Draft Compatibility Determination

Title

Draft Compatibility Determination for the Harvest of Horseshoe Crabs, Cape Romain National Wildlife Refuge.

Refuge Use Category

Other Uses

Refuge Use Types

Harvesting (commercial)

Refuge

Cape Romain National Wildlife Refuge (Refuge)

Refuge Purposes and Establishing and Acquisition Authorities

The Refuge was established under the authorities in the Migratory Bird Conservation Act (MBTA), 16 U.S.C. §§ 703-712, the Fish and Wildlife Act, 16 U.S.C. §§ 742a-754e, and the Refuge Recreation Act, 16 U.S.C. §§ 460kk-460kk-4, in recognition of the significant benefits of the Refuge's lands and waters for migratory bird and public recreation. The primary purposes of the Refuge are:

"to conserve and protect migratory birds . . . and other species of wildlife that are listed . . . as endangered species or threatened species and to restore or develop adequate wildlife habitat." Migratory Bird Conservation Act, 16 U.S.C. § 715i;

"for use as an inviolate sanctuary, or for any other management purpose, for migratory birds." Migratory Bird Conservation Act, 16 U.S.C. § 715d;

"for the development, advancement, management, conservation, and protection of fish and wildlife resources." 16 U.S.C. § 742f(a)(4);

"for the benefit of the United States Fish and Wildlife Service, in performing its activities and services. Such acceptance may be subject to the terms of any restrictive or affirmative covenant, or condition of servitude." 16 U.S.C. § 742f(b)(1);

"for [suitable] (1) incidental fish and wildlife-oriented recreational development, (2) the protection of natural resources, (3) the conservation of endangered species or threatened species." 16 U.S.C. § 406k-2; and

"to provide protection of these areas . . . and to ensure . . . the preservation of their wilderness character . . .." Wilderness Act. 16 U.S.C. § 1131(a).

National Wildlife Refuge System Mission

Congress articulated the mission of the National Wildlife Refuge System in the National Wildlife Refuge System Improvement Act (NWRS Improvement Act), 16 U.S.C. §§ 668dd-668ee. The Mission of the National Wildlife Refuge System is to "administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans." 16 U.S.C. § 668dd(a)(2).

Description of Use

Is this an existing use?

In 2022, the Fish and Wildlife Service (Service) received two applications for special use permits (SUP) to harvest horseshoe crabs within the Refuge. Although prior harvesting had occurred within the Refuge, it was conducted without the issuance of a Special Use Permit by the Service. Therefore, in anticipation of future similar requests, the Service must evaluate whether it is compatible in accordance with Federal laws, regulations and policies.

What is the use?

The use that the Service is evaluating for compatibility is the harvest of American horseshoe crabs (*Limulus polyphemus)* throughout the entire Refuge.

Is the use a priority public use**?**

No

Where would the use be conducted?

Prior horseshoe crab harvesting in the Refuge was done by hand in the tidal zone of Refuge islands. Motor craft would be navigated through Refuge waters and then beached. Harvesters would walk through the tidal zone, shallow water and on Refuge islands to pick up horseshoe crabs and load them into their boats. However, horseshoe crabs may be found and potentially harvested throughout the Refuge.

When would the use be conducted?

Horseshoe crab harvesting may occur throughout the year so long as the crabs may be present, but harvesting has typically occurred when horseshoe crabs spawn. In the Refuge this occurs during the highest tides from April 1-June 30. These tides occur at night and coincide with new and full moons.

How would the use be conducted?

As was mentioned above, horseshoe crab harvesters who previously harvested within the Refuge, utilized motor vessels to access Refuge submerged lands and islands. Previously, the harvesters exited their vessels in shallow water, on submerged lands, in marshes, in wetlands and on islands. The harvesters would walk through submerged lands, shallow waters, marshes, wetlands, and on Refuge islands to collect the crabs by hand and load them into their vessels which they pull with them.

The harvesters work in large teams and in addition to removing horseshoe crabs they flush any and all birds present in the harvesting area.

The activity generally occurs at night when the Refuge is closed to all members of the public. The volume of crabs that are harvested and the percentage of their population that is removed, is not precisely known. However, law enforcement officers have reported 25,000 crabs have been removed from the Refuge in one spawning season and upwards of 3,000 crabs removed per night. In a local news article, a local harvester reported using a 4-boat crew to collect 16,000 horseshoe crabs from the Refuge over the course of 6 days.

Harvesters primarily sell horseshoe crabs to a biomedical company for the production of *Limulus* amoebocyte lysate (LAL). The crabs are removed from their spawning locations in the Refuge and transported to a facility where they are bled. The Service knows little about the methods of and locations where harvesters dispose of the crabs that have been bled. State law requires that the crabs be returned to state waters of comparable salinity and water quality. However, there is no requirement that crabs must be returned to the same geographic area from which they were collected.

Why is this use being proposed or reevaluated?

In 2020 the Defenders of Wildlife (DOW) sued the Service alleging violations of several Federal statutes including the NWRS Improvement Act, the Endangered Species Act (ESA) and the Migratory Bird Treaty Act. Among other things, DOW alleged that the Service violated its regulation by failing to require that commercial horseshoe crab harvesters in the Refuge obtain an SUP from the Service. The Court held that the Service likely had violated its rules by not requiring a permit and that the Service had the authority to regulate commercial horseshoe crab harvesting within the Refuge.

In 2022, after the litigation, the Service received two applications for SUPs to commercially harvest horseshoe crabs within the Refuge and anticipates it will receive more in the future. One of the applications was denied because the applicant sought to harvest in areas of the Refuge where access is closed to all members of the public. The Service could not finish processing the second application prior to the end of the harvesting seasons reflected in the application.

Availability of Resources

In its compatibility determination analysis, the Service must evaluate whether it has sufficient funding, personnel, and facilities to develop, manage and maintain the proposed use to ensure it is compatible. 603 FW 2.11(A)(2). This proposed use is different than most other uses that the Service analyzes for compatibility because the use would primarily occur after the Refuge is closed to the public. This would significantly increase the resources that the Service would have to allocate to the proposed use.

If the Service were to authorize horseshoe crab harvesting on the Refuge, it would require it to divert funding and personnel time, to oversee the activity. Oversight obligations would include staff time to administer the SUPs, to coordinate after-hours access, to add law enforcement patrols, and to collect and report data from the permit holders. The Service would also have to monitor the impacts of the harvest on the Refuge's natural resources. 603 FW 2.12(11)(b) and 052 FW 1. To discharge this obligation, Service biologists would have to (1) design a horseshoe crab population monitoring and tagging program prior to harvest, (2) conduct annual biological surveys of horseshoe crab spawning densities to assess the impact of the use over time, and perform annual data analysis and reporting. The Refuge would also have to increase law enforcement patrols during the day and add them at night, to ensure that harvesters comply with all Refuge rules and permit conditions.

Table 1. Costs to Administer and Manage Horseshoe Crab Harvest Activities on Cape Romain National Wildlife Refuge

Category and Itemization	One-time Costs	Recurring Annual Expenses
Develop plan/National Environmental Policy Act documents/opening package	1 Biologist/manager ($37/hr. (GS7) to $92/hr. (GS14)) x 40 hours =$1,480 to $3,680	---
Design and implement a horseshoe crab population monitoring and tagging program on the refuge prior to harvest	1 Biologist/manager ($37/hr. (GS7) to $92/hr. (GS14)) x 80 hours =$2,960 to $7360	---
Staff time (law enforcement, administration and management, including issuing Special Use Permits, documenting harvest activities, coordinating access	--	1 Biologist/manager ($37/hr. (GS7) to $92/hr. (GS14)) x 40 hours =$1,480 to $3,680 1 law enforcement officer ($37/hr. (GS7) to $92/hr. (GS14)) x 288 hours =$10,656 to $26,496

Annual monitoring of refuge horseshoe crab populations to assess impacts of harvest on local populations of crabs	--	3 refuge staff/South Carolina Department of Natural Resources staff ($37/hr. (GS7) to $92/hr. (GS14)) X 32 hours = $3,552 to $8,832 6 volunteers to assist with monitoring (refuge staff coordinating, training, supervising volunteers by 1 Biologist/manager (($37/hr. (GS7) to $92/hr. (GS14)) x 40 hours) =$1,480 to $3,680 Fuel costs: 1 law enforcement boat 225 gallons of fuel for refuge patrol during HSC season @ 3.50/gallon = $787 Monitoring of population – two boats 80 gallons of fuel @ 3.50/gallon = $280
Annual data analysis and reporting of take	--	1 Biologist/manager ($37/hr. (GS7) to $92/hr. (GS14)) x 40 hours =$1,480 to $3,680
Total one-time expenses	**$4,440 to $11,040**	
Total recurring annual expenses		**$19,715 to $47,435**
Offsetting revenues	**-$0**	**-$0**
Total expenses	**$4,440 to $11,040**	**$19,715 to $47,435**

The Service estimates that the initial one-time cost to oversee this use, would be between $4,440 and $11,040 and the yearly recurring cost would be between $19,715 and $47,435. The Refuge's current resources are insufficient to administer this proposed use.

Anticipated Impacts of the Use

Standard for Compatibility Determinations

In addition to considering the availability of resources, in its compatibility determination analysis, the Service must evaluate whether the proposed use will materially interfere with and/or detract from the purposes of the specific refuge and/or the mission of the National Wildlife Refuge System as a whole. 603 F.W. 2.11(B)(1). The refuge manager must make his/her decision based upon his/her sound professional judgment. 603 F.W. 2.11(B)(1). "Inherent in fulfilling the System mission is not degrading the ecological integrity of the refuge." 603 FW 2.11(B)(1). The burden is on the proponent of the use to demonstrate that the use is compatible. 603 FW 2.11(B)(1).

While refuge managers should be looking for tangible impacts, the fact that a use will result in a tangible adverse effect, or a lingering or continuing adverse effect is not necessarily the overriding concern regarding "materially interfere with or detract from." These types of effects should be taken into consideration, but the primary aspect is how does the use and any impacts from the use affect our ability to fulfill the System mission and the refuge
purposes.
603 FW 2.11(B)(2).

A lack of knowledge about a proposed use does not preclude the refuge manager from making a decision regarding compatibility. The refuge manager does not need to independently generate data. 603 FW 2.11(B)(E). Rather, the Service's decision must be made on a refuge-specific basis based on reasonably anticipated impacts of the use on refuge resources. 603 FW 2.11(E). The Service's decision should be based upon readily available information including the refuge manager's field experience and familiarly with the refuge's resources. 603 FW 2.11(E). The Service's decision "may be based upon information derived from other areas or species that are similarly situated . . .." 603 F.W. 2.11(E).

Refuge Description

The Refuge was established in 1932 and is comprised of 66,000 acres, including 30,000 acres of open water and tidal creeks, 28,000 acres of salt marsh, and approximately 8,000 acres of barrier islands. A map of the Refuge is depicted on Figure 1. Over 50 percent of the Refuge is designated a Class I National Wilderness Area. Between 2019 and 2021 the Refuge hosted about 300,000 visitors a year. The Refuge was listed as a Western Hemisphere Shorebird Reserve Network (WHSRN) Site of International Importance in 1995 and has recorded 25% of the State's nesting Wilson's plovers and 42% of the State's nesting American oystercatchers (WHSRN 2022).

The Refuge is listed as one of ten birding hotspots in South Carolina by Birdwatchers Digest magazine. The Carolina Bird Club describes the Refuge, and Bulls Island in particular, as "considered by some experts to be the best birding area in South Carolina." The Refuge is also featured in the article "10 places every bird lover should visit" by Discover South Carolina. The Refuge is used by 22 species of shorebirds and eight species of sea birds at various times of the year for nesting, roosting, and foraging. The islands in the Refuge support a large percentage of South Carolina's entire nesting populations of numerous species. These include Black skimmer (*Rynchops niger,* 76%), least tern (*Sternula antillarum*, 42%), brown pelican (*Pelecanus occidentalis*, 12%) royal tern (*Thalasseus maximus*, 75%), sandwich tern (*T. sandvicensis*, 80%), gull-billed tern

(*Gelochelidon nilotica*, 81%), common tern (*Sterna hirundo*, 100%), and Forster's tern (*S. forster*i, 100%).

The Refuge provides important habitat and services for three federally threatened species, protected under the ESA, 16 U.S.C. §§ 153-1544, the rufa red knot (*Calidris canutus rufa*), piping plover (*Charadrius melodus*), and loggerhead sea turtle, as well as two federally endangered species, the leatherback sea turtle (*Dermochelys coriacea*) and Kemp's ridley sea turtle (*Lepidochelys kempii*). The red knot is listed as threatened in accordance with the ESA. Portions of the Refuge are proposed to be designated as a critical habitat for the red knot. (Figures 2 and 3). Piping plovers, identified as threatened in accordance with the ESA, use the Refuge as a wintering and migration site. Portions of the Refuge are designated critical habitat for the Piping plover. (Figure 6). As is mentioned above, the Refuge also serves as important nesting habitat for several species of sea turtles. In 2019, 40% of all the threatened loggerhead sea turtles that nested in South Carolina, nested in the Refuge. Portions of the Refuge are also designated critical habitat for the loggerhead sea turtle. (Figure 5). The endangered leatherback and Kemp's ridley sea turtles also nest in the Refuge. South Carolina has listed Wilsons's plovers as threatened. This species nests on many of the beaches throughout the Refuge. The Refuge hosts an average of 25% of South Carolina's nesting Wilson's plovers. The Refuge also hosts an average of 42% of South Carolina's nesting American oystercatchers.

Horseshoe Crabs in the Refuge

Horseshoe Crab Life Cycle: The American horseshoe crab is one of four extant species of horseshoe crabs; it is the only North American representative (Shuster Jr. 1982 [AR, 5A, 90- 1171). The horseshoe crab is not actually a true crab but is a member of an ancient group of arthropods, more closely related to spiders and scorpions, which predate dinosaurs by 250 million years. Horseshoe crabs have changed little since they adapted to their environment early in the history of life on earth (USFWS 1998a [AR, 3C, 295-2961). To understand potential impacts of harvesting horseshoe crabs on the population, it is important to consider its life cycle. In general, populations of species that are characterized by high reproductive potential (begin breeding at an early age, breed often, and produce many offspring or have high survivorship to reproductive age) are likely to reproduce quicker (Campbell 1990) and better sustain consumptive harvest pressures than species characterized by low reproductive potential. Horseshoe crabs are slow to reach sexual maturity (Shuster Jr. 1982 [AR, 5A, 90-1 171). Although female horseshoe crabs lay thousands of eggs each spawning attempt, it is unknown how many of these eggs result in mature, reproducing horseshoe crabs.

Horseshoe crabs first spawn at 9-10 years of age (Shuster Jr. 1982 [AR, 5A, 90-1 171, USFWS 1998a [AR, 3C, 295-2961). Spawning occurs on sandy beaches around new and full moon high tides from May through June (Shuster Jr. 1982 [AR, 5A, 90-1171, Shuster Jr. and Botton 1985 [AR, 5A, 172-1761, Barlow et al. 1986 [AR, 5A, 177-1871) although, in years when spawners appear to be relatively high in abundance, they seem to spawn on almost any high tide even into August (Shuster Jr. 2000). Usually, many more males than females come ashore to spawn (Shuster Jr. 2000). The adult female will dig down into the sand and lay clutches of eggs that become mixed with sand grains. A typical egg cluster, about the size and shape of a flattened golf ball, contains about 4,000 eggs (USFWS 1998a [AR, 3C, 295-2961), The nests occur in a wide band of the beach from just above the foot of the beach to the high tide line at depths up to 20cm in the sand (Shuster Jr.and Botton 1985 [AR, 5A, 172-1761, Penn and Brockmann 1988 as cited in Shuster Jr. 2000). Beach geochemistry, local tidal rhythms, predation and intraspecific competition for nesting space probably all affect nest site selection Penn and Brockman 1994). Storms can affect reproductive success by preventing adults from spawning or washing out nests that have already been laid (Shuster Jr. 1958 as cited in Shuster Jr. 2000, Shuster Jr. 2000). Page 7 of 41 Shuster Jr. and Botton (1985, as cited in Shuster Jr. 2000) note that after a female lays 80,000 to 100,000 eggs during several high tides, she returns to deeper waters.

Newly laid eggs are soft and sticky. The coat of the egg hardens in contact with seawater (USFWS 1998a [AR, 3C, 295-2961). Larvae hatch within four weeks after fertilization (Botton 1995 [AR, 5A, 315-3211), Larvae remain in the sand for several weeks and then begin moving towards the beach surface (Rudloe 1979 as in Penn and Brockmann 1994). Within two weeks, they molt into juveniles (Sekiguchi et al., 1982 as in Penn and Brockmann 1994). During the first summer, juvenile horseshoe crabs generally live in shallow waters near the shore, but undergo multiple molts, and disperse over the tidal flats moving in an offshore direction (Shuster Jr. 1979 [AR, 5A, 65-78]). The larger the animal the further it is from shore. Adults return annually to spawn on beaches and may do so for at least eight years (Shuster Jr. 2000). Horseshoe crabs may live up to 15-20 years (USFWS 1998a [AR, 3C, 295-2961). Within the mid-Atlantic region, most horseshoe crab populations exhibit partial migratory activities (Swan et al. 2005), where most horseshoe crabs migrate seasonally in the fall from local estuaries to the continental shelf and subsequently return to the estuaries for spawning during late spring. The continental shelf has shown to be an important area for maturing horseshoe crabs in the Delaware Bay population, but this is not true for all areas of the Atlantic coast. Other regions have shown that horseshoe crabs may stay in the estuarine embayment's while maturing (ASMFC 2019). In addition, the triggering mechanism for spawning to and from deeper waters appears to be water temperature related (Smith and Michels 2006, Watson et al. 2009, Bopp et al. 2021). Limited data in South Carolina exist on exact migratory behavior of the horseshoe crab between spawning events.

Natural causes of mortality include age, energy use during spawning, stranding, and predation (ASMFC 1998b [AR, 4A, 1761). Loveland et al. (1996 [AR, 5A, 4131) reports that, "Natural mortality among adult horseshoe crabs probably is very low while they are dispersed on the continental shelf." Once the crabs reach the spawning beaches, however, natural mortality increases mainly due to beach stranding. However, human actions probably account "for the greatest proportion of adult horseshoe crab mortality" (ASMFC 1998b [AR, 4A, 176]. In conclusion, the horseshoe crabs' reproductive strategy makes them vulnerable to over harvest. Horseshoe crabs congregating on beaches, during high tides to reproduce, are easily collected by harvesters in large quantities. Horseshoe crabs moving from deeper waters and subtidal areas to intertidal areas on the Refuge are also vulnerable to this type of harvest.

Horseshoe crabs migrate from deeper waters to near-shore waters during the spring to mate and lay their nests (Smith et al. 2017). Studies have found that within the spawning season, horseshoe crabs have high site-fidelity and return to the same spawning beaches multiple times to lay nests and mate (Brousseau et al. 2004, Smith et al. 2010, Beekey and Mattei 2015). Studies have shown that females spawned several times over the course of 2-5 nights, returning to the same beach (Brousseau et al. 2004, Smith et al. 2010). Beekey and Mattei (2015) found that horseshoe crabs nested at the same beach up to 6 days after first appearance (Beekey and Mattei 2015). Removing crabs from the vicinity of their preferred nesting beach and releasing them an unknown distance from the beach disrupts this behavior and will likely reduce the number of eggs laid during the tidal cycle, especially given that bled horseshoe crabs are less likely to spawn following bleeding (Anderson et al. 2013, Kurtz and James-Pirri 2002).

Takahashi (2016) counted horseshoe crabs spawning during the full moon in June 2015, and 3 days around the full moon in May 2016 across most of the Refuge islands. For both years, Marsh Island had the highest densities of spawning crabs. The night survey of the entire beach of Marsh Island in June 2015 recorded 441 horseshoe crabs. The number of horseshoe crabs spawning during the 3 days around the full moon in May 2016 ranged from 84 to 1,147 total horseshoe crabs observed on Marsh Island. Researchers also recorded spawning numbers within the shorebird plots during daytime surveys in 2016. Maximum daytime spawning numbers observed for plots within Marsh Island ranged from 789 to 1,175 horseshoe crabs.

Shorebirds need to consume thousands of horseshoe crab eggs to gain enough food stores for their energetically costly migrations (Haramis et al. 2007, Castro et al. 1989, Castro and Myers 1993). The superabundance of horseshoe crab eggs and their high nutritional quality and digestibility allows birds to rapidly maximize migratory and reproductive fitness (Haramis et al. 2007). Lack of sufficient crab eggs can be detrimental to migration, reproductive success, and survival (Baker et al. 2004). Shorebird species have been documented using the horseshoe crab eggs on the Refuge (Takahashi et al. 2021), and many of these species are facing declines in abundance (Morrison et al. 2006). Horseshoe crab eggs at the Refuge also may provide a food source for nonbreeding, juvenile shorebirds that are still present on the Refuge during late spring to early summer. (Takahashi et al. 2021).

The importance of horseshoe crab eggs to shorebirds that use the Refuge, specifically rufa red knots, has been well documented. Horseshoe crab eggs are an important food resource for rufa red knots and have been linked to the survival of rufa red knots in the Delaware Bay (Baker et al. 2004, Karpanty et al. 2006, Gillings et al. 2007, Niles et al. 2009, McGowan et al. 2011, Botton et al. 1994, Mizrahi and Peters 2009). Horseshoe crab eggs are a large part of the diet of rufa red knots staging in the Delaware Bay (Tsipoura and Burger 1999, Haramis et al. 2007, Novcic et al. 2015). Based on analyzed gut contents, Tsipoura and Burger (1999) found that rufa red knots, ruddy turnstones, semipalmated sandpipers, and sanderlings were species that foraged most heavily on horseshoe crab eggs. Studies have also shown that foraging rates of shorebirds are positively correlated to egg densities (Gillings et al. 2007).

In addition to eggs produced by horseshoe crabs, adult horseshoe crabs are high in protein content and provide a food resource for scavenging birds and sea turtles. Gull predation on stranded horseshoe crabs is identified as a significant source of mortality for adult horseshoe crabs (Botton and Loveland 1993, Botton 2009). Horseshoe crabs have also been well documented as a part of the loggerhead sea turtle diet (Seney and Musick 2007, Donaton et al. 2019, Keinath 2003, Botton 2009, Molter et al. 2022, Lutz and Musick 1996).

Impacts of Harvesting on Horseshoe Crabs

Harvesting horseshoe crabs from the Refuge will result in immediate reductions to the number of crabs on the Refuge through direct removals and mortalities. This will lead to decreased spawning and decreased number of horseshoe crab nests laid and subsequently reduced egg availability to shorebirds on beaches at the Refuge during the immediate spawning season. The consequences of these yearly short-term impacts will have negative long-term impacts on the overall health of the horseshoe crab and shorebird populations that inhabit and use the Refuge. The short- and long-term impacts to horseshoe crab and shorebird populations on the Refuge would negatively affect the Refuge’s ability to maintain the overall biological integrity, diversity, and environmental health of the Refuge (601 FW 3, USFWS 2006).

Immediate reductions to the number of horseshoe crabs on the Refuge from direct removals from harvest and mortalities from bleeding

As referenced above, Law enforcement officers have reported 25,000 crabs removed from the Refuge in one spawning season and upwards of 3,000 crabs removed per night (R. Wagner to S. Dawsey, email communications, 20 May 2014 and 17 June 2014). In a local news article, a local harvester reported using a 4-boat crew to collect 16,000 horseshoe crabs from the Refuge over the course of 6 days (Sausser and Peterson 2013).

In addition to direct removals from the Refuge, there are also mortalities associated with the bleeding process that would negatively impact the number of crabs on the Refuge over time. The Atlantic States Marine Fisheries Commission (ASMFC) accepts mortality for bleeding horseshoe crabs released to the environment as 15-30% (ASMFC 2013). Reported mortality rates for horseshoe crabs following bleeding have ranged from 10-30% (Rudloe 1983, Walls and Berkson 2003, Hurton and Berkson 2006, Leschen and Correia 2010, Anderson et al. 2013, Kurz and James-Pirri 2002). A South Carolina Department of Natural Resources study found a 20.4% mortality rate for the biomedical company that buys the horseshoe crabs harvested from the Refuge. (SCDNR 2012). The company that previously bought and bled horseshoe crabs from the Refuge, estimates a 4% mortality rate for crabs bled in South Carolina; however, there is no published data available to support this claim (Eisner 2022). The estimated harvest of horseshoe crabs from the Refuge in one spawning season was about 25,000 crabs, which would result in about 3,750-7,500 crabs lost to bleeding mortalities using the 15-30% accepted mortality rates. Females had a higher rate of mortality than males in bleeding trials (Walls and Berkson 2003, Leschen and Correia 2010, Krisfalusi-Gannon et al. 2018), which would also negatively affect the number of eggs laid.

Horseshoe crabs are exposed to a variety of potential stressors (e.g., air exposure, increased temperature, handling, blood loss, trauma, etc.) (Anderson et al. 2013, Owings et al. 2019, Kurz) during the transport to and from the biomedical company. Injuries during capture and handling to the telson (tail-like appendage on the horseshoe crab) occur and also lead to decreased numbers of horseshoe crabs on the Refuge. Horseshoe crabs use the telson to right themselves when flipped over by wave action on beaches, and injuries to the telson predisposes the crabs to stranding (Botton and Loveland 1989). Stranded horseshoe crabs are more vulnerable to predation (Botton and Loveland 1993) and at increased risk of desiccation and death (Botton and Loveland 1989).

Horseshoe crab population declines and potential for local extirpation from the Refuge

There is continued concern for populations of horseshoe crabs across the eastern seaboard (Smith et al. 2017). American horseshoe crab populations were recently assessed by the International Union for Conservation of Nature, and its status was upgraded from “Near threatened” to “Vulnerable” to extinction (Smith et al. 2016). Horseshoe crab populations in the Southeast region (North Carolina, South Carolina, Georgia, and Florida) have been reported as “appear stable or increasing,” based on trawl data from 1995-2012 (Smith et al. 2017) and “good” from the ASMFC 2019 stock assessment (ASMFC 2020). However, there are several South Carolina indices of abundance cited in the most recent stock assessment that report lower horseshoe crab abundance in recent years. The Southeast Area Monitoring and Assessment Program’s South Atlantic Coastal Trawl Survey showed a decline in South Carolina horseshoe crab abundance from 2013-2017 (ASMFC 2020). The South Carolina

Trammel Net Survey also reported abundance index declines observed from 2012 -2017 (ASMFC 2020). The South Carolina Crustacean Research and Monitoring Survey showed a lower index of abundance from 2010-2017 compared to high abundance throughout the 2000s (ASMF 2020).

Additionally, recent anecdotal reports of local declines and extirpations in South Carolina are cause for concern. Chaplin (personal communication 2021) reported that there has been no horseshoe crab spawning on Turtle Island, South Carolina, following intensive biomedical collections there in 2019 (Hunt 2022). A spokesperson from the Audubon Society noted fewer shorebirds and fewer horseshoe crabs seen in recent years in South Carolina (Eisner 2022). Refuge staff and SCDNR staff have also reported observing fewer crabs spawning on the Refuge in recent years. There is very little Refuge-specific information on spawning densities and horseshoe crab use of the Refuge over time, which makes analyzing the long-term impacts of horseshoe crab harvesting on the Refuge difficult.

Wenner et al. (2002) raised concerns about the hand-harvesting method, because large numbers of horseshoe crabs are being harvested before they can spawn on beaches. The researchers warned if this continues unchecked, it could result in a decline in the population in South Carolina that would not be apparent for 9 to 11 years—the amount of time it takes for juvenile crabs to mature (Wenner et al. 2002). Horseshoe crabs are a long-lived species (20 years) and take 9-10 years to reach sexual maturity (Sweka et al. 2007). Researchers have found that American horseshoe crabs are vulnerable to local extinctions (Smith et al. 2017). The detrimental effects of bleeding could lead to altered population dynamics and long-term declines (Krisfalusi-Gannon et al. 2018). Following years of population declines and continued biomedical harvest, Novitsky (2015) suggests that one way to ensure sustainability in the Northeast is to completely restrict all harvest during the spawning season, with no harvest January 1-July 31. As the South Carolina harvest season is limited to collection of crabs for the biomedical industry during the spawning season, no other collection method is relevant. Trawling the bottom has been employed offshore during the non-spawning season as the crabs migrate off shore but this is outside the boundary of the Refuge.

Biomedical harvest is identified as one of the major threats to the horseshoe crab that could impact population viability and lead to regional or species extinction (Smith et al. 2017). The authors cite several reasons for this, including the increasing demand for LAL, mortality rates, increasing mortality due to biomedical harvest, sublethal effects of bleeding, and the lack of reporting by biomedical companies on harvest.

Researchers predict an increase in demand for LAL production in the next two decades (Gauvry 2015, Krisfalusi-Gannon et al. 2018). A spokesperson for the local biomedical company is quoted in a recent news article as saying, "We need more, though . . .. We need access to more beaches, to get more crabs" (Kinnard 2021). Increased demand leads to increased harvest, which is followed by increased mortalities. There has been a 220% increase in reported horseshoe crab mortalities from the biomedical industry between 2004-2010 as the total number of crabs harvested for the industry has increased rapidly (Novitsky 2015). Additionally, there are still considerable knowledge gaps because few studies have analyzed the long-term effects of bleeding on horseshoe crabs (Smith et al. 2020). Owings et al. (2019) concludes that the behavioral impacts of the bleeding process could impact the sustainability of harvested populations, and more research is needed. Low population densities of horseshoe crabs can lead to decreased ability to find mates and loss of spawning opportunities (Mattei et al. 2010, Brockmann et al. 2015).

Sublethal effects of horseshoe crab harvesting

The high percentage of removals from Refuge beaches observed by law enforcement officers and Refuge staff would lead to low densities of horseshoe crabs left on the beaches to spawn. This results in less horseshoe crabs spawning on the beaches, which would result in less egg availability to shorebirds. Several studies have also shown that there are sublethal effects of bleeding horseshoe crabs that can lead to less spawning activity, and subsequently less eggs on the beaches for shorebirds, within the weeks post bleeding. James-Pirri 2002, Smith et al. (2020). Owings et al. (2019) found that bled females approached the beaches to mate less frequently than control crabs and remained in deeper waters more than control crabs. The authors suggested that this result is likely to further alter the sex ratio on spawning beaches, reduce reproductive output, lower population levels, and decrease the fitness and survival of this keystone species (Owings et al. 2019). A long-term analysis of horseshoe crab tagging data found reduced recapture rates in bled crabs, which could indicate decreased spawning activity (Smith et al. 2020). Movement patterns in bled crabs were found to be more random, concluding that crabs were more disoriented following bleeding compared to the control group (Kurz and James-Pirri 2002). Females had decreased rates of overall activity (more lethargic) and had decreased expression of tidal rhythms following bleeding (Anderson et al. 2013).

Horseshoe crabs collected for harvest are often taken before they are able to spawn and, following procedures for LAL collections in South Carolina, they are not released back to the same beaches. This reduces the total amount of eggs laid on the beaches for shorebirds. Horseshoe crab egg availability to shorebirds is also density dependent in that the bioturbation caused by multiple crabs spawning as well as wave action makes the eggs available to shorebirds in the upper layers of the sediment (Smith 2007, Botton et al. 1994). Therefore, reductions in crab densities on the beaches from harvest removals and associated mortalities will leave fewer adult crabs on the beaches during subsequent spawning events, which would decrease the number of eggs that are exhumed and brought to the surface for the birds to access for foraging.

As described above, one method that the local biomedical company uses to minimize the chance that the same crabs are not bled twice is to follow the practice "to prevent recapture, crabs are returned to same region, but not the discrete habitat harvested from." (Hunt 2022). Horseshoe crabs harvested for the biomedical industry in South Carolina are required by state regulation to be returned to state waters of comparable salinity and water quality, S.C. Code section 50-5-1330(C), however, there is no regulation that crabs must be returned to the same geographic area. Additionally, there is no reporting or enforcement of this law, so the Refuge has no knowledge on how many crabs are returned to Refuge waters within the same spawning season. Local watermen have observed harvesters releasing horseshoe crabs into the Intracoastal Waterway (S. Dawsey, personal communication). Under the current harvesting practices in South Carolina, there is no guarantee that horseshoe crabs removed from the Refuge will be returned to the Refuge beaches during the same spawning season. Additionally, based on findings that horseshoe crabs are more disoriented following bleeding and more lethargic, it is unclear how many crabs that are released into the bay will actually make their way back to the spawning beaches to lay eggs and mate. Therefore, a removal for biomedical use is functionally the same as a mortality because these crabs are not guaranteed to be returned to the Refuge to spawn or to provide ecological function.

As is mentioned above, one of the purposes for which the Refuge was established, is the protection of migratory shorebirds and sea birds. One of the Service's management goals for the Refuge is to "contribute to sustaining healthy and viable migratory bird populations representative of South

Carolina coastal ecosystems and the Atlantic Flyway" (USFWS 2010). The Refuge is an important breeding site for numerous species of migratory seabirds and shorebirds that depend upon the use of the beaches and intertidal areas of the Refuge. These are the same areas where horseshoe crab harvesting occurs. Potential impacts to the use to migratory birds include disturbance to nesting populations of shorebirds (e.g., American oystercatchers [*Haematopus palliatus*], Wilson's plovers [*Charadrius wilsonia]*), disturbance to nesting seabird colonies resulting in colony loss and nest failures, disturbance to foraging shorebirds, and decreased foraging opportunities for shorebirds and seabirds. The Service must evaluate whether the effects of horseshoe crab harvesting in the Refuge would materially interfere with or detract from the Service's goal of protecting these species.

Analysis of Impacts to Refuge Resources

To evaluate whether harvesting horseshoe crabs from the Refuge materially interferes and/or detracts from the purposes of the Refuge and the mission of the National Wildlife Refuge System, the Service must identify the reasonably foreseeable impacts to Refuge resources caused by the use. The Service must determine in its sound professional judgment the implications of those impacts to the purposes for the Refuge and the mission of the National Wildlife Refuge System. In this compatibility determination, the Service will analyze the environmental consequences on a resource only when the impacts on that resource could be more than negligible and therefore considered an "affected resource." In the Service's opinion the use would not cause more than negligible impacts to air quality, water quality, geology/soils, cultural resources, and socioeconomics. Therefore, those resources are not included in this analysis. However, harvesting horseshoe crabs from the Refuge poses reasonably foreseeable risks to other natural resources that are critical to the Refuge's purposes and the mission of the National Wildlife Refuge System.

As is outlined above, the Refuge was established for numerous reasons including the protection of (1) species protected by the ESA, and (2) species of birds protected by the Migratory Bird Conservation Act. The mission of the National Wildlife System is to "administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans . . . ." 16 U.S.C. § 668dd(a)(2). One of the Service's management goals for the Refuge is to "conserve, protect, and enhance populations of rare, threatened, and endangered species of plants and animals at existing or increased levels on the refuge, and conserve, protect, manage, and restore native South Carolina coastal plain habitats occurring on the refuge to contribute to recovery goals." (USFWS 2010).

Effects from harvesting horseshoe crabs in the Refuge impact resources in two ways: (1) decreased food sources, and (2) increased human activity associated with harvesting. Effects from harvesting horseshoe crabs and the associated human activity include but is not limited to a reduction in food availably for birds in the short and long term, increased bird flushing, and increased foraging competition. The Service must evaluate whether these effects would materially interfere with or detract from the Service's goal of protecting rare, threatened, or endangered species and conserving Refuge's resources. The Service will analyze the impacts on specific Refuge resources. The Service must also analyze the effects of horseshoe crab harvesting on the priority public uses of the Refuge and the impacts of climate change.

Effects from decreased food availability for birds and other endangered or threatened species

Allowing horseshoe crab harvesting on the Refuge would lead to decreased egg availability to shorebirds. Reducing the availability of this important food resource would significantly impact the migratory shorebirds that rely on the Refuge as a stopover site. Destruction or degradation of a stopover habitat may compromise a bird's ability to reach its goal and, for individuals migrating to the breeding grounds, this could negatively affect nesting success and long-term population viability (Skagen 2006).

Rufa red knot

The rufa red knot is a federally threatened shorebird that has experienced a population decline of over 85% in recent decades (USFWS 2021). During the winter, the Southeast region of the U.S. supports as much as 25% of the global rufa red knot population (Andres et al. 2012, Lyons et al. 2018). Pelton et al. (2022) estimates that 41% of the Southeast region of rufa red knot population use or pass through the nearby Kiawah and Seabrook islands in South Carolina during migration. A recent study estimated that over 10,000 rufa red knots winter in the Southeast region (Lyons et al. 2018). Recent research has also shown that rufa red knots are using the entire Southeast as a region of interconnected use sites (Tuma 2021), and the Refuge is one of these sites.

Researchers have documented rufa red knots and other shorebird species foraging on horseshoe crab eggs in South Carolina, including on the Refuge. Horseshoe crabs spawn on Deveaux Bank (approximately 50 miles southwest of the Refuge), where rufa red knots have been observed feeding on their eggs (Thibault and Levinson 2013). Research conducted on the Refuge concluded that rufa red knots and other shorebirds were foraging on horseshoe crab eggs at the Refuge, and the spatial and temporal distributions of shorebirds were related to the presence of horseshoe crab eggs (Takahashi et al. 2021). There are also several photos documenting shorebirds excavating horseshoe crab nests and foraging on horseshoe crab eggs at the Refuge over the years (*See* Figure 4).

Reduced food availability (horseshoe crab eggs) is listed in the most recent 5-year status review for rufa red knots as a "natural or manmade factor affecting its continued existence" (USFWS 2021). Reduced availability of horseshoe crab eggs affects the continued existence of red knots because it is associated with red knot rates of mass gain (Robinson et al. 2003, Atkinson et al. 2007) and the ability of birds to reach threshold departure weights for migration, which also influences adult survivorship (Baker et al. 2001, Niles et al. 2008, McGowan et al. 2011). Pelton et al. (2022) found that some red knots leave South Carolina and fly directly to the arctic, bypassing the Delaware Bay, showing the importance of South Carolina sites and the associated foraging resources to red knot migration and survival. Allowing horseshoe crab harvest from the Refuge would lead to a dramatic reduction in horseshoe crab eggs laid and therefore reduce the availability of this preferred food resource for red knots.

Piping plover

Piping plovers are small, stocky shorebirds that use the Refuge as a wintering and migration site, including during the horseshoe crab spawning months of April-May (Jamieson 2019, Wallover et al. 2015, Sanders et al. 2001, Dodd et al. 1999, Cubie et al. 2012, Dodd and Spinks 2001). The Refuge is included as part of the critical habitat designation for the wintering piping plover (USFWS 2001, Figure 6). The critical habitat units include the beaches of Lighthouse Island, North and Middle Raccoon Key, and the south end of Bulls Island. Additionally, nonbreeding piping plover populations are present in small numbers on the Refuge year-round.

Piping plovers in South Carolina have been documented foraging on horseshoe crab eggs (Chaplin personal communication 2022). The superabundance of horseshoe crab eggs and their high nutritional quality and digestibility allows shorebird species, including the piping plover, to rapidly maximize migratory and reproductive fitness (Haramis et al. 2007, Castro and Myers 1993), making horseshoe crab eggs an important resource for shorebirds using the Refuge. Studies have shown that lack of horseshoe crab eggs at stopover sites is linked to declines in overall fitness and population declines in other shorebirds (Baker et al. 2004, McGowan et al. 2011). Horseshoe crab harvesting at the Refuge would negatively impact the piping plovers in the Refuge that rely on horseshoe crab eggs. If the Service were to allow horseshoe crab harvesting at the Refuge, it would detract from or interfere with the Service's ability to fulfill the purpose for which the Refuge was established.

Foraging shorebirds

Non-breeding shorebirds, especially shorebirds that forage more extensively on horseshoe crab eggs would be impacted by horseshoe crab harvesting at the Refuge. There are 17 shorebird species and 3 gull species that have been observed foraging at the Refuge on beaches with horseshoe crab eggs: American oystercatcher, black bellied plover (*Pluvialis squatarola*), dunlin (*Calidris alpina*), least sandpiper (*Calidris minutilla*), marbled godwit (*Limosa fedoa*), piping plover, red knot, ruddy turnstone (*Arenaria interpres*), sanderling (*Calidris alba*), short-billed dowitcher (*Limnodromus griseus*), semipalmated plover (*Charadrius semipalmatus*), semipalmated sandpiper (*Calidris pusilla*), spotted sandpiper (*Actitis macularius*), western sandpiper (*Calidris mauri*), willet (*Tringa semipalmata*), Wilson's plover, white-rumped sandpiper (*Calidris fuscicollis*), herring gull (*Larus argentatus*), laughing gull (*Leucophaeus atricilla*), and ring billed gull (*Larus delawarensis*). (Takahashi et al. 2021). Many of these shorebird species are in decline (Morrison et al. 2006, North American Bird Conservation Initiative [NABCI], 2016, Bart et al. 2007). Additionally, shorebird populations in North America have declined by approximately 37% since 1974 (NABCI 2019), making this group of birds particularly vulnerable to impacts from horseshoe crab harvesting.

Loggerhead sea turtle

Another federally protected species that would be impacted by horseshoe crab harvesting in the Refuge is the loggerhead sea turtle. The Refuge is a designated critical habitat site for nesting loggerhead turtles under the ESA. (USFWS 2014). The critical habitat units on the Refuge include Cape Island, Lighthouse Island and Raccoon Key (Figure 5). In 2019, 40% of the loggerhead sea turtle nests in South Carolina were located at the Refuge (USFWS 2019), making the Refuge the most important breeding ground for loggerheads north of Florida.
Horseshoe crabs have been well documented as a part of the loggerhead sea turtle diet (Seney and Musick 2007, Donaton et al. 2019, Keinath 2003, Botton 2009, Molter et al. 2022, Lutz and Musick 1996). The crabs are high in protein content relative to other prey items in the loggerhead diet (Molter et al. 2022), which makes them a valuable prey resource to sea turtles. One study found that horseshoe crabs were the dominant prey item for loggerhead sea turtles and, in response to decreased availability due to overharvesting of horseshoe crabs, loggerheads switched their diet to less valuable other species (Seney and Musick 2007). Harvesting horseshoe crabs from the Refuge would lead to less adult and juvenile horseshoe crabs within the Refuge, which would lead to fewer opportunities for loggerhead sea turtles to consume horseshoe crabs. The Service is of the opinion that the harvesting of horseshoe crabs from the Refuge would diminish a critical food source in the Refuge

for loggerhead sea turtles.

Effects from increased human activity associated with harvesting horseshoe crabs

Allowing horseshoe crab harvesting on the Refuge would lead to increased human activity associated with harvesting, such as walking, wading, boating, etc. Increasing human activity in and around sensitive areas has been known to cause increased nest abandonment, additional energy expenditures due to flushing and alert behaviors, and detrimental changes to foraging activities. Prolonged or intense direct anthropogenic disturbance may cause shorebirds to increase energy expenditure to avoid disturbance or completely abandon a site (Burger 1986, Pfister et al. 1992). Ultimately, the human activity associated with horseshoe crab harvesting leads to negative impacts to shorebird and seabird survival. Impacts arising from human disturbance associated with recreational activities are currently managed by temporary seasonal closures in important bird and sea turtle nesting areas.

Rufa red knot

One of the most important conservation issues along the Atlantic Coast flyway is the impact of human disturbance on migrating shorebirds (Winn et al. 2013, AFSI 2015). Human disturbance causes shorebirds to spend more time on alert behaviors (running, crouching) and less time spent foraging (Burger 1990). Research has shown that red knots also forage at night, which may be necessary for birds to attain sufficient mass to complete migration (Cohen et al. 2011). Horseshoe crab harvesting activities, occurring during the day and evening, disturb red knots foraging. Human disturbance has also been shown to increase foraging competition between red knots and gulls for horseshoe crab eggs (Burger et al. 2007), which is also listed as a threat to red knot populations (Niles et al. 2007).

Piping plover

Increasing human disturbance is a major threat to piping plovers in their coastal migration and wintering range (USFWS 2009d). One of the priority recovery actions for piping plovers is to "protect wintering and migrating piping plovers and their habitat from human disturbance and to manage sites to reduce human-caused disturbance to non-breeding plovers" (USFWS 2015). Intense human disturbance in shorebird winter habitat can be functionally equivalent to habitat loss if the disturbance prevents birds from using an area (Goss-Custard et al. 1996). Disturbance can cause shorebirds to spend less time roosting or foraging and more time in alert postures or fleeing from the disturbances (Burger 1990, Burger 1991, Burger and Gochfeld 1991, Lafferty 2001, Thomas et al. 2003). Shorebirds that are repeatedly flushed in response to disturbance expend energy on costly short flights (Nudds and Bryant 2000).

Human activity associated with horseshoe crab harvesting, such as walking and wading along beaches during mid-high tides, boating, boat landings, and collecting crabs would impact piping plovers by causing disturbance to the birds' foraging and roosting activities. Piping plovers are also known to forage at night (Staine and Burger 1994); therefore, the most active times of horseshoe crabs harvesting would affect piping plover foraging activities. Human disturbance impacts to shorebirds are well documented (e.g. Pfister et al. 1992, Fitzpatrick and Bouchez 1998, McCrary and Pierson 2000, Cornelius et al. 2001, Burger and Niles 2013, Lafferty et al. 2013, Burger and Niles 2014, Gibson et al. 2018, Gibson et al. 2021, Cestari 2015).

Disturbance leads to negative impacts to survival. Research on piping plovers wintering in the Southeast has shown that piping plover body mass was substantially lower for individuals in areas with greater human disturbance than for individuals associated with less disturbed habitats. Likewise, survival rates of individuals in disturbed sites were lower than undisturbed sites (Gibson et al. 2018). Gibson et al. (2018) found piping plovers using disturbed sites across North Carolina, South Carolina, and Georgia had lower true annual survival rates than those using undisturbed sites. The study also found that plovers using more disturbed sites weighed an average of 7 percent less than those using less disturbed sites (Gibson et al. 2018). Due to their strong site fidelity, plovers that have previously used disturbed habitat are likely to return to that same location instead of finding more suitable habitat elsewhere (Gibson et al. 2018). Harvesters have not reported information on how many people would be disturbing the site, how long harvesters would be in an area, or how frequently. Therefore, the scale of the impact harvesting would have on piping plover disturbance is unknown.

Nesting Seabirds

The Refuge is an important breeding site for eight species of seabirds. The nesting seabirds use the ends of all the islands on the Refuge as well as the entirety of White Banks, Marsh Island, and the ephemeral islands, such as Bird Key-Bulls Bay that appears periodically off the north tip of Bulls Island. The islands in the Refuge support a large percentage, from 12%-100%, of the entire nesting populations of each species in the State of South Carolina: Black skimmer (*Rynchops niger,* 76%), least tern (*Sternula antillarum*, 42%), brown pelican (*Pelecanus occidentalis*, 12%) royal tern (*Thalasseus maximus*, 75%), sandwich tern (*T. sandvicensis*, 80%), gull-billed tern (*Gelochelidon nilotica*, 81%), common tern (*Sterna hirundo*, 100%), and Forster's tern (*S. forster*i, 100%). Therefore, protection of these colonies in the Refuge is critical to the breeding success of these populations in South Carolina.

Human activity associated with horseshoe crab harvesting is likely to impact seabird colonies, specifically around mid-high tides when there is less shoreline available as a buffer zone for human disturbance. Seabirds nest in tightly packed colonies and are particularly susceptible to human disturbance. Human disturbance lowers the reproductive success rate of gulls, terns, skimmers, and alcids (Carney and Sydeman 1999). Impacts to reproductive success include egg and nesting mortality and nest evacuation (Rodgers and Smith 1995). A study of the long-term trends in colonial seabirds in South Carolina suggests that one of the top management activities that would benefit the success of seabird breeding colonies would be limiting human access to the colony islands (Jodice et al. 2007). Black skimmers subjected to human disturbance abandoned colonies and had lower hatching success and lower fledgling success (Safina and Burger 1983). Colonies were most sensitive to disturbance during early stages of colony establishment (Safina and Burger 1983), which would coincide with peak horseshoe crab spawning season.

Boating activities associated with horseshoe crab harvesting could also negatively affect seabird colonies nesting on the Refuge. Burger (1998) documented common tern colonies flushing in response to motorized boats. Flushing birds from nests can lead to hyperthermia and hypothermia of the eggs, predation, and increased vulnerability to attacks from conspecifics, all of which can result in lowered nesting productivity (Burger 1998).

Beach nesting shorebirds

The State of South Carolina has listed Wilsons's plovers as threatened. This species nests on many of the beaches throughout the Refuge. (Dikun 2008, Sanders et al. 2012, Western Hemisphere Shorebird Reserve Network [WHSRN] 2022). Seventeen pairs of Wilson's plovers nested on Bulls Island in 2021 (Chaplin personal communication 2022), which include areas of the island that have previously been harvested for horseshoe crabs. The Refuge hosts an average of 25% of South Carolina's nesting Wilson's plovers yearly, making the Refuge a crucial breeding location for this species (WHSRN 2022). The nesting season for Wilson's plovers is March through July, which includes the horseshoe crab spawning season. Therefore, harvesting activity including walking on beaches at mid to high tides, boating near nests, landing boats on shore, and human presence near nests for extended periods of time, would impact birds.

Human disturbance is listed as a major threat to Wilson's plovers survival (South Carolina Department of Natural Resources [SCDNR] 2022) and can negatively affect reproductive success on beach nesting birds by reducing hatching and brood success (Burger 1995). Several studies have documented negative Wilson's plover responses to human disturbance (Sanders et al. 2012, Ray 2011, Derose-Wilson 2012). For example, Wilson's plovers in South Carolina were observed more frequently in remote sites with less human access compared to sites with more human access (Sanders et al. 2012). Researchers found a decrease in incubation and an increase in time spent alert in response to researcher presence (Derose-Wilson 2012). Nest abandonment caused by human disturbance (i.e., physical presence of humans) has also been observed in studies of Wilson's plover (Ray 2011). Therefore, the horseshoe crab harvest (and the associated human disturbance) along with any other human disturbance, could result in decreased reproductive success of Wilson's plovers on the Refuge. Horseshoe crab harvest activities would, especially at night, exacerbate disturbance on these birds as the refuge islands are closed at night to the public.

Another beach nesting shorebird that would be impacted by horseshoe crab harvesting activities is the American oystercatcher. American oystercatchers are a species of special concern in South Carolina and nest on many of the beaches and shell rakes throughout the Refuge. (WHSRN 2022, Sanders et al. 2013, Thibault 2008, Hand 2008, Sanders et al. 2008, Collins 2012, Thibault et al. 2010). The Refuge averages 42% of South Carolina's nesting American oystercatchers, making it a critical breeding location for this species (WHSRN 2022). Oystercatchers breed in early April through July, which coincides with the horseshoe crab spawning season. Therefore, similar to Wilson's plovers, harvesting activity such as walking on beaches at mid-high tides, boating near nests, landing boats on shore, and human presence near nests for extended periods of time would interfere with nesting, especially any night activity on the islands of the refuge that are closed to the public.

Human disturbance can lower the productivity of nesting American oystercatchers on the Refuge in several ways. The presence of humans flushes American oystercatchers from their nests (Sabine et al. 2006), resulting in lower productivity due to losses related to hyperthermia and hypothermia (Toland 1999). There is also the potential for eggs to be crushed by humans walking on the beach, resulting in nest failures (Sabine et al. 2006). Horseshoe crab harvesting often occurs at night, when the risk of crushing eggs and nests would be elevated due to decreased visibility. Researchers also found that American oystercatchers had higher nest success in areas closed to human disturbance (Gibson et al. 2021, Toland 1999).

Studies have shown that human disturbance can lead to nest abandonment and increased depredation from human-attracted predators, resulting in increased predation rates (MacIvor et al. 1990, Lord et al. 2001, Toland 1999). Predation is a main source of nest failure in American oystercatcher nests on the Refuge (Brooks 2011, Jodice et al. 2014). Therefore, any activities that would increase predation would have impacts to the local population of nesting shorebirds. Additionally, the presence of people has been documented to displace shorebirds and influence habitat use (Pfister et al. 1992, Fitzpatrick and Bouchez 1998, McCrary and Pierson 2000, Cornelius et al. 2001, Burger and Niles 2013, Lafferty et al. 2013, Burger and Niles 2014, Cestari 2015,). This would be another cumulative behavioral impact of horseshoe crab harvest to shorebirds on the Refuge that could negatively affect the birds over time; exacerbating pressure already present from general public use of the refuge beaches.

Foraging shorebirds

Impacts to foraging shorebirds from human activities is well documented, and research has shown that the presence of people displaces shorebirds and influences habitat use (Pfister et al. 1992, Fitzpatrick and Bouchez 1998, McCrary and Pierson 2000, Cornelius et al. 2001, Burger and Niles 2013, Lafferty et al. 2013, Burger and Niles 2014, Cestari 2015). Horseshoe crab harvest activities would deter birds from accessing beaches with horseshoe crab eggs. Studies show that the presence of humans on beaches deters birds from foraging patches and can result in decreased foraging rates (Burger 1981, Burger and Gochfeld 1991, Pfister et al. 1992, Yasué 2005, Tarr et al., 2010, Thomas et al. 2003). Another study found that shorebirds were more abundant in areas closed to human access (Gibson et al. 2021).

Non-breeding shorebirds, especially shorebirds that forage more extensively on horseshoe crab eggs would be impacted by horseshoe crab harvesting at the Refuge. There are 17 shorebird species and 3 gull species that have been observed foraging at the Refuge on beaches with horseshoe crab eggs: American oystercatcher, black bellied plover (*Pluvialis squatarola*), dunlin (*Calidris alpina*), least sandpiper (*Calidris minutilla*), marbled godwit (*Limosa fedoa*), piping plover, red knot, ruddy turnstone (*Arenaria interpres*), sanderling (*Calidris alba*), short-billed dowitcher (*Limnodromus griseus*), semipalmated plover (*Charadrius semipalmatus*), semipalmated sandpiper (*Calidris pusilla*), spotted sandpiper (*Actitis macularius*), western sandpiper (*Calidris mauri*), willet (*Tringa semipalmata*), Wilson's plover, white-rumped sandpiper (*Calidris fuscicollis*), herring gull (*Larus argentatus*), laughing gull (*Leucophaeus atricilla*), and ring billed gull (*Larus delawarensis*). (Takahashi et al. 2021). Many of these shorebird species are in decline (Morrison et al. 2006, North American Bird Conservation Initiative [NABCI], 2016, Bart et al. 2007). Additionally, shorebird populations in North America have declined by approximately 37% since 1974 (NABCI 2019), making this group of birds particularly vulnerable to impacts from horseshoe crab harvesting.

Disturbance to foraging shorebirds can also impact birds by increasing foraging competition with gulls, which reduces their ability to forage. Shorebirds were found to be more sensitive to human disturbance compared to gulls and can therefore be displaced by gulls from their foraging beaches by disturbances (Burger et al. 2007). The results of the disturbance associated with horseshoe crab harvest activities can have long-term impacts on the shorebird species using the Refuge. Disturbance to foraging shorebirds can reduce individual body condition, survival, and other fitness components, potentially leading to local population declines (Lafferty 2001, Thomas et al. 2003, Tarr et al. 2010, Schlacher et al. 2013, Burger and Niles 2013, Gibson et al. 2018).

Loggerhead sea turtle

Impacts to loggerhead sea turtles on the Refuge from horseshoe crab harvesting activities are injuries and mortalities from boat strikes, a major cause of sea turtle injuries and mortalities (Ataman et al. 2021, Foley et al. 2019, Sobin 2008, Fuentes et al. 2021). Horseshoe crab harvesting often takes place during the evening hours when the ability to detect and avoid hitting a sea turtle would be more limited. One study found that female loggerhead sea turtles are most vulnerable to boat strikes following a false crawl event, within 12 hours after nesting, and the night before returning to the beach to nest (Sobin 2008), elevating the risk to female sea turtles during the most active times of horseshoe crab harvesting. The Service is of the opinion that the harvesting of horseshoe crabs from the Refuge would pose a negligible increased risk of boat strike injuries and mortalities to the loggerhead sea turtle.

Leatherback sea turtle and Kemp's ridley sea turtle

Other species of sea turtles that nest on the Refuge in smaller numbers include the federally endangered leatherback sea turtle and the federally endangered Kemp's ridley sea turtle. These species may also be affected by horseshoe crab harvesting similarly to loggerhead sea turtles including negligible increased risk of boat strikes and decreased foraging opportunities for horseshoe crabs.

Conservation, Management, and Restoration of the Refuge Resources

In addition to the purposes of the Refuge, the Service must analyze whether this proposed use is compatible with the mission of the National Wildlife Refuge System. The removal of horseshoe crabs from the Refuge and the subsequent declines in shorebird use of the Refuge, would impact two of the "Big 6" wildlife-dependent visitor uses on the Refuge that are established in the National Wildlife Refuge System Improvement Act-wildlife observation and photography. The average number of visitors to the Refuge between 2019 and 2021 was about 300,000 visitors per year (Refuge Rapp report, 2021). Visitors come to the Refuge for a variety of recreational and educational uses, and many of the visitors come for the bird watching opportunities. Declines in horseshoe crabs and declines in shorebird use of the Refuge due to horseshoe crab harvesting could affect this popular form of wildlife observation by reducing wildlife available for bird watching and photography. This use will interfere with and detract from the mission of the National Wildlife Refuge System to protect wildlife and their habitats for the enjoyment of the American public.

Declining shorebird use of the Refuge due to decreased habitat quality

The Refuge is one of many sites throughout South Carolina that are used by migratory birds, including red knots (Dodd and Spinks 2001, Wallover et al. 2015, Pelton et al. 2020). Shorebirds on the Refuge are known to forage on horseshoe crab eggs in the spring (Takahashi 2016), and the eggs provide an abundant and nutritious food source for birds to gain weight for their long migrations (Gillings et al. 2007). Several studies have correlated shorebird distributions to densities of horseshoe crab eggs (Karpanty et al. 2006, Gillings et al. 2007, Fraser et al. 2010, Takahashi et al. 2021). A study on the Refuge found that shorebirds were found less often on beaches with lower densities of horseshoe crab eggs, and shorebird densities were higher on beaches with higher densities of horseshoe crab eggs (Takahashi et al. 2021).

Horseshoe crab harvesting on the Refuge will lead to less horseshoe crab eggs available for shorebirds over time. Given that shorebird distributions on Refuge beaches in the spring are correlated to horseshoe crab egg abundance (Takahashi et al. 2021), the number of shorebirds using the beaches of the Refuge for foraging will likely decline as the amount of horseshoe crab eggs available declines. This would result in long-term declines in the numbers of shorebirds using the Refuge. This is supported by recent observations from Refuge staff and SCDNR staff that there have been lower numbers of horseshoe crabs spawning in recent years on the Refuge as well as lower numbers of shorebirds foraging in these areas.

Destruction or degradation of a stopover habitat may compromise a bird's ability to reach its energy-reserve goal and for individuals migrating to the breeding grounds, this could affect nesting success and long-term population viability (Skagen 2006).

Climate change

The impacts of horseshoe crab harvesting to the wildlife on the Refuge as detailed in the previous sections, will be exacerbated by the long-term effects of climate change to the Refuge. Shorebirds and horseshoe crabs, which will be the wildlife species most affected by the proposed use, are particularly vulnerable to the effects of climate change. Ninety percent of North American shorebirds are predicted to have an increase in risk of extinction due to climate change (Galbraith et al. 2014). The effects of climate change are also magnified for migratory shorebird species that are reliant on few stopover sites (Iwamura et al. 2013).

Horseshoe crabs are also vulnerable to the effects of climate change. Climate change and habitat loss, specifically loss of beach habitat for spawning, are listed as two of the major threats to horseshoe crab populations (Smith et al. 2017). Climate change will lead to loss of spawning habitat due to sea-level rise and storms (Loveland and Botton 2015). Increased water temperatures and altered storm frequency and severity associated with climate change would affect the timing and success of spawning activity (Smith et al. 2017).

The Refuge will continue to lose habitat for spawning horseshoe crabs, foraging shorebirds, and nesting seabirds and shorebirds due to climate change. A recent study conducted by the Audubon Society analyzed changes in satellite imagery of the Refuge and found that, between 1984 and 2020, approximately 18,233 acres (10.9% of the study area) transitioned from land to water, while 7,568 acres (4.5% of the study area) transitioned from water to land, translating to a net water increase of 10,665 acres on the Refuge (National Audubon Society 2020). A geomorphological analysis of Marsh Island (where the highest densities of horseshoe crabs are observed spawning on the Refuge) from 2011-2019 showed a decline in the total acreage of the island from 50 acres in 2011 to 37 acres in 2019. Von Holle et al. (2019) investigated the effect of sea-level rise on important sea turtle, seabird, and shorebird habitat across the South Atlantic Bight and found a substantial increase in the coastal erosion vulnerability under a modest increase in sea-level rise by 2030.

Conclusion

As is discussed above, horseshoe crab harvesting impacts endangered and threatened species, shorebirds, and seabirds. It also detracts from at least one of the priority recreational uses of the Refuge and the mission of the National Wildlife Refuge System. Finally, these impacts will be exacerbated by climate change.

Public Review and Comment

The draft compatibility determination will be available for public review and comment for 30 calendar days from March 8, 2023 to April 6, 2023. The public will be made aware of this comment opportunity through newspapers, refuge website, Facebook, postings at local libraries, post office, refuge visitor center and headquarters, letters to potentially interested people such as the SC Department of Natural Resources and Defenders of Wildlife. The SC Department of Natural Resources have been asked to review and comment on the draft compatibility determination. Concerns expressed during the public comment period will be addressed in the final.

A hard copy of this document will be posted at the Refuge Headquarters (5801 Hwy 17 North Awendaw, SC 29429), and will be available electronically on the refuge website https://www.fws.gov/refuge/cape-romain. Contact the Refuge Manager at (843) 928-3264 extension 213 if you need the document in an alternative format. Individuals in the United States who are deaf, blind, hard of hearing, or have a speech disability may dial 711 (TTY, TDD, or TeleBraille) to access telecommunications relay services.

Proposed Determination

Is the use compatible?

No

Stipulations Necessary to Ensure Compatibility

The use cannot be modified with stipulations sufficient to ensure compatibility.

Justification

In accordance with its policies, the literature cited above, and the sound-judgment of the Refuge Manager, FWS must conclude that this use is not compatible with the purposes for which the Refuge was established and the mission of the National Wildlife Refuge System. Any removal of a vital food source from the ecosystem, especially in the volume described above, has short- and long-term negative impacts to the species for which the Refuge was established to protect. It also detracts from at least one of the priority recreational uses of the Refuge and the mission of the National Wildlife Refuge System. These impacts will be exacerbated by climate change. Finally, the Refuge does not have sufficient resources to administer and regulate horseshoe crab harvesting on the Refuge. Based upon information derived from work, studies, and observations on the Refuge, information about similar locations and species, and the Service's knowledge of the Refuge, horseshoe crab harvesting at Cape Romain National Wildlife Refuge would materially interfere and detract from the purposes for which the Refuge was established and the mission of the National Wildlife Refuge System. However, FWS's regulatory authority over the submerged lands of the Refuge is not exclusive. This is because in the 1991 lease of the submerged lands within the Refuge, the State of South Carolina reserved the right "to authorize the taking of shellfish, finfish and other salt water species within the refuge boundaries." That reserved right is not exclusive, either. At a minimum, FWS can limit the time, place and manner of the scope of that authorization. Based upon the discussion above, FWS concludes that horseshoe crab harvesting cannot be authorized during the spawning season which runs from March 15 through July 15.

As is referenced above, the Service and the State of South Carolina share jurisdiction over the take of certain species in the Refuge. However, if someone applies for a special use permit for the commercial harvesting of horseshoe crabs using methods not discussed in this compatibility determination, and/or outside of the spawning season, the Service must analyze the facts to ascertain if there are time, place and manner restrictions necessary to ensure that the proposed use is appropriate and compatible.

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Figure 1. Map of Cape Romain NWR.

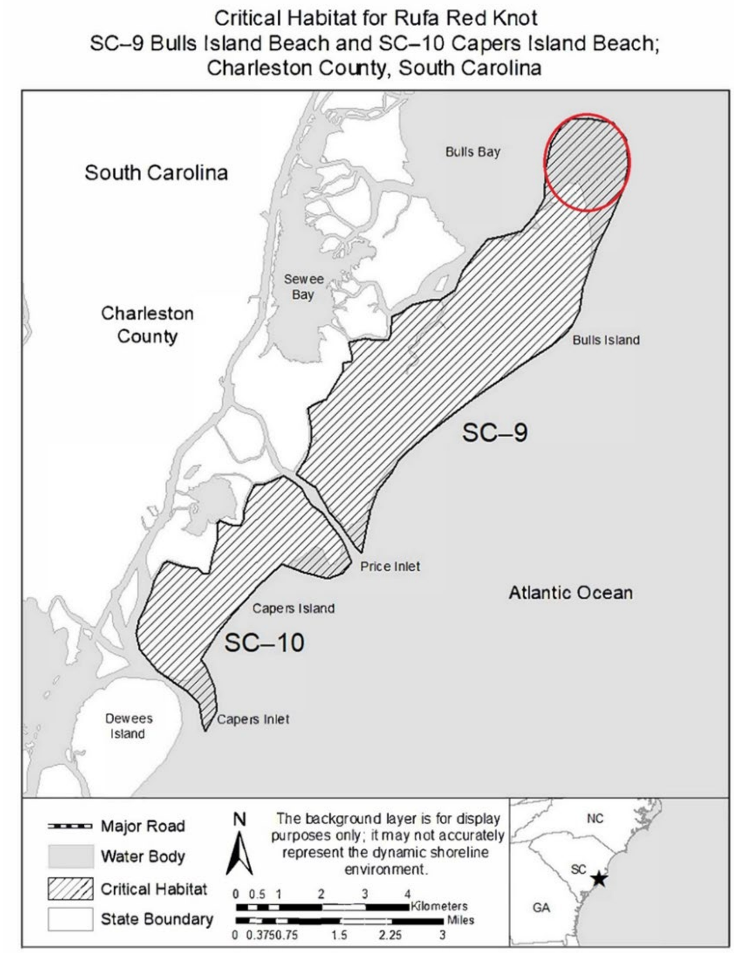

Figure 2. Critical habitat map for the rufa red knot, including locations on Cape Romain NWR.

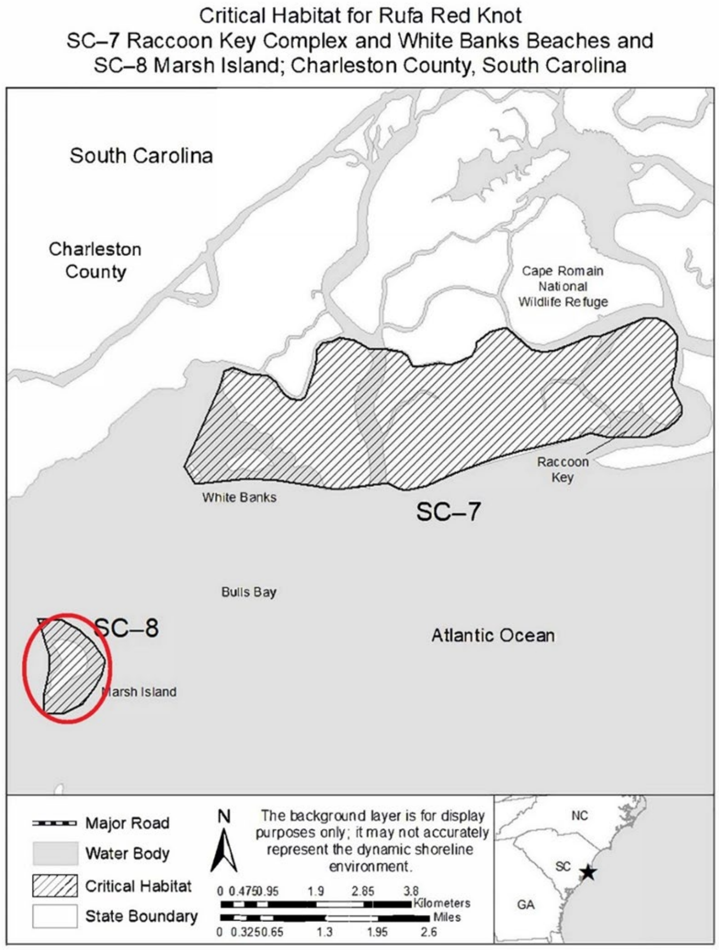

Figure 3. Critical habitat map for rufa red knot including locations on Cape Romain NWR.

Figure 4. Shorebirds foraging on horseshoe crab eggs in horseshoe crab nest depressions at Marsh Island, Cape Romain NWR, 2016.

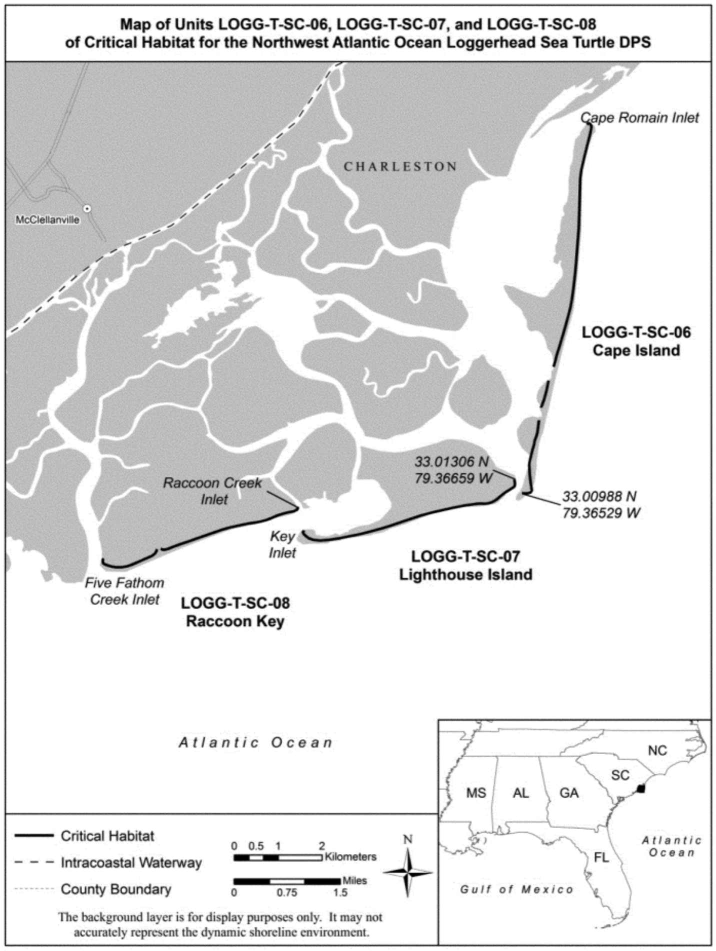

Figure 5. Critical habitat map for loggerhead sea turtles, including areas on Cape Romain NWR.

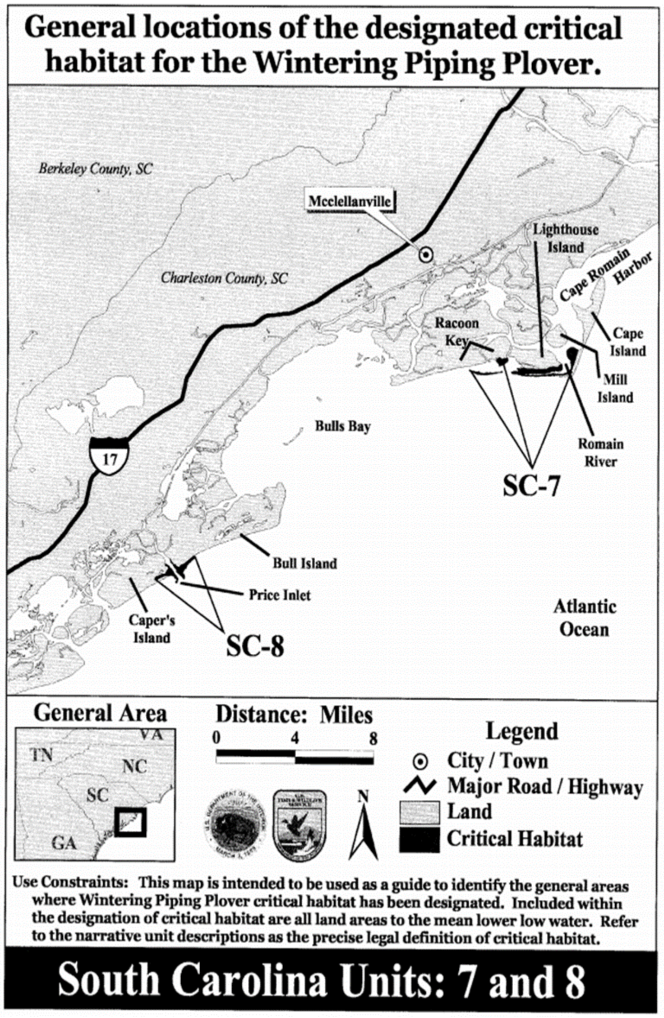

Figure 6. Critical habitat map for the piping plover, including locations on Cape Romain NWR.

Signature of Determination

Refuge Manager Signature and Date

Signature of Concurrence

Assistant Regional Director Signature and Date

Mandatory Reevaluation Date

Delete this text and insert year for reevaluation