase was documented in Brazil (Dey *et al.* 2014, p. 1). Emerging information from Virginia also suggests a decline relative to the 1990s (B. Watts pers. comm. August 22, 2014). We do not conclude that the Southeast wintering region has declined over this period despite some years of lower counts in Florida, due to the likelihood that the birds' usage shifts geographically within this region from year to year (Harrington 2005a, pp. 1, 15). In summary, the best available data indicate a sustained decline occurred in the 2000s, and may have stabilized at a relatively low level in the last few years. Attempts to evaluate long-term population trends using national or regional data from volunteer shorebird surveys and other sources have also generally concluded that red knot numbers have declined, probably sharply (National Park Service (NPS) 2013; Andres 2009; Morrison *et al.* 2006, pp. 71, 76–77).

**Listing Factors:** Under section 4(a)(1) of the Endangered Species Act (the Act), we may list a species based on any of the following five factors: (A) the present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; or (E) other natural or manmade factors affecting its continued existence. We have evaluated each of these five factors.

***Factor A:*** Threats to the red knot from habitat destruction and modification are occurring throughout the entire range of the subspecies. These threats include climate change, shoreline stabilization, and coastal development, exacerbated regionally or locally by lesser habitat-related threats such as beach cleaning, invasive vegetation, agriculture, and aquaculture. The subspecies-level impacts from these activities are expected to continue into the future.

Within the nonbreeding portion of the range, red knot habitat is primarily threatened by the highly interrelated effects of sea level rise, shoreline stabilization, and coastal development. The primary red knot foraging habitats, intertidal flats and sandy beaches, will likely be locally or regionally inundated as sea levels rise, but replacement habitats are likely to re-form along eroding shorelines in their new positions (U.S. Climate Change Science Program (CCSP) 2009b, p. 186; Scavia *et al.* 2002, p. 152). However, if shorelines experience a decades-long period of rapid sea level rise, high instability, and landward migration, the formation rate of new foraging habitats may be slower than the rate at which existing habitats are lost (Iwamura *et al.* 2013, p. 6). In addition, low-lying and narrow islands (e.g., in the Caribbean, along the Gulf and Atlantic coasts) may disintegrate rather than migrate, representing a net loss of red knot habitat (Chapter 5 in International Panel on Climate Change (IPCC) 2014, p. 15; Titus 1990, p. 67).

Superimposed on changes from sea level rise are widespread human efforts to stabilize the shoreline, which are known to exacerbate losses of intertidal habitats by blocking their landward migration. About 40 percent of the U.S. coastline within the range of the red knot is already developed, and much of this developed area is stabilized by a combination of existing hard structures and ongoing beach nourishment programs (Rice 2012a, p. 6; Titus *et al.* 2009, p.

5). Hard stabilization structures and dredging degrade and often eliminate existing intertidal habitats, and in many cases prevent the formation of new shorebird habitats (CCSP 2009b, pp. 99–100; Nordstrom 2000, pp. 20, 98–107). Beach nourishment may temporarily maintain suboptimal shorebird habitats where they would otherwise be lost as a result of hard structures or sea level rise (Nordstrom and Mauriello 2001, entire), but beach nourishment can also have adverse effects to red knots and their habitats (Defeo *et al.* 2009, p. 4; Rice 2009, entire; Peterson *et al.* 2006, entire; Peterson and Bishop 2005, entire; Greene 2002, p. 5). In those times and places where artificial beach maintenance is abandoned (e.g., due to constraints on funding or sediment availability), the remaining alternatives available to coastal communities would likely be limited to either a retreat from the coast or increased use of hard structures to protect development (CCSP 2009b, p. 87; Defeo *et al*. 2009, p. 7). The quantity of red knot habitat would be markedly decreased by a proliferation of hard structures. Red knot habitat would be significantly increased by retreat, but only where hard stabilization structures do not exist or where they get dismantled. Relative to the United States, little is known about development-related threats to red knot nonbreeding habitat in other countries. However, in some key international wintering and stopover sites, development pressures are likely to exacerbate habitat impacts caused by sea level rise (CSRPN 2013; WHSRN 2012; Niles *et al.* 2008, pp. 17, 19, 73, 97–98; Ferrari *et al.* 2002, p. 39).

Lesser threats to nonbreeding habitat include beach cleaning, invasive vegetation, agriculture, and aquaculture. The practice of intensive beach raking may cause physical changes to beaches that degrade their suitability as red knot habitat (Defeo *et al.* 2009, p. 4; Nordstrom and Mauriello 2001). Although not a primary cause of habitat loss, invasive vegetation can be a regionally important contributor to the overall loss and degradation of the red knot's nonbreeding habitat (U.S. Fish and Wildlife Service (USFWS) 2012a, p. 27; Defeo *et al.* 2009, p. 6). Agriculture and aquaculture are a minor but locally important contributor to overall loss and degradation of the red knot's nonbreeding habitat, particularly for moderate numbers of red knots that winter or stopover in Northeast Brazil where habitats were likely impacted by the rapid expansion of shrimp farming since 1998 (Carlos *et al.* 2010, entire).

Within the breeding portion of the range, the primary threat to red knot habitat is from climate change. With arctic warming, vegetation conditions on the breeding grounds are changing, which is expected to eventually cause the zone of nesting habitat to shift north and contract (Feng *et al.* 2012, pp. 1359, 1366; Meltofte *et al.* 2007, p. 35; Arctic Climate Impact Assessment (ACIA) 2005, pp. 991, 998). Studies have already documented changes in arctic vegetation (e.g, increases in peak "greenness" and plant biomass; advancing of the arctic tree line; increased shrub abundance, biomass, and cover; increased plant canopy heights; and decreased prevalence of bare ground (Summary for Policymakers in IPCC 2014, p. 32; Chapter 28 in IPCC 2014, p. 12)). Vegetation effects are likely exacerbated by loss of sea ice (Bhatt *et al*. 2010, pp. 1–2l; Meltofte *et al.* 2007, p. 36). Arctic freshwater systems, foraging areas for red knots during the nesting season, are particularly sensitive to climate change and are already being affected (ACIA 2005, p. 1012; Meltofte *et al.* 2007, p. 35). Unpredictable but profound ecosystem changes (e.g., changing interactions among predators, prey, and competitors) are also likely to occur. There are early warning signs that arctic ecosystems are already experiencing irreversible regime shifts (Summary for Policymakers in IPCC 2014, p. 12). We conclude that ecosystem changes in the Arctic are already underway and likely to continue, and that arctic ecosystems likely face much greater future change that may be abrupt and irreversible. Further, climate change is opening the Arctic to development such as oil and gas exploration, commercial shipping, tourism, and fishing (Niles 2013; National Research Council (NRC) 2013, p. 4; Smith and Stephenson 2013, p. 2; Astill 2012; Roach 2007).

***Factor B:*** Threats to the red knot from overutilization for commercial, recreational, scientific, or educational purposes exist in parts of the Caribbean and South America. Specifically, legal and illegal hunting do occur. We expect mortality of individual knots from hunting to continue into the future, but at stable or decreasing levels due to the recent international attention to shorebird hunting, and due to new voluntary and regulatory hunting restrictions in some areas.

Legal and illegal sport and market hunting in the mid-Atlantic and Northeast United States substantially reduced red knot populations in the 1800s, and we do not know if the subspecies ever fully recovered its former abundance or distribution (Karpanty *et al.* 2014, p. 2; Cohen *et al.* 2008; Harrington 2001, p. 22). Neither legal nor illegal hunting are currently a threat to red knots in the United States, but both occur in the Caribbean and parts of South America (Harrington 2001, p. 22). Hunting pressure on shorebirds in the Lesser Antilles (e.g., Barbados, Guadeloupe) is very high (USFWS 2011e, pp. 2–3), but only small numbers of red knots have been documented on these islands, so past mortality may not have exceeded tens of birds per year (G. Humbert pers. comm. November 29, 2013). Red knots are no longer being targeted in Barbados or Guadeloupe, and other measures to regulate shorebird hunting on these islands are being negotiated (G. Humbert pers. comm. November 29, 2013; McClain 2013; USFWS 2011e, p. 2). Much larger numbers (thousands) of red knots occur in the Guianas, where legal and illegal subsistence shorebird hunting is common (CSRPN 2013; Niles 2012b; Ottema and Spaans 2008, p. 343). About 20 red knot mortalities have been documented in the Guianas (D. Mizrahi pers. comm. October 16, 2011; Harrington 2001, p. 22), but total red knot hunting mortality in this region cannot be surmised. As of 2013, shorebird hunting was unregulated in French Guiana (A. Levesque pers. comm. January 8, 2013; D. Mizrahi pers. comm. October 16, 2011). However, a ban on hunting all shorebird species has been proposed in French Guiana (CSRPN 2013), and the red knot was designated a protected species in October 2014 (C. Carichiopulo and N. de Pracontal pers. comm. October 10, 2014). Subsistence shorebird hunting was also common in northern Brazil, but has decreased in recent decades (Niles *et al.* 2008, p. 99).

We have no evidence that hunting was a driving factor in red knot population declines in the 2000s, or that hunting pressure is increasing. While only low to moderate red knot mortality is documented, additional undocumented mortality is likely. The findings of Watts (2010, p. 39) suggest that even moderate (hundreds of birds) direct human-caused mortality may begin to have population-level effects on the red knot. We do not have reliable information to reasonably know if hunting mortality is or was previously at this level in the Guianas, though we conclude it was likely much lower (tens of birds) in the Caribbean islands. In contrast, catch limits, handling protocols, and studies on the effects of research activities on survival all indicate that overutilization for scientific purposes is not a threat to the red knot (Niles *et al*. 2010a, p. 124; L. Niles and H. Sitters pers. comm. September 4, 2008; Niles *et al.* 2008, p. 100).

***Factor C:*** From our review of best available data, we conclude that disease is not a threat to red knot populations. Predation pressures exacerbate other threats in some nonbreeding areas, but likely contribute little direct mortality. Natural cycles of high predation rates on the breeding grounds are not a threat to red knot populations, but disruption of these cycles from climate change, which may lead to prolonged periods of low productivity, is a threat to the red knot.

Red knots may be adapted to parasite-poor habitats and may, therefore, be susceptible to parasites when migrating or wintering in high-parasite regions (Piersma 1997, p. 623). However, we have no evidence that parasites have affected red knot populations beyond causing normal, background levels of mortality (D'Amico *et al*. 2008, pp. 193, 197; Harrington 2001, p. 21), and we have no indications that parasite infection rates or red knot fitness impacts are likely to increase. Therefore, we conclude that parasites are not a threat to the red knot. For the most prevalent viruses found in shorebirds within the red knot's geographic range (e.g., avian influenza, avian paramyxovirus), infection rates in red knots are low, and health effects are minimal or have not been documented (D. Stallknecht pers. comm. January 25, 2013; Maxted *et al.* 2012, pp. 322–323; Coffee *et al.* 2010, p. 484; Escudero *et al.* 2008, pp. 494–495; Niles *et al*. 2008, p. 101; D'Amico *et al.* 2007, p. 794). Therefore, we conclude that viral infections do not cause significant mortality and are not a threat to the red knot. However, we acknowledge an unlikely but potentially high-impact, synergistic effect among avian influenza, environmental contaminants, and climate change could produce a population-level impact in Delaware Bay.

Outside of the breeding grounds, predation is not directly effecting red knot populations despite some mortality (Niles *et al.* 2008, p. 28). At key stopover sites, however, localized predation pressures exacerbate other threats to red knot populations by pushing red knots out of otherwise suitable foraging and roosting habitats, causing disturbance, and possibly causing changes to stopover duration or other aspects of the migration strategy (Niles 2010a; Watts 2009b; Niles *et al.* 2008, pp. 101, 116; Lank *et al.* 2003, p. 303). In addition, predation pressure may induce sublethal physiological stress that can impact shorebird fitness (Clark and Clark 2002, p. 49). We expect the direct and indirect effects of predators to continue at the same level or decrease slightly over the next few decades.

Within the breeding range, normal 3- to 4-year cycles of high predation, mediated by rodent (e.g., lemming) cycles, result in years with extremely low reproductive output but do not threaten the survival of the red knot at the subspecies level (Niles *et al.* 2008, pp. 64, 101; Meltofte *et al.* 2007, p. 20). It is believed shorebirds, such as red knots, have adapted to these cycles, therefore these natural cycles are not considered a threat to the red knot. What is a threat, however, is that these natural rodent/predator cycles are being disrupted by climate change, which may increase predation rates on shorebirds over the long term and have subspecies-level effects (Chapter 28 in IPCC 2014, p. 14; Fraser *et al.* 2013, pp. 13, 16; Brommer *et al.* 2010, p. 577; Ims *et al.* 2008, p. 79; Kausrud *et al.* 2008, p. 98). Disruptions in the rodent-predator cycle pose a substantial threat to the red knot, as they may result in prolonged periods of very low reproductive output (Meltofte *et al.* 2007, p. 22). Such disruptions have already occurred and may increase due to climate change (Chapter 28 in IPCC 2014, p. 14; Fraser *et al.* 2013, pp. 13, 16; Brommer *et al*. 2010, p. 577; Ims *et al.* 2008, p. 79; Kausrud *et al.* 2008, p. 98). The substantial impacts of elevated egg and chick predation on shorebird reproduction are well known (Smith and Wilson 2010, pp. 615, 621; Meltofte *et al.* 2007, p. 20), although the red knot's capacity to adapt to long-term changes in predation pressure is unknown (Meltofte *et al.* 2007, p. 34). The threat of persistent increases in predation in the Arctic may already be having subspecies-level effects (Fraser *et al.* 2013, p. 13) and is anticipated to increase into the future. Further, warming temperatures and changing vegetative conditions in the Arctic are likely to bring additional changes in the predation pressures faced by red knots, such as colonization by new predators from the south, though we cannot forecast how such ecosystem changes are likely to unfold.

***Factor D:*** We have reviewed the adequacy of existing regulatory mechanism across the range of the red knot. In Canada, the Species at Risk Act provides protections for the red knot and its habitat, both on and off of Federal lands. The red knot is afforded additional protections under Canada's Migratory Birds Convention Act and by provincial law in four of the Provinces. Red knots are legally protected from direct take and hunting in several Caribbean and Latin American countries, but we lack information regarding the implementation or effectiveness of these measures. For many other countries, red knot hunting is unregulated, or we lack sufficient information to determine if red knot hunting is legal. We also lack information for countries outside the United States regarding the protection or management of red knot habitat, and regarding the regulation of other activities that threaten the red knot such as development, disturbance, oil spills, environmental contaminants, and wind energy development.

In the United States, the Migratory Bird Treaty Act and state wildlife laws protect the red knot from direct take resulting from scientific study and hunting. The Sikes Act, the National Park Service Organic Act, and the National Wildlife Refuge System Improvement Act provide protection for the red knot from habitat loss and inappropriate management on Federal lands. Section 404 of the Clean Water Act, the Rivers and Harbors Act, the Coastal Barrier Resources Act, the Coastal Zone Management Act, and State mechanisms regulate shoreline stabilization and development. State and local regulations provide varying levels of protection from impacts associated with beach grooming. Several Federal and State policies are in effect to stem the introductions and effects of invasive species, but collectively do not provide complete protection to the red knot from impacts to its habitats or food supplies resulting from beach or marine invaders or the spread of harmful algal species. Although threats to the horseshoe crab egg food resource remain, regulatory management of the horseshoe crab fishery under the Adaptive Resource Management (ARM) framework is adequate to address threats to the knot's Delaware Bay food supply from direct harvest. Regarding climate change, the U.S. Environmental Protection Agency (USEPA) has developed several initiatives related to greenhouse gasses (GHGs). However, some of the USEPA's proposed GHG regulations are not yet final and, even when final, substantially greater reductions in GHGs would still be needed at multiple scales to reduce the magnitude of likely climate changes over the next several decades. Although we lack information regarding the overall effect of recreation management policies on the red knot, we are aware of a few locations in which beaches are closed, regulated, or monitored to protect nonbreeding shorebirds. Relatively strong Federal laws likely reduce risks to red knots from oil spills, but cannot fully abate the risk of oil spills and leaks. Similarly, Federal law and policy reduce the red knot's collision risks from new wind turbine development, but some level of mortality is expected upon build-out of the Nation's wind energy infrastructure.

***Factor E:*** Based on our review of the best available scientific and commercial data, the red knot faces subspecies-level impacts from other natural and manmade factors that are already occurring and are anticipated to continue and possibly increase into the future.

Reduced food availability at the Delaware Bay stopover site due to commercial harvest of the horseshoe crab is considered a primary causal factor in the decline of rufa red knot populations in the 2000s (Escudero *et al.* 2012, p. 362; McGowan *et al.* 2011a, pp. 12–14; Niles *et al.* 2008, pp. 1–2; Baker *et al.* 2004, p. 875). Under the current management framework (the ARM), the present horseshoe crab harvest is not considered a threat to the red knot. However, continued implementation of the ARM is imperiled by lack of funding to support the requisite monitoring programs. With or without the ARM, it is not yet known if the horseshoe crab egg resource will continue to adequately support red knot population growth over the next decade. Notwithstanding the importance of the horseshoe crab and Delaware Bay, the red knot faces a range of ongoing and emerging threats to its food resources throughout its range, including small prey sizes from unknown causes (Escudero *et al.* 2012, pp. 359–362; Espoz *et al.* 2008, pp. 69, 74), warming water and air temperatures (Jones *et al.* 2010, pp. 2255–2256), ocean acidification (International Geosphere-Biosphere Programme (IGBP) *et al.* 2013, pp. 9, 16; NRC 2010b, pp. 68–69), physical habitat changes (Chapter 5 <u>in</u> IPCC 2014, p. 21; Rehfisch and Crick 2003, p. 88; Najjar *et al.* 2000, p. 225), possibly increased prevalence of disease and parasites (Ward and Lafferty 2004, p. 543), marine invasive species (Seebens *et al.* 2013, p. 782; Ruesink *et al.* 2005, pp. 671–674; Grosholz 2002, p. 22–23), and burial and crushing of invertebrate prey from sand placement and recreational activities (Sheppard *et al.* 2009, p. 113; Schlacher *et al.* 2008b, pp. 345, 348; Schlacher *et al.* 2008c, pp. 878, 882; Greene 2002, p. 24).

In addition, the red knot's life-history strategy makes this species inherently vulnerable to mismatches in timing between its annual cycle and those periods of optimal food and weather conditions upon which it depends (Galbraith *et al.* 2014, p. 7 and Supplement 1; Liebezeit *et al.* 2014, p. 2; Conklin *et al.* 2010, p. 4; Gill *et al.* 2013, p. 1; Hurlbert and Liang 2012, pp. 4–5; McGowan *et al*. 2011a, pp. 2, 16; Smith *et al.* 2011a, p. 575; Meltofte *et al.* 2007, p. 36). The red knot's sensitivity to timing asynchronies has been demonstrated through a population-level response, as the late arrivals of birds in Delaware Bay is generally accepted as a key causative factor (along with reduced supplies of horseshoe crab eggs) behind population declines in the 2000s (Baker *et al*. 2004, p. 878). The factors that caused delays in the spring migrations of red knots from Argentina and Chile are still unknown (Niles *et al*. 2008, p. 2), and we have no information to indicate if this delay will reverse, persist, or intensify in the future. Superimposed on the existing threat of late arrivals in Delaware Bay are new threats emerging due to climate change (Summary for Policymakers <u>in</u> IPCC 2014, p. 30; Root *et al.* 2013, pp. 85–88; Hurlbert and Liang 2012, p. 4), such as changes in the timing of reproduction for both horseshoe crabs and mollusks (Burrows *et al.* 2011, p. 652; Poloczanska *et al.* 2013, pp. 3–4; Smith *et al.* 2010b, p. 563; van Gils *et al.* 2005a, p. 2615; van Gils *et al.* 2005b, pp. 126–127; Philippart *et al.* 2003, p. 2171). Climate change may also cause shifts in the period of optimal arctic insect and snow conditions relative to the time period when red knots currently breed (Grabowski *et al.* 2013, p. 1097; McGowan *et al*. 2011a, p. 13; Smith *et al*. 2010a, p. 292; Tulp and Schekkerman 2008, p. 48; Meltofte *et al.* 2007, pp. 7, 25; Piersma *et al.* 2005, p. 270; Schekkerman *et al.* 2003, p. 340). The red knot's adaptive capacity to deal with numerous changes in the timing of resource availability across its geographic range is largely unknown (Liebezeit *et al.* 2014, pp. 1, 10;

Grabowski *et al.* 2013, p. 1103; Meltofte *et al.* 2007, p. 34). A few examples suggest some flexibility in red knot migration strategies (D. Newstead pers. comm. May 8, 2014; Grabowski *et al.* 2013, pp. 1097, 1100–1103; Smith *et al*. 2010a, p. 292; González *et al.* 2006, p. 115; González *et al.* in International Wader Study Group (IWSG) 2003, p. 18), but differences between the annual timing cues of red knots (at least partly celestial and endogenous) (Liebezeit *et al.* 2014, p. 10; Conklin *et al.* 2010, p. 5; Gill *et al.* 2013, p. 1; McGowan *et al.* 2011a, p. 16; Cadée *et al.* 1996, p. 82) and their prey (primarily environmental) (Smith *et al.* 2010b, p. 563; Philippart *et al.* 2003, p. 2171) suggest there are limitations on the adaptive capacity of red knots to cope with increasing frequency or severity of asynchronies.

Other factors are likely to exacerbate the effects of reduced prey availability and asynchronies, including human disturbance (Burger and Niles 2013a, p. 23; Burger and Niles 2013b, p. 657; Escudero *et al.* 2012, pp. 358, 362), competition with gulls (Niles *et al.* 2008, p. 107; Burger *et al.* 2007, p. 1162), and behavioral changes from wind energy development (Kuvlesky *et al.* 2007, p. 2489). Additional factors are likely to increase the levels of direct red knot mortality, such as harmful algal blooms (HABs) (Newstead 2014a, p. 23; Anderson 2007, p. 2), oil spills (Anderson *et al*. 2012, p. 10; WHSRN 2012; Kalasz 2008, pp. 39–40; Niles *et al.* 2008, p. 98, 100), and collisions with wind turbines (D. Newstead pers. comm. March 5, 2013; Burger *et al*. 2012c, p. 370; Burger *et al.* 2011, p. 348; Watts 2010, p. 1; Kuvlesky *et al.* 2007, p. 2487). In addition to elevating background mortality rates, these three factors pose the potential for a low-probability but high-impact event if a severe HAB or major oil spill occurs when and where large numbers of red knots are present, or if a mass-collision event occurs at wind turbines during migration.

**Conclusion:** Red knots face a wide range of threats across their range on multiple geographic and temporal scales. The effects of some smaller threats may act in an additive fashion to ultimately impact populations or the subspecies as a whole (cumulative effects). Other threats may interact synergistically to increase or decrease the effects of each threat relative to the effects of each threat considered independently (synergistic effects). For example, reduced food availability has been shown to interact synergistically with asynchronies and several other threats, such as asynchronies, disturbance, predation pressure, and competition with gulls (Escudero *et al.* 2012, p. 362; Dey *et al.* 2011a, pp. 7, 9; Breese 2010, p. 3; Niles *et al*. 2008, p. 2; Atkinson *et al.* 2007, p. 892; Niles *et al.* 2005, p. 4; Baker *et al.* 2004, p. 878). We conclude that a number of threats are likely contributing to habitat loss, anthropogenic mortality, or both, and thus contribute to the red knot's threatened status, particularly considering the cumulative and synergistic effects of these threats, and that several key populations of this species have already undergone considerable declines.