~~EXPLOITERS~~
FRIENDS
of ANIMALS

December 21, 2023

Via USPS & Email (janet.coit@noaa.gov)

Gina Raimondo
Secretary of Commerce
U.S. Department of Commerce
1401 Constitution Ave. NW
Washington, DC 20230

Janet Coit
Asst. Administrator for Fisheries
NOAA Fisheries Service Headquarters
1315 East West Highway
Silver Springs MD 20910

Re: Notice of Petition to List the Atlantic Horseshoe Crab as Endangered or Threatened

Dear Secretary Raimondo and Assistant Administrator Coit:

Friends of Animals hereby petitions the Secretary of Commerce, acting through the National Marine Fisheries Service (NMFS), an agency within the National Oceanic and Atmospheric Administration (NOAA), to list the Atlantic horseshoe crab (*Limulus polyphemus*) as "endangered" or "threatened" under the U.S. Endangered Species Act (ESA), 16 U.S.C. §§ 1531 *et seq.* We request that NMFS list the species throughout its entire range and designate critical habitat for the species in Atlantic waters.

This species plays an important ecological role and is considered a "keystone" species. The loss of horseshoe crabs would cause devastating environmental changes for shorebirds, finfish, and Atlantic loggerhead turtles.

The horseshoe crab faces several threats to its continued survival, including multiple listing factors under the ESA. First, the species is overutilized for commercial and scientific purposes. The species is used as bait to catch eels and whelk, with the destructive emphasis on using female horseshoe, who are critical for the species' reproduction since horseshoe crabs can take up to ten years to mature. The ongoing harvest of horseshoe crabs for biomedical purposes has also resulted in widespread exploitation and kills at least 30% of all crabs who are drained of their blood. Second, inadequate regulatory mechanisms have allowed exploitation of the species to cause continued declines in population. State-specific regulatory mechanisms have been ineffective in restoring the population, and the Atlantic States Marine Fisheries Commission management plan has not been successful either. Third, destruction, modification, or curtailment of its habitat or range is threatened by sea-level rise

associated with climate change. NOAA has already admitted that the horseshoe crab's vulnerability to climate change is "very high." Lastly, other natural or manmade factors—bycatch, impingement, pollution, and a slow maturation rate—all negatively impact the horseshoe crab, threatening the continued survival of this species.

The petition, filed pursuant to 5 U.S.C. § 553(e) and 50 C.F.R. § 424.14, consists of this cover letter and the attached petition, as well as all material cited within which are hereby incorporated by reference.

Please do not hesitate to contact me if you need more information. My contact information appears below.

Sincerely,

Jennifer Best
Director, Wildlife Law Program

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PETITION TO LIST THE ATLANTIC HORSESHOE CRAB (*Limulus polyphemus*) UNDER THE ENDANGERED SPECIES ACT

Credit: Wikimedia Commons

Petitioner:

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EXECUTIVE SUMMARY

The Atlantic horseshoe crab (*Limulus polyphemus*) is a marine arthropod found along the Atlantic coasts of North and Central America that is in steep decline. The International Union for Conservation of Nature (IUCN) Red List already lists this "living fossil" as "threatened" due to decades of widespread exploitation by the commercial bait and biomedical industries, and imminent threats from climate-change-associated risks have worsened its already-precarious position.

Several of the listing criteria identified in the Endangered Species Act (ESA) are contributing to the decline of the Atlantic horseshoe crab: it has been historically overutilized for commercial and scientific purposes; existing regulatory mechanisms purportedly protecting it are inadequate for its survival; its habitat is threatened by sea-level rise associated with climate change; and other man-made factors threaten its continued existence. Considered cumulatively, these factors demonstrate the necessity of listing this keystone species under the ESA.

Therefore, this petition requests that the U.S. Secretary of Commerce list the Atlantic horseshoe crab as an "endangered," or alternatively as a "threatened," species under the ESA.

SPECIES ACCOUNT

A. Taxonomy

Limulus polyphemus is commonly known as the "Atlantic horseshoe crab" or "American horseshoe crab."[1] This petition refers to *Limulus polyphemus* as "Atlantic horseshoe crab." A full taxonomic classification of the Atlantic horseshoe crab is listed below in Figure 1.

The Atlantic horseshoe crab is a member of the Limulidae family, which consists of four extant species: *Limulus polyphemus*, *Tachypleus tridentatus*, *T. gigas*, and *Carcinoscorpius rotundicauda*.[2] *Limulus polyphemus* can be found along the Atlantic coasts of North and Central America, while *Tachypleus tridentatus*, *T. gigas*, and *Carcinoscorpius rotundicauda* can be found in Asia's coastal waters.[3]

The Atlantic horseshoe crab does not share its range with any other species of Limulidae. It is a full species and therefore is eligible for protection under the ESA.

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[1] Smith, D.R., et al., *Limulus polyphemus*, THE IUCN RED LIST OF THREATENED SPECIES 1, 1 (2016), http://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T11987A80159830.en (last visited Dec. 5, 2023) [hereinafter "IUCN Red List"].
[2] Atl. States Marine Fisheries Comm'n, *Interstate Fishery Management Plan For Horseshoe Crab* 46 (1998) [hereinafter, "*Interstate Fishery Management Plan*"].
[3] *Id.*

Figure 1. Taxonomy of *Limulus polyphemus*[4]

Kingdom	Animalia
Phylum	Arthropoda
Class	Merostomata
Order	Xiphosura
Family	Limulidae
Genus	*Limulus*
Species	*polyphemus*

B. Physical Characteristics

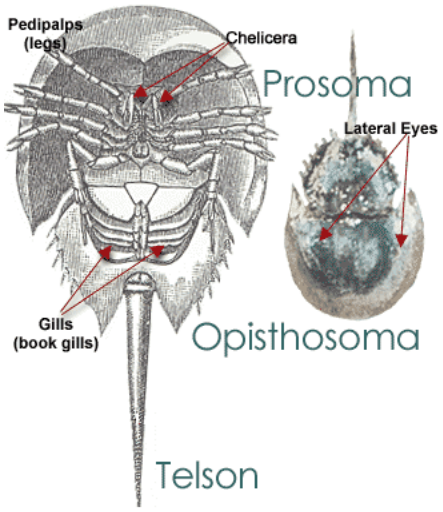
The Atlantic horseshoe crab is often referred to as a living fossil because its basic physical characteristics have remained evolutionarily unchanged for approximately 200 million years.[5]

Its body is divided into three parts: the forepart, or prosoma; the midpart, or opisthosoma; and the end part, or telson/tail.[6] The forepart, consisting of a "hard, rounded, brownish-green exoskeleton," resembles a bowl cut in half and placed on top of the crab.[7] This "dome" creates a cavity within which the crab's prosomal appendages, used primarily for walking and feeding, are masked from exterior view.[8] The midpart contains musculature crucial for operation of the horseshoe crab's book gills.[9] Finally, the end part, or telson, is a "long spike-like" protrusion resembling a tail that is used by the crab to right itself in the event it

[4] *See* IUCN Red List, *supra* note 1, at 1.
[5] *Id.* at 4.
[6] Carl N. Shuster, Jr., & Lyall I. Anderson, *A History of Skeletal Structure: Clues to Relationships Among Species*, *in* THE AMERICAN HORSESHOE CRAB 154, 157-59 (Carl N. Shuster, Jr., et al. eds., 2003).
[7] *Id.* at 157; Chesapeake Bay Program, *Horseshoe Crab*, https://www.chesapeakebay.net/discover/field-guide/entry/horseshoe-crab#:~:text=Limulus%20polyphemus,and%20a%20spike%2Dlike%20tail (last visited Dec. 5, 2023).
[8] Shuster & Andreson, *supra* note 6, at 157.
[9] Ecological Research & Development Group, *Anatomy*, The Horseshoe Crab, https://www.horseshoecrab.org/anat/anat.html# (last visited Dec. 5, 2023).

is flipped onto its back.[10] The Atlantic horseshoe crab generally grows up to two feet in length.[11] Notably, female prosomal widths are generally 70-80% larger than that of males.[12]

Figure 2. Anatomy of an Atlantic horseshoe crab[13]



C. Habitat and Range

The Atlantic horseshoe crab can be found along the Eastern coast of North America from the Yucatán Peninsula in México to the Gulf of Maine.[14] In the United States, distribution occurs along the Atlantic coast from Maine to Florida.[15] The highest densities occur in the Delaware Bay area (New Jersey, Delaware, Maryland, and Virginia),[16] but crab populations have been identified along the entire coast.[17]

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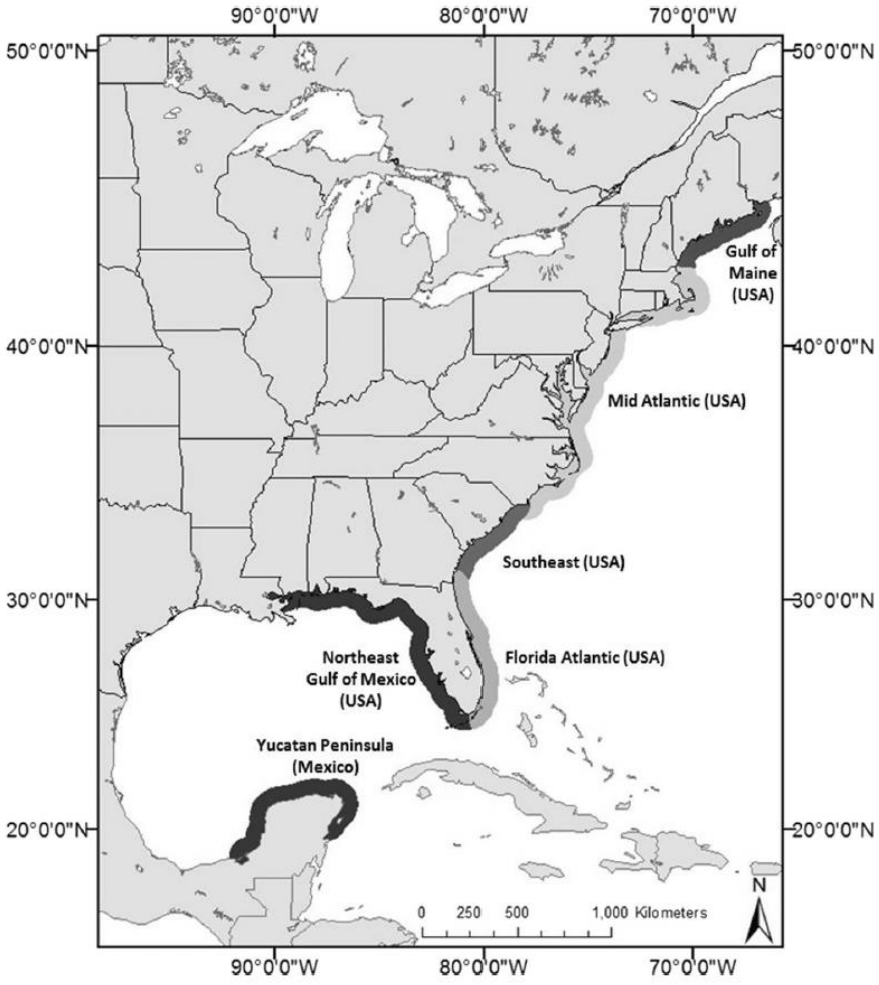
[10] Shuster & Andreson, *supra* note 6, at 158-59.
[11] Chesapeake Bay Program, *supra* note 7.
[12] Shuster & Anderson, *supra* note 6, at 165.
[13] Md. Dep't Nat. Res., *Horseshoe Crab Anatomy*, https://dnr.maryland.gov/ccs/Pages/horseshoecrab-anatomy.aspx (last visited Dec. 5, 2023).
[14] IUCN Red List, *supra* note 1, at 6.
[15] *Id.* at 4.
[16] *Id.* at 4, 10.
[17] *Id.* at 4.

Figure 3. Range map for the Atlantic horseshoe crab, including regions used in the IUCN Red List.[18]



Habitat requirements for the Atlantic horseshoe crab change with crab maturation and life cycle.[19] Spawning adults, for instance, require "undisturbed sandy beach" in "bays and coves that are protected from wave energy."[20] Nests are typically "located between the low tide terrace . . . and the extreme high tide water line."[21] Optimal spawning habitat for egg survival generally must include "a sufficient depth of porous, well-oxygenated sediments"

[18] David R. Smith et al., *Conservation status of the American horseshoe crab*, (Limulus polyphemus): *a regional assessment*, 27 REV. FISH BIOLOGY AND FISHERIES 135, 137 (2017).
[19] IUCN Red List, *supra* note 1, at 17.
[20] *Id.* at 13, 21.
[21] *Id.* at 13.

and rate of egg development can vary based on factors like "temperature, moisture, oxygen, and salinity."[22]

Juvenile crabs require "[n]earshore, shallow water, intertidal flats."[23] As juvenile crabs age, they incrementally move towards deeper water.[24] And although adult horseshoe crabs have been found in water as deep as 200m, data shows that most Atlantic horseshoe crabs are found in water shallower than 20m.[25] They also tend to congregate where there is abundant food.[26] In cold weather, adults "may remain in local embayments or migrate offshore to overwinter on the continental shelf."[27]

D. Feeding

Horseshoe crabs primarily feed on "slow-moving bottom-dwelling organisms."[28] These organisms include marine worms, bivalve mollusks, and algae.[29] To eat, the crab captures pieces of food using its walking legs.[30] The prosomal appendages then move the food to its mouth.[31]

E. Reproduction and Lifespan

In the spring, warming water prompts the Atlantic horseshoe crab to migrate from the intercontinental shelf toward shallow waters and sandy beaches, where they spawn.[32] Spawning timing varies by location, but in the Delaware Bay region, spawning generally occurs in April through July, with peaks in May and June.[33] Female crabs typically arrive at the spawning beach with a male attached to their spine, and "will spawn approximately 80,000 . . . eggs, in batches of 2,000 to 4,000, within a few days."[34] The accompanying male then fertilizes the eggs externally as they are deposited into the nest.[35] Studies have concluded there are approximately eighteen growth stages in the Atlantic horseshoe crab's

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[22] *Id.* at 17.
[23] *Id.*
[24] *Id.* at 18.
[25] *Id.*
[26] Mark L. Botton, et al., *Horseshoe Crabs in a Food Web: Who Eats Whom?*, *in* THE AMERICAN HORSESHOE CRAB 133, 138 (Carl N. Shuster, Jr., et al. eds., 2003).
[27] IUCN Red List, *supra* note 1, at 18.
[28] S.C. Dep't of Nat. Res., *Sea Science*, https://www.dnr.sc.gov/marine/pub/seascience/pdf/horseshoecrab.pdf (last visited Dec. 5, 2023).
[29] Botton et al., *supra* note 26, at 139-40.
[30] M.L. Botton, *Diet and food preferences of the adult horseshoe crab* Limulus polyphemus *in Delaware Bay, New Jersey, USA*, 81 MARINE BIOLOGY 199, 199 (1984).
[31] *Id.*
[32] IUCN Red List, *supra* note 1, at 12.
[33] *Id.*
[34] Sebastian B. Okun, *Mating in the Moonlight: The Battle to Save the American Horseshoe Crab*, 18 OCEAN & COASTAL L.J. 195, 197 (2012).
[35] IUCN Red List, *supra* note 1, at 14.

lifecycle.[36] It takes each crab about ten years to mature,[37] and individual crabs can live up to 25 years.[38]

F. Population Status

The IUCN Red List categorizes the Atlantic horseshoe crab as "vulnerable," and the population as "decreasing."[39] It identifies six subpopulations of horseshoe crabs: Gulf of Maine (USA), Mid-Atlantic (USA), Southeast (USA), Florida Atlantic (USA), Northeast Gulf of México (USA), and Yucatán Peninsula (México).[40] It further identifies three sub-regions of the Mid-Atlantic region: New England states (New Hampshire, Rhode Island, and Massachusetts); New York area (Connecticut and New York); and Delaware Bay area (New Jersey, Delaware, Maryland, and Virginia).[41]

The IUCN notes that data shows "there have been significant declines in at least one dataset in all areas except the Southeast and Florida."[42] Of the sub-regions, the declines were highest in the New England area.[43] The IUCN states that continuation of negative trends "would result in projected population reductions of 100% in Gulf of Maine (NH), 92% in New England, 11% in New York, 55% in Florida Atlantic, and 32% in Northeast Gulf of México."[44] Although projections would predict population increases in the Delaware Bay and Southeast regions, the IUCN still concluded that as a whole, Atlantic horseshoe crab populations are trending downward.[45]

Current threats contributing to population declines are: bait harvest, biomedical harvest, marine life and scientific collection, bycatch, habitat loss, and climate change.[46]

G. Ecological Function

The Atlantic horseshoe crab is considered a "keystone species" due to the "important ecological role" its eggs play in the food web for migratory shorebirds, finfish, and Atlantic loggerhead turtles.[47]

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[36] Carl N. Shuster, Jr., & Koichi Sekiguchi, *Growing Up Takes About Ten Years and Eighteen Stages*, *in* THE AMERICAN HORSESHOE CRAB 103, 123 (Carl N. Shuster, Jr., et al. eds., 2003).
[37] *Id.* at 103.
[38] S.C. Dep't of Nat Res., *supra* note 28.
[39] IUCN Red List, *supra* note 1, at 1, 12.
[40] *Id.* at 9.
[41] *Id.* at 10.
[42] *Id.*
[43] *Id.* at 11.
[44] *Id.*
[45] *Id.* at 11-12.
[46] *Id.* at 19-24.
[47] Jordan Krisfalusi-Gannon et al., *The Role of Horseshoe Crabs in the Biomedical Industry and Recent Trends Impacting Species Sustainability*, FRONTIERS IN MARINE SCI. 1, 1 (2018); *Interstate Fishery Management Plan*, *supra* note 2, at 12.

One scholar described the relationship between Arctic-nesting shorebirds and Atlantic horseshoe crabs as "[o]ne of the most renowned and well-documented convergences of migratory animals with a seasonally pulsed resource."[48] Migratory shorebirds typically arrive in Delaware Bay and adjacent areas during horseshoe crab spawning season.[49] During this spring stopover, the birds utilize horseshoe crab eggs as their "dominant dietary component."[50] The endangered red knot, in particular, depends so heavily on the horseshoe crab eggs that it is "physically unable to rely on any other substitute" as food during its migration, because the length of its journey "causes its stomach to wither to the point where only easily digestible foods are edible."[51] Other shorebird species that depend on the horseshoe crab egg supply include: the ruddy turnstone, the semipalmated sandpiper, the sanderling, the dowitcher, and the dunlin.[52] The Atlantic States Marine Fisheries Commission (ASMFC) notes that "[a] significant decrease in the number of horseshoe crabs could leave a large portion of migrating shorebirds without either the necessary food resources . . . or the necessary fat reserves" to complete their migration and to initiate egg laying upon arrival.[53]

Horseshoe crab eggs and larvae are also a dietary component of invertebrates and finfish.[54] During spawning season, species such as striped bass, white perch, American eel, killifish, silver perch, weakfish, kingfish, silversides, summer flounder, and winter flounder eat either horseshoe crab eggs, larvae, or both.[55]

Additionally, the horseshoe crab is the most common prey of the Atlantic loggerhead turtle in the Chesapeake Bay.[56]

THE ENDANGERED SPECIES ACT AND LISTING CRITERIA

The Endangered Species Act of 1973 ("ESA") protects plants and animals that are listed by the federal government as "endangered" or "threatened."[57] Any interested person may petition the Secretary of Commerce requesting that a species be listed as endangered or threatened under the ESA.[58]

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[48] Joseph A.M. Smith et al., *Horseshoe crab egg availability for shorebirds in Delaware Bay: Dramatic reduction after unregulated horseshoe crab harvest and limited recovery after 20 years of management*, AQUATIC CONSERVATION: MARINE AND FRESHWATER ECOSYSTEMS 1, 2 (2022).
[49] *Id.*
[50] *Id.*
[51] Sami B. Ghubril, *Saving the Horseshoe Crab: The Case for the Oft-Forgotten, Critically Important Living Fossil*, 37 VA. ENV'T L.J. 272, 281 (2019).
[52] *Interstate Fishery Management Plan*, *supra* note 2, at 13.
[53] *Id.* at 15.
[54] *Id.*
[55] *Id.*
[56] *Id.*
[57] 16 U.S.C. § 1531 *et seq.*
[58] 50 C.F.R. § 424.14(a).

The ESA defines an "endangered species" as one that is "in danger of extinction throughout all or a significant portion of its range."[59] A "threatened species" is one that "is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range."[60] The term "species" includes "any subspecies of fish or wildlife or plants."[61]

The ESA sets forth the following listing factors under which a species may qualify for protection:

> (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.[62]

A species need only meet one of these factors to qualify for federal listing as an endangered or threatened species.[63]

Upon receipt of a petition to list, the Secretary is required to determine "whether the petition presents substantial scientific or commercial information indicating that the petitioned action may be warranted" within 90 days.[64] For purposes of the 90-day finding, the ESA defines "substantial scientific or commercial information" as "credible scientific or commercial information" which would compel "a reasonable person conducting an impartial scientific review [to] conclude that the action proposed in the petition may be warranted."[65]

Of the above factors, four are contributing to the decline of the Atlantic horseshoe crab: it is overutilized for commercial and scientific purposes; existing regulatory mechanisms purportedly protecting it are inadequate for its survival; its habitat is threatened by sea-level rise associated with climate change; and other man-made factors threaten its continued existence.

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[59] 16 U.S.C. § 1532(6).
[60] *Id.* at § 1532(20).
[61] *Id.* at § 1532(16).
[62] *Id.* at § 1533(a)(1)(A)-(E).
[63] *Id.* at § 1533(a)(1).
[64] *Id.* at § 1533(b)(3)(A).
[65] 50 C.F.R. § 424.14(h)(1)(i).

A. Horseshoe crabs have historically been and continue to be overutilized for commercial and scientific purposes.

Since the mid-nineteenth century, the horseshoe crab has been targeted for commercial use.[66] Harvest for use as fertilizer and livestock feed followed by significant unregulated bait harvest in the 1990s threatened crab survival.[67] That ongoing threat combined with current harvest for biomedical use has resulted in widespread exploitation of the horseshoe crab for commercial and scientific purposes that puts the horseshoe crab at risk of extinction.[68]

1. Historical and continued harvest for use as commercial bait poses an ongoing threat to horseshoe crabs.

The horseshoe crab has long been targeted for various commercial uses. According to the ASMFC, between 1.5 to 2 million crabs were harvested annually between 1850 and 1920 for use as fertilizer and livestock feed.[69] Between 1920 and 1960, this practice slowed before ceasing entirely, at least partly due to significant population decline.[70]

But in the 1990s, thirty years after that practice ceased—again, due in part to population decline—commercial fishermen began using female horseshoe crabs as bait for the American eel and whelk pot industries.[71] Significantly, this harvest focused on mature, egg-bearing females due to their larger size and because the eggs could be used as additional bait.[72]

Due to the lack of regulation for horseshoe crab harvest during this time, no states required mandatory reporting of horseshoe crab landings, so it is difficult to state exactly how many crabs were utilized as bait.[73] However, some scholars estimate a "20-fold" harvest increase, and the ASMFC reports that harvest peaked at almost six million pounds of horseshoe crabs harvested in 1997.[74] These numbers, which themselves indicate a trend of overutilization, were compounded by the deliberate targeting of mature female crabs by the bait industry.[75] Because horseshoe crabs can take ten years to mature, egg-bearing females are critical to

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[66] *Interstate Fishery Management Plan*, *supra* note 2, at 5-6.
[67] *Id.*
[68] *See* Krisfalusi-Gannon et al., *supra* note 47, at 2.
[69] *Interstate Fishery Management Plan*, *supra* note 2, at 5.
[70] Krisfalusi-Gannon et al., *supra* note 47, at 2; Ghubril, *supra* note 51, at 274.
[71] *Interstate Fishery Management Plan*, *supra* note 2, at 6.
[72] Ghubril, *supra* note 51, at 275.
[73] Okun, *supra* note 34, at 201.
[74] Lawrence J. Niles et al., *Effects of Horseshoe Crab Harvest in Delaware Bay on Red Knots: Are Harvest Restrictions Working?*, 59 BIOSCIENCE 153, 153 (2009); *Interstate Fishery Management Plan*, *supra* note 2, at 3, 6, 11.
[75] Ghubril, *supra* note 51, at 275.

species reproduction, and their overutilization has had lasting effects on horseshoe crab egg abundance in areas where heavy harvesting occurred.[76]

Horseshoe crab egg abundance is important not only as an indication of species population health, but also because horseshoe crab eggs are a vital food source for the red knot, a migratory shore bird currently listed as "threatened."[77] In 1998, partially in response to concerns that declining horseshoe crab numbers would negatively impact the red knot, the ASMFC adopted a Horseshoe Crab Fisheries Management Plan (FMP).[78] The FMP mandated a bait harvest threshold that capped the permissible amount of crabs caught and left it up to the individual states to "[implement] management measures and [protect] horseshoe crab habitat within [their] jurisdiction to ensure the viability of the population segment."[79]

Although the FMP resulted in decreased numbers of crabs harvested as bait, over 700,000 crabs were harvested for that purpose in 2021.[80] This number is consistent with the average reported by the ASMFC from 2004-2017, which is powerful evidence that the horseshoe crab has been and continues to be overutilized for commercial purposes.[81] The loss of almost one million horseshoe crabs per year, in combination with crabs' historical overuse as fertilizer and feed, is not sustainable and threatens overall species survival.

2. The overutilization of Atlantic horseshoe crabs by the biomedical industry has led to ongoing population harm and decline.

Horseshoe crab harvest for bleeding by the biomedical industry also poses an urgent threat to species survival.[82] The biomedical bleeding process not only results in the death of up to 30% of bled crabs, but it also fundamentally alters crab behavior that is vital to spawning and species survival.[83] Considered in the context of unprecedented vaccine demand exacerbated by decreased availability of *Tachypleus* Amoebocyte Lysate (TAL), it is clear that the biomedical harvest of Atlantic horseshoe crabs is unsustainable and reflects ongoing overutilization of crabs for commercial and scientific purposes.

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[76] *Id.; see* Smith et al. 2022, *supra* note 48, at 8.
[77] *See* Smith et al. 2022, *supra* note 48, at 8..; 50 C.F.R. § 17.11(h).
[78] Smith et al. 2022, *supra* note 48, at 2; Ghubril, *supra* note 51, at 281-82; *Interstate Fishery Management Plan*, *supra* note 2, at iii-iv.
[79] *Interstate Fishery Management Plan*, *supra* note 2, at 25.
[80] Atl. States Marine Fisheries Comm'n, *Review of the Interstate Fishery Management Plan*, 5 (2021).
[81] Atl. States Marine Fisheries Comm'n, *2019 Horseshoe Crab Benchmark Stock Assessment and Peer Review Report* ii (2019) [hereinafter *2019 Stock Assessment*] ("Landings have remained under 1 million horseshoe crabs since 2003 and from 2004-2017 average landings were 752,886 horseshoe crabs").
[82] Ghubril, *supra* note 51, at 285.
[83] A.S. Leschen & S.J. Correia, *Mortality in female horseshoe crabs (Limulus polyphemus) from biomedical bleeding and handling: implications for fisheries management*, *in* 43 MARINE AND FRESHWATER BEHAV. AND PHYSIOLOGY, 135, 144 (2010); Rebecca L. Anderson et al., *Sub-lethal Behavior and Physiological Effects of the Biomedical Bleeding Process on the American Horseshoe Crab*, BIOLOGICAL BULL. 1, 2-3 (2014).

Atlantic horseshoe crab blood is unique in that it clots in the presence of endotoxins.[84] This characteristic led to the development in the 1970s of the *Limulus* amoebocyte lysate (LAL) test, which uses amebocytes harvested from horseshoe crab blood to detect endotoxins in vaccines or other medical devices before they are distributed for use.[85] It was licensed by the United States Food and Drug Administration in 1977 and has been used by the biomedical industry in quality assurance for intravenous drugs, biologicals like vaccines, recombinant drugs, implantable medical devices, and air and water quality screening.[86]

The LAL test relies on the harvest of large quantities of horseshoe crab blood, which bleeding facilities obtain by catching live crabs then draining their blood through a hypodermic needle inserted directly into the crabs' exposed pericardial membrane.[87] Studies have shown that up to 30% of bled crabs do not survive this process.[88] And some scholars have suggested that blood loss itself may not be the primary cause of death resulting from the biomedical harvest.[89] Instead, they point to "capture, handling and transportation," during which crabs may be "crushed under the weight of other stacked crabs" or "accidentally impaled by the telsons of neighboring crabs."[90] Mortality rates, therefore, may actually exceed 30%.

Additionally, and concerningly, crabs that do not die from the bleeding process often experience "significant" changes post-release, including "changes in activity levels and behavioral rhythms, reductions in hemocyanin levels (potentially affecting immune function) and decreased reproductive fitness (prompting concerns about longer-term population impacts).[91] The bleeding process has also been proven to affect crab expression of tidal activity rhythms, a behavioral feature that is vital to successful spawning and foraging.[92] Because females are preferentially harvested,[93] these post-bleeding behavioral alterations have serious long-term consequences for the species.[94] In fact, scholars have hypothesized that these changes in spawning ability "may partially account for declining

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[84] Krisfalusi-Gannon et al., *supra* note 47, at 2.
[85] Thomas J. Novitsky, *Biomedical Applications of Limulus Amebocyte Lysate*, *in* BIOLOGY AND CONSERVATION OF HORSESHOE CRABS 315, 316 (John T. Tanacredi, Mark L. Botton, & David R. Smith eds., 2009); Ghubril, *supra* note 51, at 277-78.
[86] *See* Licensing of Limulus Amebocyte Lysate, Use as an Alternative for Rabbit Pyrogen Test, 42 Fed. Reg. 57749 (Nov. 4, 1977); Krisfalusi-Gannon et al., *supra* note 47, at 2.
[87] Krisfalusi-Gannon et al., *supra* note 47, at 3.
[88] Leschen & Correia, *supra* note 83, at 144-45.
[89] Krisfalusi-Gannon et al., *supra* note 47, at 4.
[90] *Id.*
[91] Richard Gorman, *Atlantic Horseshoe Crabs and Endotoxin Testing: Perspectives on Alternatives, Sustainable Methods, and the 3Rs (Replacement, Reduction, and Refinement)*, FRONTIERS IN MARINE SCIENCE 1, 2 (2020).
[92] Anderson et al., *supra* note 83, at 15.
[93] *Id.*
[94] Ghubril, *supra* note 51, at 275 (noting that "females are critical for the species' reproduction, especially since horseshoe crabs can take up to ten years to mature").

populations in heavily harvested regions" like the Delaware Bay.[95] Thus, biomedical harvest harms the Atlantic horseshoe crab at a population-wide level long after the bleeding process ends. That harm, considered in combination with crab deaths from the harvesting and bleeding processes, threatens the species' continued survival.

As global demand for vaccines and medical devices increases, the demand for LAL and horseshoe crab harvest proportionately increases.[96] Thus, the three-fold increase in vaccine production from 2019 to 2021 in response to COVID-19 likely resulted in a proportionate increase in horseshoe crab harvest.[97] This increase in already-unsustainable harvesting practices likely had and will continue to have devastating effects on Atlantic horseshoe crabs. And given recent studies showing that the risk of novel disease outbreaks is increasing rapidly, the devastation has no end in sight.[98]

Compounding the problem, the demand for Atlantic horseshoe crab blood and LAL only increases as Asian horseshoe crab populations decline.[99] The blood of *Tachypleus tridentatus* and *Tachypleus gigas* (two species of Asian horseshoe crabs) is used to produce TAL, a counterpart to LAL also used for endotoxin testing.[100] The current rate of harvest for these species puts them at risk, and as their populations decline, the "residual demand" will result in increased Atlantic horseshoe crab harvest.[101]

Because the ASMFC has not conducted a stock assessment for the Atlantic horseshoe crab since 2019,[102] it is impossible to know exactly how COVID-19 affected crab population numbers. However, the decrease in TAL availability and three-fold increase in vaccine production almost certainly resulted in an increase of harvested crabs. And given that crabs were already being harvested by the biomedical industry at unsustainable rates, and that the bait industry continued to harvest almost 750,000 crabs in 2021, it is evident that the Atlantic horseshoe crab is being overutilized for commercial purposes.[103]

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[95] Anderson et al., *supra* note 83, at 15.
[96] Glenn Gauvry, *Current Horseshoe Crab Harvesting Practices Cannot Support Global Demand for TAL/LAL: The Pharmaceutical and Medical Device Industries' Role in the Sustainability of Horseshoe Crabs*, *in* CHANGING PERSPECTIVES ON HORSESHOE CRAB BIOLOGY, CONSERVATION AND MANAGEMENT 475, 479 (R.H. Carmichael et. al. eds., 2015).
[97] World Health Organization, *Global Vaccine Market Report 2022: A Shared Understanding for Equitable Access to Vaccines* 2, 5 (2023).
[98] Marco Marani et. al., *Intensity and frequency of extreme novel epidemics*, Proceedings of the National Academy of Sciences of the United States of America, 1, 1 (2021).
[99] Gauyry, *supra* note 96, at 481.
[100] *Id.* at 477-78.
[101] *Id.* at 481.
[102] *2019 Stock Assessment*, *supra* note 81.
[103] Atl. States Marine Fisheries Comm'n 2021, *supra* not 80 at 1, 5.

B. The existing regulatory mechanisms protecting the Atlantic horseshoe crab are inadequate for its survival.

Atlantic horseshoe crabs are managed by the ASMFC under the 1998 FMP and subsequent addenda.[104] Because of the patchwork nature of state-specific measures allowed under the FMP, its skewed approach to horseshoe crab management, and its failure to meaningfully restore crab numbers, the FMP alone is not adequate to protect the Atlantic horseshoe crab's survival.

The FMP was developed partially in response to concerns that declining horseshoe crab numbers would jeopardize the continued survival of the red knot, a migratory shorebird listed as threatened under the ESA.[105] Its stated goal is therefore to manage "horseshoe crab populations **for continued use by**: current and future generations of the fishing and non-fishing public, including the biomedical industry, scientific and educational researchers; migratory shorebirds; and other dependent fish and wildlife, including federally listed sea turtles."[106]

To accomplish this goal, Addendum I establishes commercial bait harvest quotas in the Atlantic states, while Addendum II allows voluntary transfers of those quotas between states.[107] Addenda III and IV reduce quotas in the Delaware Bay region, implement a closed season for bait harvest of horseshoe crabs during spawning season, revise monitoring requirements, and strengthen protections in Maryland and Virginia.[108] Addenda V and VI extend Addendum IV's requirements.[109] In 2012, Addendum VII established a new Adaptive Resource Management (ARM) Framework which "directs that future regulations should take into account the populations of both red knots and horseshoe crabs" and sets a maximum allowable horseshoe crab harvest tied to red knot population recovery.[110] Addendum VIII, approved in 2022, introduces new methodologies for determining horseshoe crab abundance.[111]

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[104] *See Interstate Fishery Management Plan* , *supra* note 2.
[105] Ghubril, *supra* note 51, at 281-82.
[106] Atl. States Marine Fisheries Comm'n, *Addendum VI to the Interstate Fishery Management Plan for Horseshoe Crab*, 1, 1 (2010) (emphasis added) [hereinafter, *Addendum VI* 2010] .
[107] Atl. States Marine Fisheries Comm'n, *Addendum I to the Fishery Management Plan for Horseshoe Crab*, 3 (2000); Atl. States Marine Fisheries Comm'n, *Addendum II to the Interstate Fishery Management Plan for Horseshoe Crab*, 1 (2001).
[108] Atl. States Marine Fisheries Comm'n, *Addendum III to the Interstate Fishery Management Plan for Horseshoe Crab*, 5 (2004); Atl. States Marine Fisheries Comm'n, *Addendum IV to the Interstate Fishery Management Plan for Horseshoe Crab*, 4 (2006).
[109] Atl. States Marine Fisheries Comm'n, *Addendum V to the Interstate Fishery Management Plan for Horseshoe Crab*, 1 (2008); *Addendum VI* 2010, *supra* note 106, at 2., 2
[110] Ghubril, *supra* note 51, at 283; Atl. States Marine Fisheries Comm'n, *Addendum VII to the Interstate Fishery Management Plan for Horseshoe Crab*, 6 (2012).
[111] Atl. States Marine Fisheries Comm'n, *Addendum VIII to the Interstate Fishery Management Plan for Horseshoe Crab*, 1 (2022).

Each Atlantic state is responsible for implementing FMP requirements in its own jurisdiction, but states may also impose more conservative measures, and many have.[112] Massachusetts, New York, and Rhode Island, for instance, have each imposed state-level harvest restrictions allowing only 46-55% of the quota authorized by ASMFC.[113] Other states have imposed seasonal harvest restrictions,[114] daily take limits,[115] or even have instituted a complete moratorium on horseshoe crab harvest.[116] While these state-level conservation measures are laudable, the data shows that when one region strengthens its regulations, other regions experience corresponding increases in harvest rates.[117] For example, scholars note that "[s]tricter horseshoe crab regulations around the Delaware Bay/New Jersey coastlines have led to increased harvesting in New England."[118] And any population recovery observed in the Delaware Bay region has been "more than offset by shifting commercial activity to other geographic regions."[119] This regulatory leakage indicates that the patchwork nature of state regulation authorized by the FMP is inadequate to ensure the Atlantic horseshoe crab's survival.

The FMP further fails to adequately protect the Atlantic horseshoe crab for several reasons. First, and most importantly, it is not intended to do so; rather, the plain text of the FMP is clear that the ASMFC considers the horseshoe crab a "resource" that must be preserved only to the extent that it remains available "for continued use by" the public, listed species, and industry.[120] The FMP does not prioritize horseshoe crab survival for the crab's own sake; instead, it considers only whether there are sufficient numbers of horseshoe crabs for use by other entities.[121] As a result, it focuses more on "crabs harvested" than "crabs left in the ocean."[122] This flawed approach to crab conservation cannot ensure its survival: when the Atlantic horseshoe crab's interests don't align with those of industry or with the red knot, the crab is sure to lose.

Unsurprisingly, given its stated goals, the FMP does not limit the biomedical harvest of horseshoe crabs in any way. While it includes a 15% biomedical mortality rate in its crab abundance calculation (used for the purpose of setting harvest thresholds for the bait

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[112] IUCN Red List, *supra* note 1, at 25-27; *Interstate Fishery Management Plan*, *supra* note 2, at 28.
[113] IUCN Red List, *supra* note 1, at 25-26.
[114] *Id.* (noting that Maine "prohibits harvest from May 1 to October 30" and Connecticut "enforces seasonal . . . closures").
[115] *Id.* at 25 ("New Hampshire limits Horseshoe Crab takings to 10 a day").
[116] *Id.* at 27 ("New Jersey instituted a complete moratorium on harvesting Limulus from state waters in 2006, and this ban remains in effect . . .").
[117] Krisfalusi-Gannon et al., *supra* note 47, at 5; *see also* Gauvry, *supra* note 96, at 481 (noting that regional changes may shift demand from one market to another).
[118] Krisfalusi-Gannon et al., *supra* note 47, at 5.
[119] *Id.*
[120] *Addendum VII* 2010, *supra* note 106, at 1.
[121] *Id.*
[122] *See* Ghubril, *supra* note 51, at 284.

industry) it does not regulate the biomedical industry.[123] In fact, the FMP explicitly exempts the biomedical industry from harvest quotas with the caveat that "[i]f horseshoe crab mortality associated with . . . the biomedical industry exceeds 57,500 horseshoe crabs per year, [ASMFC] would reevaluate potential restrictions on horseshoe crab harvest by the biomedical industry."[124] Although this threshold has been exceeded every year since 2007, the ASMFC has declined to put any restrictions in place.[125] Given that experts agree the biomedical harvest is a serious threat to the Atlantic horseshoe crab, this continuing failure to act is yet another reason the FMP is inadequate to ensure the horseshoe crab's survival.[126]

To make matters worse, the data relied on by ASMFC in setting quotas for the bait industry has been widely criticized.[127] In 2022, ASMFC revised its ARM Framework to require a Catch Multiple Survey Analysis (CMSA) for estimating crab populations.[128] The CMSA collates the data of three trawl surveys to estimate horseshoe crab abundance and uses the results to set a "maximum allowable harvest value" for the crabs.[129] Of these surveys, only the Virginia Tech Horseshoe Crab Trawl Survey ("Virginia Tech Survey") was designed for the purpose of estimating horseshoe crab abundance in the Delaware Bay region, and it is cited by at least two members of the Commission as the most reliable survey.[130] But problematically, the CMSA weighs each survey equally, a skewed approach which has resulted in artificially inflated population estimates bolstered by the conclusions of less-reliable surveys.[131]

These flawed conclusions are belied by data showing that the FMP has **not** succeeded in restoring populations to pre-1998 numbers. A 2021 study states that horseshoe crab egg abundance is "an order of magnitude lower" than it was before the wave of unregulated harvest in the 1990s.[132] It concludes that this marker indicates a failure of the horseshoe

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[123] 2019 Stock Assessment, *supra* note 81, at 12.
[124] *Interstate Fishery Management Plan* , *supra* note 2, at 27.
[125] 2019 Stock Assessment, *supra* note 81, at 36.
[126] Gauvry, *supra* note 96, at 477; Krisfalusi-Gannon et al., *supra* note 47, at 2; Gorman et al., *supra* note 91, at 2; IUCN Red List, *supra* note 1, at 19.
[127] Earthjustice, *Fisheries Commission Rejects Female Horseshoe Crab Harvest Proposal for Delaware Bay* (Oct. 16, 2023) https://earthjustice.org/press/2023/fisheries-commission-rejects-female-horseshoe-crab-harvest-proposal-for-delaware-bay (last visited Dec. 14, 2023) (noting that ASMFC decided to reverse its decision to authorize harvest of female crabs in Delaware Bay due to widespread opposition and concern regarding the ARM Framework).
[128] Atl. States Marine Fisheries Comm'n, *Revision to the Framework for Adaptive Management of Horseshoe Crab Harvest in the Delaware Bay Inclusive of Red Knot Conservation*, ii, v (2022).
[129] *Id.* at vi.
[130] *Id.* at 83, 102.
[131] *Id.* at 101-102 (in her minority opinion, Commission member Wendy Walsh specifically requested that the Virginia Tech Survey be weighted more heavily than the other data sets, citing inflated population estimates).
[132] Smith et al. (2022), *supra* note 48, at 8.

crab population to recover despite decades of management under the FMP.[133] And despite the CMSA's finding that populations are increasing, the Virginia Tech Survey—considered "the preferred method to determine abundance in the region" and "the only continuing survey across the Atlantic seaboard focused on abundance"—has not demonstrated a consistent increase in population from 2001 to 2019.[134]

Given the FMP's documented failure to restore the horseshoe crab's population to pre-regulation numbers, its flawed approach to species management, and the regulatory leakage resulting from its management structure, it is evident that the FMP alone cannot adequately ensure the horseshoe crab's survival. And because no other regulatory mechanism purports to do so, protection under the ESA is not only warranted but necessary.

C. The destruction, modification, or curtailment of the Atlantic horseshoe crab's habitat is threatened by sea-level rise associated with climate change.

In addition to threats from the biomedical and bait industries and the lack of uniform national regulation adequate to protect the Atlantic horseshoe crab, its habitat also faces a serious, long-term threat from rising sea levels associated with climate change.[135] Recognizing this reality, the National Oceanic and Atmospheric Administration (NOAA) has listed the horseshoe crab's vulnerability to climate change as "very high" due in part to its susceptibility to sea-level rise.[136]

The ASMFC defines the Atlantic horseshoe crab's "essential habitat" as "those waters and substrate necessary for fish spawning, breeding, feeding, or growth to maturity."[137] It notes that "[s]pawning adults prefer sandy beach areas within bays and coves that are protected from wave energy" and that "include porous, well-oxygenated sediments to provide a suitable environment for egg survival and development."[138] It additionally points to "large intertidal sand flat areas" as essential for the maturation of juvenile crabs.[139]

Thus the "obvious threat" to species survival, according to the IUCN, is the loss of habitat resulting from sea-level rise.[140] Sea-level rise, which NOAA projects will increase ten to fourteen inches on the East Coast over the next three decades, threatens to destroy or

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[133] *Id.* at 11.
[134] Ghubril, *supra* note 51, at 296.
[135] IUCN Red List, *supra* note 1, at 21-22, 24.
[136] NOAA, *Horseshoe Crab* – Limulus Polyphemus, https://www.st nmfs.noaa.gov/Assets/ecosystems/climate/images/species-results/pdfs/Horseshoe_Crab.pdf (last visited Dec. 14, 2023).
[137] *Interstate Fishery Management Plan*, *supra* note 2, at 15.
[138] *Id.*
[139] *Id.*
[140] IUCN Red List, *supra* note 1, at 24.

severely curtail the availability of beaches that are necessary both for spawning and for juvenile crab maturation.[141] And land subsidence along the Atlantic Coast compounds this effect, "resulting in an increase of 25-30 centimeters greater than the global average."[142] Even where beaches remain, sea-level rise, shoreline erosion, and shoreline development "increase[s] the likelihood that Horseshoe Crab . . . habit becomes compressed between the rising sea and existing housing and other infrastructure."[143]

D. Other natural or manmade factors negatively affect the Atlantic horseshoe crab's continued existence.

In its Red List Assessment for the Atlantic horseshoe crab, the IUCN identifies several additional threats to the species' survival.[144] Viewed in combination with the above-mentioned factors, it is clear that the cumulative effect warrants the listing of the crab under the ESA.

1. Bycatch

Although horseshoe crabs are generally not considered a target bycatch in commercial fisheries, it was the "most abundant invertebrate bycatch species caught in shrimp trawls" in Florida during two sampling seasons.[145] The most serious threat to horseshoe crabs from bycatch is injury resulting from capture.[146] In a study measuring trawl discard mortality, the injury rate was 11%, and 6% of those injuries were severe enough to cause death.[147]

2. Impingement on Coastal Infrastructure

Crab impingement risk is tied to increased coastal infrastructure development.[148] For example, in an impingement study conducted at two power plants on the Indiana River, over 90,000 crabs were trapped on intake screens over a twelve-month period.[149] And extensive impingement was also observed at breakwaters in Delaware.[150] For a population already in decline, this threat is substantial.

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[141] NOAA, *2022 Sea Level Rise Technical Report Key Takeaways*, https://oceanservice.noaa.gov/hazards/sealevelrise/sealevelrise-tech-report.html#step1 (last visited Dec. 14, 2023).
[142] Atl. States Marine Fishers Comm'n, *supra* note 1, at 24.
[143] IUCN Red List, *supra* note 1, at 24.
[144] *Id.* at 21-24.
[145] *Id.* at 21.
[146] *Id.*
[147] *Id.*
[148] *Id.* at 22.
[149] *Id.*
[150] *Id.*

3. Pollution Events

The ASFMC notes that "[b]ecause the Delaware estuary is a major petrochemical center on the East Coast . . . oil spills during the horseshoe crab spawning season could threaten populations in the Delaware Bay."[151] The IUCN echoes this sentiment, stating that "an oil spill that coincided with spawning activity with oil washed onto spawning beaches could be catastrophic to a local population."[152] That the Atlantic horseshoe crab has not yet been affected by an oil spill of this kind is a matter of chance; past spills have not coincided with the crabs' spawning season.[153] However, without further protection, this threat is inevitable.

4. Cumulative Effects

Considering all of these factors in combination, it is clear that the Atlantic horseshoe crab must be listed under the ESA to ensure its continued survival. The historic and current exploitation of this species for bait, the steadily increasing biomedical harvest, the lack of adequate regulation, the looming threat to coastlines posed by climate change and sea-level rise, and the above-mentioned factors all provide convincing evidence of a population in crisis.

REQUESTED DESIGNATION

Petitioners hereby request the Secretary of Commerce to list the Atlantic horseshoe crab (*Limulus polyphemus*) as endangered or threatened under the ESA. Listing is warranted given that the species is in danger of extinction due to multiple listing factors under the ESA: it is overutilized for commercial and scientific purposes; existing regulatory mechanisms purportedly protecting it are inadequate for its survival; its habitat is threatened by sea-level rise associated with climate change; and other man-made factors threaten its continued existence.

The Atlantic horseshoe crab is a species in decades-long decline. It is already listed as "vulnerable" under the IUCN Red List, and it faces escalating threats from the commercial bait industry, biomedical industry, and worsening climate change risks exacerbated by an inadequate regulatory structure that purports to protect it but instead endorses its continued exploitation. The loss of this keystone species would be ecologically devastating, not just for the crab itself, but for the other federally listed species it sustains. Federal listing is therefore necessary to prevent this living fossil from extinction.

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[151] *Interstate Fishery Management Plan*, *supra* note 2, at 18.
[152] IUCN Red List, *supra* note 1, at 23.
[153] *Id.*

The following documents[154] are submitted with this petition:

1. A.S. Leschen & S.J. Correia, *Mortality in female horseshoe crabs (Limulus polyphemus) from biomedical bleeding and handling: implications for fisheries management*, *in* 43 MARINE AND FRESHWATER BEHAV. AND PHYSIOLOGY (2010).
2. Atl. States Marine Fisheries Comm'n, *2019 Horseshoe Crab Benchmark Stock Assessment and Peer Review Report* (2019).
3. Atl. States Marine Fisheries Comm'n, *Addendum I to the Fishery Management Plan for Horseshoe Crab* (2000).
4. Atl. States Marine Fisheries Comm'n, *Addendum II to the Interstate Fishery Management Plan for Horseshoe Crab* (2001).
5. Atl. States Marine Fisheries Comm'n, *Addendum III to the Interstate Fishery Management Plan for Horseshoe Crab* (2004).
6. Atl. States Marine Fisheries Comm'n, *Addendum IV to the Interstate Fishery Management Plan for Horseshoe Crab* (2006).
7. Atl. States Marine Fisheries Comm'n, *Addendum V to the Interstate Fishery Management Plan for Horseshoe Crab* (2008).
8. Atl. States Marine Fisheries Comm'n, *Addendum VI to the Interstate Fishery Management Plan for Horseshoe Crab* (2010).
9. Atl. States Marine Fisheries Comm'n, *Addendum VII to the Interstate Fishery Management Plan for Horseshoe Crab* (2012).
10. Atl. States Marine Fisheries Comm'n, *Addendum VIII to the Interstate Fishery Management Plan for Horseshoe Crab* (2022).
11. Atl. States Marine Fisheries Comm'n, *Interstate Fishery Management Plan For Horseshoe Crab* (1998).
12. Atl. States Marine Fisheries Comm'n, *Review of the Interstate Fishery Management Plan* (2021).
13. Atl. States Marine Fisheries Comm'n, *Revision to the Framework for Adaptive Management of Horseshoe Crab Harvest in the Delaware Bay Inclusive of Red Knot Conservation* (2022).
14. Carl N. Shuster, Jr., & Koichi Sekiguchi, *Growing Up Takes About Ten Years and Eighteen Stages*, *in* THE AMERICAN HORSESHOE CRAB 103 (Carl N. Shuster, Jr., et al. eds., 2003).

[154] Some documents contain highlights that we added to direct the reader to the specific portion we cited.

15. Carl N. Shuster, Jr., & Lyall I. Anderson, *A History of Skeletal Structure: Clues to Relationships Among Species*, *in* THE AMERICAN HORSESHOE CRAB 154 (Carl N. Shuster, Jr., et al. eds., 2003).

16. Chesapeake Bay Program, *Horseshoe Crab*, https://www.chesapeakebay.net/discover/field-guide/entry/horseshoe-crab#:~:text=Limulus%20polyphemus,and%20a%20spike%2Dlike%20tail (last visited Dec. 5, 2023).

17. David R. Smith et al., *Conservation status of the American horseshoe crab*, (Limulus polyphemus): *a regional assessment*, 27 REV. FISH BIOLOGY AND FISHERIES 135 (2017).

18. Earthjustice, *Fisheries Commission Rejects Female Horseshoe Crab Harvest Proposal for Delaware Bay* (Oct. 16, 2023) https://earthjustice.org/press/2023/fisheries-commission-rejects-female-horseshoe-crab-harvest-proposal-for-delaware-bay (last visited Dec. 14, 2023).

19. Ecological Research & Development Group, *Anatomy*, The Horseshoe Crab, https://www.horseshoecrab.org/anat/anat.html# (last visited Dec. 5, 2023).

20. Glenn Gauvry, *Current Horseshoe Crab Harvesting Practices Cannot Support Global Demand for TAL/LAL: The Pharmaceutical and Medical Device Industries' Role in the Sustainability of Horseshoe Crabs*, *in* CHANGING PERSPECTIVES ON HORSESHOE CRAB BIOLOGY, CONSERVATION AND MANAGEMENT 475 (R.H. Carmichael et. al. eds., 2015).

21. Jordan Krisfalusi-Gannon et al., *The Role of Horseshoe Crabs in the Biomedical Industry and Recent Trends Impacting Species Sustainability*, FRONTIERS IN MARINE SCI. 1 (2018).

22. Joseph A.M. Smith et al., *Horseshoe crab egg availability for shorebirds in Delaware Bay: Dramatic reduction after unregulated horseshoe crab harvest and limited recovery after 20 years of management*, AQUATIC CONSERVATION: MARINE AND FRESHWATER ECOSYSTEMS 1 (2022).

23. Lawrence J. Niles et al., *Effects of Horseshoe Crab Harvest in Delaware Bay on Red Knots: Are Harvest Restrictions Working?*, 59 BIOSCIENCE 153 (2009).

24. Licensing of Limulus Amebocyte Lysate, Use as an Alternative for Rabbit Pyrogen Test, 42 Fed. Reg. 57749 (Nov. 4, 1977).

25. Marco Marani et. al., *Intensity and frequency of extreme novel epidemics*, Proceedings of the National Academy of Sciences of the United States of America, 1 (2021).

26. Mark L. Botton, et al., *Horseshoe Crabs in a Food Web: Who Eats Whom?*, *in* THE AMERICAN HORSESHOE CRAB 133 (Carl N. Shuster, Jr., et al. eds., 2003).

27. M.L. Botton, *Diet and food preferences of the adult horseshoe crab* Limulus polyphemus *in Delaware Bay, New Jersey, USA*, 81 MARINE BIOLOGY 199, 199 (1984).

28. Md. Dep't Nat. Res., *Horseshoe Crab Anatomy*, https://dnr.maryland.gov/ccs/Pages/horseshoecrab-anatomy.aspx last visited Dec. 5, 2023).
29. NOAA, *2022 Sea Level Rise Technical Report*, https://oceanservice.noaa.gov/hazards/sealevelrise/sealevelrise-tech-report.html#:~:text=Sea%20level%20along%20the%20U.S.,years%20(1920%20%2D%202020) (last visited Dec. 14, 2023).
30. NOAA, *Horseshoe Crab* – Limulus Polyphemus, https://www.st nmfs.noaa.gov/Assets/ecosystems/climate/images/species-results/pdfs/Horseshoe_Crab.pdf (last visited Dec. 14, 2023).
31. Rebecca L. Anderson et al., *Sub-lethal Behavior and Physiological Effects of the Biomedical Bleeding Process on the American Horseshoe Crab*, BIOLOGICAL BULL. 1 (2014).
32. Richard Gorman, *Atlantic Horseshoe Crabs and Endotoxin Testing: Perspectives on Alternatives, Sustainable Methods, and the 3Rs (Replacement, Reduction, and Refinement)*, FRONTIERS IN MARINE SCIENCE 1 (2020).
33. Sami B. Ghubril, *Saving the Horseshoe Crab: The Case for the Oft-Forgotten, Critically Important Living Fossil*, 37 VA. ENV'T L.J. 272 (2019).
34. S.C. Dep't of Nat. Res., *Sea Science*, https://www.dnr.sc.gov/marine/pub/seascience/pdf/horseshoecrab.pdf (last visited Dec. 5, 2023).
35. Sebastian B. Okun, *Mating in the Moonlight: The Battle to Save the American Horseshoe Crab*, 18 OCEAN & COASTAL L.J. 195 (2012).
36. Smith, D.R., et al., *Limulus polyphemus*, THE IUCN RED LIST OF THREATENED SPECIES 1, (2016), http://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T11987A80159830.en (last visited Dec. 5, 2023).
37. Thomas J. Novitsky, *Biomedical Applications of Limulus Amebocyte Lysate*, *in* BIOLOGY AND CONSERVATION OF HORSESHOE CRABS 315 (John T. Tanacredi, Mark L. Botton, & David R. Smith eds., 2009).
38. World Health Organization, *Global Vaccine Market Report 2022: A Shared Understanding for Equitable Access to Vaccines* 2 (2023).

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