Looking to Hybrid Species for the Future of Coral Reefs

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Climate change and global warming threaten biodiversity around the world. According to a recent report from the United Nations, approximately one million species are threatened with extinction. Such a decrease in the diversity of species means the natural ecosystems of today—the forests, fields, deserts, coasts, and oceans—will undergo dramatic change in our lifetimes. The wild spaces as we know them will no longer exist.

Coral reefs are an example of vital ecosystems facing extinction. Global warming and other stressors will cause coral reefs to decline to less than 1 percent of their former cover. But while today's reefs languish, nature has produced a possible path forward: hybrid corals. Hybrid corals, or a mix of two different coral species, are in some cases more resilient to climate change and other stressors than their parent species. However, hybrid corals, like many species around the world, are threatened by human activity. A suite of international, federal, state, and local laws purport to protect endangered and threatened species, including corals. Unfortunately, these laws, notably the U.S. Endangered Species Act, do not protect hybrid species. Given the crisis facing biodiversity and coral reefs around the world, hybrid corals should no longer be overlooked.

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This Note discusses naturally occurring hybrid corals in Florida and the Caribbean. It provides background on the role coral reefs play in human societies around the world and in Florida, explains the importance of hybrid corals to global coral reefs, and surveys the patchwork of laws that purport to protect corals. Given the potential role hybrid corals may have in coral reef persistence, this Note suggests revising the Endangered Species Act's implementing regulations to protect hybrid corals. Regulations should permit the listing of hybrid species as threatened and endangered, or agencies should reevaluate best available science regarding hybrid corals in listing such organisms under the Act. Considering the threats facing biodiversity, ignoring naturally occurring hybrids that may be resilient to climate change is an oversight we cannot afford.

> The last word in ignorance is the man who says of an animal or plant: 'What good is it?' . . . If the biota, in the course of aeons, has built something we like but do not understand, then who but a fool would discard seemingly useless parts? To keep every cog and wheel is the first precaution of intelligent tinkering.
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> - Aldo Leopold, 1949.[1]

INTRODUCTION

Fisher Island, FL 33109, is the wealthiest zip code in the United States, with an average annual adjusted gross income of $2.2 million per capita.[2] It's an exclusive, 216-acre, man-made island off the southwest tip of Miami Beach, stocked with ultra-luxury residential inventory and edged by private beaches. It has its own golf course,[3] a $38.5 million new penthouse,[4] a $60,000-a-month beachfront rental,[5] and a recently renovated, gently used $21 million penthouse.[6]

But the most valuable thing on Fisher Island may not be the luxury real estate or the investment portfolios of the billionaires who call the island home. Growing on the side of a Fisher Island seawall may be one of the keys to the future of coral reefs.

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In recent years, a growing body of research has documented a precipitous decline in global coral populations. In 2019, the National Academies of Sciences, Engineering, and Medicine (National Academies) published a research review on "the state of science on genetic, ecological, and environmental interventions

1. ALDO LEOPOLD, ROUND RIVER 145, 146–47 (Luna Leopold ed., 1993); *see also* Melinda Harm Benson, *Intelligent Tinkering: the Endangered Species Act and Resilience*, 17 ECOLOGY & SOC'Y 28, 28 (2012) (noting that this Aldo Leopold quote "is frequently invoked by supporters of the Endangered Species Act") (citation omitted).

2. *See* Shelley Hagan & Wei Lu, *NYC's Trendy Neighborhood Leaps into Top Five Richest Zip Codes*, BLOOMBERG (Mar. 4, 2019), https://www.bloomberg.com/news/articles/2019-03-04/nyc-s-trendy-neighborhood-leaps-into-top-five-richest-zip-codes [https://perma.cc/U5LX-LLEY].

3. *See* MIAMI-DADE CTY., PORTMIAMI 2035 MASTER PLAN 2-3, https://www.miamidade.gov/portmiami/library/2035-master-plan/complete-master-plan.pdf [https://perma.cc/RW2K-5PPY].

4. *See* Josh Baumgard, *Palazzo Del Sol Penthouse Is Fisher Island's Priciest Listing at $38.5M*, CURBED MIAMI (Aug. 9, 2016), https://miami.curbed.com/2016/8/9/12413864/palazzo-del-sol-penthouse-sale [https://perma.cc/FHA5-AKLB].

5. *See* Josh Baumgard, *Fisher Island Rental with Backyard Beach Seeks $60,000*, CURBED MIAMI (Apr. 24, 2017), https://miami.curbed.com/2017/4/24/15406742/miami-fisher-island-home-beach-rent [https://perma.cc/4TGU-P9F6].

6. Robyn A. Friedman, *$21 Million Island Penthouse Puts You Among the Rich and Fabulous*, SUN SENTINEL (Feb. 14, 2019), https://www.sun-sentinel.com/real-estate/prime-property/fl-bz-prime-property-fisher-island-penthouse-20190212-story.html [https://perma.cc/R5WA-YC87].

meant to enhance the persistence and resilience of coral reefs."[7] The reason for the 259-page review is clear: since the 1980s, approximately 30 to 50 percent of global coral reef cover has disappeared due to threats such as "habitat destruction, pollution, overfishing, disease, and climate change."[8] And unfortunately for corals around the world, simply stopping local and regional stressors such as pollution or boat groundings is not enough to protect reefs in the coming decades.

Even if coastal communities reduced these stressors, coral reefs would still be in danger because they are exceptionally vulnerable to climate change. A 2019 intergovernmental report on the threats to global biodiversity estimated that with just two degrees Celsius of global warming, global coral reefs will decline to less than 1 percent of former cover.[9] Sadly for corals and the rest of the world, global warming is likely to reach 1.5 degrees Celsius between 2030 and 2052 if industry, transportation, and human activity continue at current rates.[10]

However, certain tools may be available to fortify coral reefs. The National Academies committee identified various interventions that may be key to the future of coral reefs. And there is an example of one such "genetic and reproductive"[11] intervention clinging to a Fisher Island seawall: hybridization. Specifically, *Acropora prolifera*: a hybrid coral of *Acroporas cervicornis* and *palmata*.

Although corals can hybridize and adapt to the threat of climate change, the existing legal framework in the United States is insufficient to ensure their protection. This regulatory gap leaves hybrid corals exposed to local and regional stressors. But legal protections, like the corals themselves, can adapt and evolve. If we value coral reefs, we should modify the legal framework that protects corals and related marine ecosystems to encompass naturally occurring resiliency tools such as hybrid corals.

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7. *See* NAT'L ACADS. OF SCIS., ENG'G, & MED., A RESEARCH REVIEW OF INTERVENTIONS TO INCREASE THE PERSISTENCE AND RESILIENCE OF CORAL REEFS 2 (2019), https://www.nap.edu/catalog/25279/a-research-review-of-interventions-to-increase-the-persistence-and-resilience-of-coral-reefs [https://perma.cc/BWP9-YQHJ] [hereinafter NAS RESEARCH REVIEW].

8. *Id.* at 1.

9. Sandra Díaz et al., *Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, at 8, *Addendum* to REPORT OF THE PLENARY OF THE INTERGOVERNMENTAL SCIENCE-POLICY PLATFORM ON BIODIVERSITY AND ECOSYSTEM SERVICES ON THE WORK OF ITS SEVENTH SESSION, IPBES/7/10 (2019), https://ipbes.net/sites/default/files/ipbes_7_10_add.1_en_1.pdf [https://perma.cc/KU6J-YKJ9].

10. *See* U.N. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, GLOBAL WARMING OF 1.5°C: HEADLINE STATEMENTS FROM THE SUMMARY FOR POLICYMAKERS (2018), https://www.ipcc.ch/site/assets/uploads/sites/2/2018/07/sr15_headline_statements.pdf [https://perma.cc/42TC-LFUG]; *see also* DAVID WALLACE-WELLS, THE UNINHABITABLE EARTH: LIFE AFTER WARMING 5–11 (2019) (summarizing consensus that the current course of greenhouse gas emissions is on track to increase global temperatures by more than four degrees Celsius by 2100).

11. NAS RESEARCH REVIEW, *supra* note 7, at 10 tbl.S.1.

This Note suggests extending legal protections for threatened and endangered species to cover hybrid coral species, so that legal mechanisms like the U.S. Endangered Species Act (ESA) are more responsive—and adaptive—to rapidly changing environments. In order to show the importance of such flexibility in the law to the overall goal of protecting biodiversity, this Note addresses hybridization as a response to oceans undergoing rapid change, identifies existing gaps in legal regimes' consideration of hybrid corals, and ultimately proposes allowing species-level protections for hybrids. This Note focuses on South Florida, given the prevalence of naturally occurring hybrids in the area. Part I of this Note explores the biology and importance of coral reefs and factors that imperil their existence. Part II summarizes current legal and political mechanisms that may protect corals, and how these laws fail to protect hybrids, especially hybrid corals located in urban and developed coastal environments. Finally, Part III proposes modifying implementation of federal biodiversity and wildlife laws such as the ESA to protect hybrid species with the potential for longevity, including hybrid and human-cultivated corals.

I.
CORAL REEF BIOLOGY AND HYBRIDIZATION AS A STRATEGY TO ADAPT TO A WARMING WORLD

Before diving into the coral-protection legal regime—or lack thereof—it is important to understand exactly what corals are, why they are imperiled in the Anthropocene,[12] and why they are important to marine ecosystems and the human world. Coral anatomy and physiology are ill-suited for protection under traditional biodiversity laws, and rapid environmental change exacerbates this problem. Coral reefs are poised to experience catastrophic species death in the next decades unless climate change is slowed and resiliency and persistence interventions are thoroughly explored. This devastation will not just affect the ocean waters in which corals are found; it will dramatically alter the human economies and social structures dependent on healthy coral reefs.

A. How Corals' Biology Complicates Their Legal Status

Certain aspects of coral biology, such as corals' invertebrate nature and ability to reproduce asexually, foreclose legal protections available to other types of non-coral species. Coral species' unique biology and life histories make them more difficult to protect legally compared to other wildlife. Thus, it is all the more important to permit protection of hybrid coral species to fill such legal gaps. In addition, part of the difficulty in protecting corals and determining which resiliency interventions to pursue—whether genetic and reproductive,

12. "Anthropocene" is defined by Merriam-Webster as "the period of time during which human activities have had an environmental impact on the Earth regarded as constituting a distinct geological age." *Anthropocene*, MERRIAM-WEBSTER, https://www.merriam-webster.com/dictionary/Anthropocene [https://perma.cc/SS26-GH2D].

physiological, population and community, or environmental[13]—is that corals themselves have unique life histories.

The numerous species of corals present visually in different ways. Therefore, it can be difficult to tell what a coral is from morphology, the physical shape and structure of an organism. Some corals look like big, rocky boulders; others resemble branching bushes.[14] Some are soft, and some are stony. Some present as waving ferns, others sprawl out across rocks or the sea floor, and still other corals cling like fungus. The plethora of seemingly different corals makes species categorization difficult. While at first glance a sea floor-clinging, branching coral may seem fundamentally different from a tall, tree-like branching coral, the former may actually be a hybridization of the latter. Unfortunately, species categorization is necessary for species-dependent legal schemes, such as the ESA, to apply.

Corals serve fundamental ecosystem functions, and yet coral reefs are only found in 0.1 percent of ocean waters.[15] The relative scarceness of coral reefs makes it more likely that corals will become threatened, endangered, or extinct. The boom in marine ecosystems research in general is relatively recent, which means there are still unknowns regarding coral reefs and related ecosystems.[16]

In addition to being difficult to categorize and comparatively scarce, corals depend on other organisms for survival. Although at first glance corals resemble plants, they are classified as animals and can present as numerous tiny anemones housed in a larger structure. Corals are in a symbiotic relationship with microscopic zooxanthellae algae, which produce energy for the coral through photosynthesis.[17] The zooxanthellae[18] are also known as algal symbionts, or organisms that live within the coral in a symbiotic relationship.[19] Zooxanthellae are incredibly important to corals because they provide one of corals' primary

13. *See* Oceans Stud. Bd. , *Overview of Coral Interventions*, NAT'L ACADS. SCI. ENGINEERING & MED., http://nas-sites.org/dels/coral-interventions-table/ [https://perma.cc/FHY5-K5B3] (describing the different interventions summarized in the NAS RESEARCH REVIEW).

14. *See generally Species Profiles: Florida's Common Corals*, FLA. MUSEUM, https://www.floridamuseum.ufl.edu/southflorida/habitats/corals/species-profiles [https://perma.cc./H8L7-W7SC] (describing *Diploria labrynthiformis* and *Acropora cervicornis*, also known as grooved brain coral and staghorn coral).

15. *See Coral Reefs*, WORLD WIDE FUND FOR NATURE, http://wwf.panda.org/our_work/oceans/coasts/coral_reefs/ [https://perma.cc/AA7D-2P68].

16. Angel Borja, *Grand Challenges in Marine Ecosystems Ecology*, FRONTIERS MARINE SCI., Feb. 2014, at 1, 1.

17. *See* Gisèle Muller-Parker & Christopher F. D'Elia, *Interactions Between Corals and Their Symbiotic Algae*, *in* LIFE AND DEATH OF CORAL REEFS 97, 100 (Charles Birkeland ed., 1997).

18. "Zooxanthellae" is a general term for dinoflagellate symbiotic algae that live in animals, including corals. *See id.* at 98.

19. *See id.* at 96.

sources of fuel.[20] This is why coral bleaching is devastating: when corals bleach, they can expel their algal symbionts and lose a food source.[21]

Corals' invertebrate status also creates legal challenges. Corals secrete and create a calcium carbonate exoskeleton,[22] but lack a backbone and are thus invertebrates. Corals' invertebrate nature is part of what makes protecting them under legal doctrines like the ESA difficult, because these laws provide certain protections for vertebrate animals, such as mammals, fish, and birds, while denying such protections to invertebrates.[23]

As colonial organisms, corals have unique ecosystem functions. Different corals also serve different ecosystem functions, including the all-important reef-building function of stony corals, which create the physical structure of the reef. Each "coral" is actually a colony of coral polyps that share a gastrovascular system[24] and build skeletons out of calcium and carbon dioxide. Imagine individual coral units (polyps) fixing calcium and carbon dioxide to build scaffolding. Within each unit live even tinier algae, zooxanthellae. That scaffolding is observable as the high-rise coral colony.

There are two main types of corals: stony reef-building corals, which build skeletons, and soft octocorals, such as sea fans and sea whips. There are more than forty-five species of stony corals and thirty-five species of octocorals living on the Florida Reef Tract,[25] near where the corals at the heart of this Note live.

Corals' reproductive abilities enable them to adapt to changing climate conditions. Corals can reproduce sexually (two corals exchange eggs and sperm) or asexually (through an action like propagation, where one individual splits into two genetically identical individuals).[26] Asexual and sexual reproduction processes are not mutually exclusive.[27] Asexual reproduction happens within coral colonies, where budding creates new polyps, and through fragmentation, where coral fragments become detached and land elsewhere and continue to

20. *See id.* at 100. Corals eat in two different ways: (1) each polyp has an opening, or mouth, and corals catch zooplankton through polyp mouths; or (2) corals receive photosynthesized fuel from their algal symbionts. *See id*.

21. *See infra* Part I.C.1 (describing coral bleaching as the process in which healthy coral expel algal symbionts and lose color, turning white).

22. *See How Coral Reefs Grow*, CORAL REEF ALLIANCE, https://coral.org/coral-reefs-101/coral-reef-ecology/how-coral-reefs-grow/ [https://perma.cc/B9XD-UXX7].

23. *See generally* Policy Regarding the Recognition of Distinct Vertebrate Population Segments Under the Endangered Species Act, 61 Fed. Reg. 4722, 4722 (Feb. 7, 1996) (noting the history of "distinct population segments" (DPS) which limited the original definition of species under the ESA from "any subspecies of fish or wildlife or plants . . . that interbreed when mature" to "any subspecies of fish or wildlife or plants, and any [DPS] of any species of *vertebrate* fish or wildlife which interbreeds when mature" (emphasis added)). See *infra* Part II for an examination of how the ESA treats invertebrates.

24. *See* Muller-Parker & D'Elia, *supra* note 17, at 96–97.

25. *See id.*

26. *See* Robert H. Richmond, *Reproduction and Recruitment in Corals: Critical Links in the Persistence of Reefs*, *in* LIFE AND DEATH OF CORAL REEFS 175, 176 (Charles Birkeland ed., 1997).

27. *Id.*

grow.[28] Coral sexual reproduction occurs in the crossing of eggs and sperm and results in a coral larva.[29] Sexual reproduction may result in hybridization when "eggs of one species become fertilized by sperm from another."[30] Hybridization is problematic for legal protection under laws such as the ESA, which does not include protections for hybrids.[31] Because of their unique physiology, in particular their invertebrate nature and ability to propagate asexually, corals present difficult questions for classification and protection.

B. The Importance of Coral Reefs Around the World and in Florida

Although their unique biology and ability to build physical structures make it difficult to protect corals,[32] those same biologies and capabilities mean coral reefs are important to a variety of animal and plant species, humans included. Coral reefs provide ecosystem services globally, supporting economically important fisheries and protecting shoreline and coastal areas by buffering against storm surge.[33] In Florida and the Caribbean, certain fisheries depend on reefs.[34] In general, coral reefs serve as nurseries and sources of food for commercial fish species.[35] Although disease and other stressors have ravaged Florida's reefs,[36] the corals have produced a hybrid species that may provide a way to extend reef longevity. Thus, Florida is a useful area for considering further protections for hybrid corals in the existing legal environment.

Known as the "rainforests of the sea,"[37] coral reefs are among the most biodiverse ecosystems on the planet. Corals reefs in the central Indo-Pacific and Caribbean are thought to house the greatest diversity of marine life on a per-unit-area basis.[38] While rainforests house a greater diversity of *species* due to insects and flowering plants, coral reefs house a greater diversity of *phyla* and *classes*.[39] Although occupying less than one-quarter of one percent of ocean waters, coral

28. *Id.*

29. *Id.* at 177.

30. *Id.* at 189.

31. *See* Final Listing Determinations on Proposal to List 66 Reef-Building Coral Species and to Reclassify Elkhorn and Staghorn Corals, 79 Fed. Reg. 53,851, 53,852 (Sept. 10, 2014).

32. *See supra* Part I.A.

33. *See generally* CONSERVATION INT'L ET AL., ECONOMIC VALUES OF CORAL REEFS, MANGROVES, AND SEAGRASSES 1 (2008), https://www.icriforum.org/sites/default/files/Economic_values_global%20compilation.pdf [https://perma.cc/KME9-E877] (outlining economic benefits of coral reefs).

34. *See, e.g.*, LAURETTA BURKE ET AL., WORLD RES. INST., REEFS AT RISK REVISITED 78 (2011), https://pdf.wri.org/reefs_at_risk_revisited.pdf [https://perma.cc/ZQ4E-3QJB] (noting that the annual net benefit of Caribbean coral reef fisheries was estimated at $395 million in 2010).

35. *See id.* at 1.

36. *See infra* Part I.C.

37. Richard Stone, *A World Without Corals?*, 316 SCIENCE 678, 678 (2007).

38. *See* Gustav Paulay, *Diversity and Distribution of Reef Organisms*, *in* LIFE AND DEATH OF CORAL REEFS 298, 301 (Charles Birkeland ed., 1997).

39. Charles Birkeland, *Introduction to* LIFE AND DEATH OF CORAL REEFS 1, 4 (Charles Birkeland ed., 1997).

reefs "supply habitat for one-quarter to one-third of all marine fish species and support perhaps as many as 9 million species of marine plants and animals."[40] Given humans' relative lack of knowledge of marine ecosystems compared to terrestrial ecosystems, some estimate "the actual species diversity on coral reefs may be even three to five times greater than previously recognized."[41]

Coral reefs are integral to contemporary economies as well as marine ecosystems. Globally, coral reefs provide an estimated $29.8 billion in annual net benefit, comprised of $9.6 billion from tourism and recreation, $9 billion in coastal protection, $5.7 billion from fisheries, and $5.5 billion from biodiversity.[42] Beyond direct economic benefits, coral reefs are also believed to hold pharmaceutical cures to human ailments, including human immunodeficiency virus (HIV).[43]

Coral reefs are of paramount economic importance in Florida. In Southeast Florida, which includes Palm Beach, Broward, Miami-Dade, and Monroe counties, natural and artificial reefs generated over $4.3 billion between June 2000 and May 2001.[44] Natural reefs accounted for $2.7 billion of that total.[45] During that same period, reef-related activities, including snorkeling and diving tourism, fishing, and associated charter and boating industries, provided 71,300 jobs in the region.[46]

One Florida state park alone generated millions in direct economic impact from corals in fiscal year 2016-2017.[47] John Pennekamp Coral Reef State Park, which welcomes visitors near the beginning of the entry to the Florida Keys, contributed approximately $59.2 million in direct economic impact and attracted

40. *See* Robin Kundis Craig, *Acropora spp.: Water Flow, Water Quality, and Threatened Florida Corals*, NAT. RESOURCES & ENV'T, Fall 2007, at 8, 8.

41. Birkeland, *supra* note 39, at 4.

42. CONSERVATION INT'L, *supra* note 33, at 1.

43. *See Novel Anti-HIV Proteins from Coral Reefs*, NAT'L INSTS. HEALTH, https://www.ott.nih.gov/technology/e-295-2012 [https://perma.cc/E5SB-2W67]. Scientists at the National Cancer Institute discovered that certain proteins found in Australian soft corals are capable of blocking the HIV virus from penetrating immune cells. *See id*. The exploration of other species for human therapeutic use is known as "bioprospecting." *See* Edwin L. Cooper et al., *Corals and Their Potential Applications to Integrative Medicine*, EVIDENCE-BASED COMPLEMENTARY & ALTERNATIVE MED., 2014, at 1. According to some researchers, corals are well-suited for bioprospecting and show potential for arthritis and cancer applications. *See id.* at 1–3.

44. *See* CORAL REEF CONSERVATION PROGRAM, NAT'L OCEANIC & ATMOSPHERIC ADMIN., U.S. DEP'T OF COMMERCE, SUMMARY REPORT: THE ECONOMIC VALUE OF U.S. CORAL REEFS 7 (Peter E.T. Edwards ed., 2013), https://www.ncei.noaa.gov/data/oceans/coris/library/NOAA/CRCP/other/other_crcp_publications/Economic_Value_US_Coral_Reefs_Summary_2013.pdf [https://perma.cc/8BSE-5MWG].

45. *Id.*

46. *Id.*

47. Memorandum from Steven A. Cutshaw, Chief, Office of Park Planning, Fla. Dep't of Envtl. Prot. (Oct. 6, 2017), https://floridadep.gov/sites/default/files/Economic%20Impact%20Assessment%202016-2017.pdf [https://perma.cc/Y5NA-F9BT].

628,005 visitors in that period.[48] John Pennekamp is located along the Florida Reef Tract and offers popular attractions such as swimming and snorkeling on shallow reefs.[49] In addition to John Pennekamp, Southeast Florida is home to national parks and reserves such as Everglades National Park, Biscayne National Park, Dry Tortugas National Park, and the Florida Keys National Marine Sanctuary, all of which offer coral-based activities such as snorkeling.[50]

The immense value coral reefs provide stems from a variety of different functions. Coral reefs act as habitats for fisheries, natural curiosities for locals and tourists to explore, self-repairing storm barriers for coastal communities, laboratories for untold medical and scientific breakthroughs, and sources of artistic inspiration.[51] A coral reef can simultaneously provide shelter for millions of different marine organisms, which in turn sustain local coastal communities, and also provide an activity around which residents can create social and economic structures.[52] Without coral reefs, fisheries that provide an important protein source and billions of dollars of other economic stimuli will disappear.

C. Gone by the End of the Century: The Dangers Facing Coral Reefs

Despite their incredible economic, esthetic, and recreational value, coral reefs around the world will likely be gone by the end of the century. Reefs will disappear due to global climate change, which causes ocean warming and acidification.[53] In addition to larger global threats, coral reefs are also highly susceptible to local threats from human activity such as erosion runoff from coastal development, pesticide and pollution runoff from agriculture,

48. *Id.*

49. *See John Pennekamp Coral Reef State Park*, FLA. ST. PARKS, https://www.floridastateparks.org/parks-and-trails/john-pennekamp-coral-reef-state-park [https://perma.cc/S38U-UY8X] (noting that John Pennekamp Coral Reef State Park is "the country's first undersea park" and provides opportunities to visit "colorful coral reefs" by glass-bottom boat, scuba diving, and snorkeling).

50. *See Everglades National Park Florida*, NAT'L PARK SERV., https://www.nps.gov/ever/index.htm [https://perma.cc/NU3P-PRLY]; *Biscayne National Park Florida: A Watery Wonderland*, NAT'L PARK SERV., https://www.nps.gov/bisc/index.htm [https://perma.cc/E843-4WBN]; *Dry Tortugas National Park Florida*, NAT'L PARK SERV., https://www.nps.gov/drto/index.htm [https://perma.cc/L75X-34LL]; *Florida Keys National Marine Sanctuary*, NAT'L OCEANIC & ATMOSPHERIC ADMIN., https://floridakeys.noaa.gov [https://perma.cc/46N6-FPSD].

51. *See Shallow Coral Reef Habitat*, NOAA FISHERIES, https://www.fisheries.noaa.gov/national/habitat-conservation/shallow-coral-reef-habitat [https://perma.cc/GZ68-6Y9H]; *see also* Birkeland, *supra* note 39, at 5–6; *Pantone Color of the Year 2019: Living Coral 16-1546*, PANTONE, https://www.pantone.com/color-intelligence/color-of-the-year/color-of-the-year-2019 [https://perma.cc/HDP4-MBE9].

52. *See* Birkeland, *supra* note 39, at 5–6.

53. *See* WORLD HERITAGE CONVENTION, UNESCO, IMPACTS OF CLIMATE CHANGE ON WORLD HERITAGE CORAL REEFS 9 (2017), https://whc.unesco.org/document/158688 [https://perma.cc/F289-U3XU].

overfishing, and shipping and recreational traffic.[54] These activities can cut off food and life sources, effectively choking coral reefs.[55]

Florida is home to both the only shallow-water coastal reef in the continental United States[56] and the naturally occurring hybrid coral *Acropora prolifera*. The Dante B. Fascell Port of Miami (PortMiami), a highly trafficked commercial port,[57] is located adjacent to Fisher Island and known colonies of *Acropora prolifera*. The PortMiami area consists of a recently dredged[58] shipping channel which continues out from the port to bisect a shallow-water coastal reef. In addition to commercial cargo and cruise traffic, the area is busy with recreational boat and water traffic from nearby islands such as Fisher Island and Miami Beach. Thus, PortMiami is a good area to examine global climate change and localized threats to coral reefs, as well as the potential tools available to protect such reefs. To protect corals against climate change and other man-made threats, we cannot simply protect "natural" areas: we should protect corals in developed spaces, where such corals naturally occur.

1. Global Climate Change Threats Imperiling Coral Reefs

Since the 1980s, coral reefs have declined by an average of 30 to 50 percent in all major tropical ocean basins globally.[59] A 2008 study estimated that one-third of reef-building corals face a rapidly increasing risk of extinction because of rising ocean temperatures due to climate change. Higher ocean temperatures cause coral "bleaching" and ocean acidification, which impairs corals' ability to build skeletons by reducing ocean carbonate ion concentrations.[60]

One of the major threats global warming poses to corals is the increase in coral bleaching events. Coral bleaching looks much like it sounds: previously healthy-appearing corals lose color and "bleach" to white in response to warming ocean temperatures. But what's happening is a bit more complicated than a loss of color. Reef-building corals, like the *Acropora cervicornis* (staghorn coral) and *Acropora palmata* (elkhorn coral), host algal symbionts.[61] These algal symbionts are pigmented and are one of the reasons living corals do not typically appear

54. *See* Elizabeth Kolbert, The Sixth Extinction 140–41 (2014).

55. *See id*.

56. Coral Reef Information System: Florida, NAT'L OCEANIC & ATMOSPHERIC ADMIN., https://www.coris.noaa.gov/portals/florida.html [https://perma.cc/44CW-CK4V].

57. *See* PORTMIAMI, PORT GUIDE 2018-2019, at 8 (2019), https://www.miamidade.gov/portmiami/library/2019-port-guide.pdf [https://perma.cc/83DL-7W42] (noting that 1,220 cruise ships and 1,000 cargo ships docked in 2018).

58. Dredging in general is the excavation of sediment and debris from underwater surfaces. *See, e.g.*, 40 C.F.R. § 232.2(5)(2)(ii) (2019).

59. *See* NAS RESEARCH REVIEW, *supra* note 7, at 1.

60. *See* Kent E. Carpenter et al., *One-Third of Reef-Building Corals Face Elevated Risk from Climate Change and Local Impacts*, 321 SCIENCE 560, 560 (2008).

61. Andrew C. Baker et al., *Climate Change and Coral Reef Bleaching: An Ecological Assessment of Long-term Impacts, Recovery Trends and Future Outlook*, 80 ESTUARINE, COASTAL & SHELF SCI. 435, 436 (2008).

white. Zooxanthellae are sensitive to temperature, and high temperature or irradiance (increased sun) damages the zooxanthellae's "photosynthetic machinery, resulting in the overproduction of oxygen radicals."[62] This overproduction can lead to a breakdown in cellular structure, causing the coral animal to expel its symbiotic algae. In stony reef-building corals, 50 percent or more of algal symbionts must be expelled before bleaching is visible to the naked eye.[63]

But bleaching causes more than just color loss. Because zooxanthellae provide the main source of fuel for the coral animal, expulsion of these algal symbionts means that corals lose a valuable feeding partner. Even worse, once a coral loses its zooxanthellae, it can be difficult for the zooxanthellae to recolonize. In asexually produced corals, zooxanthellae are inherited from parent-coral fragments.[64] Sexually produced corals receive zooxanthellae from their parents or the environment.[65] While corals can reuptake algal symbionts from their surroundings,[66] if coral bleaches and does not regain more zooxanthellae, it is likely to starve. Under normal conditions, the concentration of zooxanthellae in seawater—and thus available for reuptake—is "quite low."[67]

The coral resiliency review from the National Academies estimated (assuming no adaptation of corals and regardless of how or if humans reduce carbon dioxide emissions) coral reefs will experience severe annual or biannual bleaching by 2050.[68] More than other ecosystems, coral reefs are incredibly sensitive to global change events and "vanish about a million years before other groups of organisms each time there is a global mass extinction."[69] The ability of coral reefs to vanish and then reappear suggests resiliency on an evolutionary and million-year-plus timescale.[70] But for humans interested in living in a world with corals, such long-term resiliency isn't practical or valuable in a decades- or even centuries-long time frame.

2. A Florida Perspective: Examining Local Threats

In addition to global climate change and ocean acidification, human activity is rushing coral reefs toward extinction: overfishing and agricultural runoff promote algae growth that crowds out corals; and deforestation, dredging, and

62. *See id.*
63. *See id.*
64. *See* Muller-Parker & D'Elia, *supra* note 17, at 99.
65. *Id.*
66. *See id. passim*.
67. *See id.*
68. *See* NAS RESEARCH REVIEW, *supra* note 7, at 26.
69. *See* Birkeland, *supra* note 39, at 1; *see also* KOLBERT, *supra* note 55, at 140–41 (discussing the historical and contemporaneous vulnerability of coral reefs to environmental change).
70. *See* Pamela Hallock, *Reefs and Reef Limestones in Earth History*, *in* LIFE AND DEATH OF CORAL REEFS 13, 20 fig.2-1 (Charles Birkeland ed., 1997) (displaying a geological time scale that illustrates major reef-related events, including mass extinctions and coral extinctions such as prior Caribbean coral extinctions in the Miocene).

other land uses increase sedimentation and water turbidity.[71] Natural disease also ravages reefs and leaves scars of necrotic tissue across healthy corals.[72]

In areas with high human traffic and construction-related activities like dredging, increased sedimentation is likely because there are more instances of coastal disturbance. Recent dredging of a shipping channel (known as a "cut") in PortMiami shows how harmful human activity can be to coral reefs: the dredging harmed tens of thousands of coral individuals and blanketed hundreds of acres of protected reef with sediment.[73]

Any activity that disturbs sediment on the sea floor can kick up particles and increase turbidity in the surrounding waters. And while some research suggests corals can survive short-term high-level sedimentation, there is vast literature cataloging reefs killed by sediment.[74] Sedimentation stresses coral reefs in four ways: smothering of the coral, abrasion of the coral, shading by blocking sunlight, and inhibition of recruitment of young coral larva in a colony.[75]

The benefits of the inclusion of hybrid coral species under U.S. law is made clear in Florida and PortMiami for two main reasons: Florida is the only state in the continental U.S. with extensive shallow coastal barrier coral reefs;[76] and *Acropora prolifera*, a resilient hybrid species, has been found in Florida and the nearby Caribbean. Florida's reefs are under siege from various stressors and disease, and two species in particular continually suffer: the elkhorn and staghorn corals. Attacks on Florida reefs began more than a century ago with the construction of the Overseas Highway to Key West, and today the reefs are among the most degraded in the Caribbean.[77] The dredging of the PortMiami Government Cut shipping channel is just one example of continued assaults on Florida reefs. Threats can also be more mundane, such as vessel groundings or dragging boat anchors.[78]

The coral hybrid *Acropora prolifera* also faces threats in PortMiami. In the human-created deep-water cut of PortMiami in Miami-Dade County, *Acropora prolifera* were discovered in 2009.[79] But PortMiami, a rapidly growing cargo

71. *See* KOLBERT, *supra* note 55, at 140–41.

72. *Id.*

73. *See Corps Commits to Conduct New Environmental Studies Before Port Everglades Expansion Dredging Begins*, EARTHJUSTICE (Jan. 23, 2017), https://earthjustice.org/news/press/2017/corps-commits-to-conduct-new-environmental-studies-before-port-everglades-expansion-dredging-begins [https://perma.cc/QN9R-ESZJ].

74. Dennis K. Hubbard, *Reefs as Dynamic Systems*, *in* LIFE AND DEATH OF CORAL REEFS 43, 57 (Charles Birkeland ed., 1997).

75. *Id.*

76. Coral Reef Information System: Florida, *supra* note 56.

77. *See* Mary Gray Davidson, *Protecting Coral Reefs: The Principal National and International Legal Instruments*, 26 HARV. ENVTL. L. REV. 499, 508 (2002).

78. *See* BURKE ET AL., *supra* note 34, at 65 box 5.7.

79. Telephone Interview with Colin Foord, Co-founder, Coral Morphologic (Mar. 6, 2019) [hereinafter Foord Interview].

and cruise capital,[80] underwent a massive dredging project beginning in 2013, which killed or greatly harmed these hybrids. Other corals, such as the staghorn, protected under the ESA, were also damaged during the dredging.[81] The conflict between coral survival and human development comes to a head in South Florida: the marinescape around Biscayne Bay, Fisher Island, Miami Beach, and PortMiami is crowded. It is dense with residents, tourists, jet skis, yachts, kayaks, paddleboards, and lightning-fast speedboats.[82] PortMiami, moreover, has ingress and egress routes right through coral reefs. There is already a channel, Government Cut, carved through near-coast reefs to allow ships port access.

The dredging of Government Cut rocked the reefs' delicate ecosystems. Between 2013 and 2015, the U.S. Army Corps of Engineers (Army Corps) dredged the Government Cut, deepening it from forty-four to fifty-two feet deep.[83] The Army Corps used a cutter-head dredge, likened to an "eggbeater around a vacuum pipe" to cut the ocean floor, and then deposited the slurry of produced sediment onto barges.[84] The act of dredging itself is violent: it is the literal disruption of the sea floor, the "dredging" up of what lies on the bottom. Additionally, the slurry dumped on barges did not always stay put. Along Government Cut, unfortunately, the slurry overflowed into Biscayne Bay. The Army Corps' own contractor "reported finding sediment-stressed corals near [Government Cut]."[85]

By the end of the dredging, fine-grained sediment harmed tens of thousands of coral colonies, and over 250 acres of "critical habitat" for the ESA-protected staghorn corals.[86] Such sedimentation can blanket corals, shading zooxanthellae and reducing or cutting off sunlight, valuable fuel to the small coral animal. Local environmental nonprofit Miami Waterkeeper and other groups engaged in a legal fight, alleging the Army Corps violated the ESA's "permitted take" provision.[87] Thankfully, the dredging of Government Cut did not end with the

80. *See* News Release, Miami-Dade Cty., PortMiami sets a record year -- its strongest ever, (Oct. 23, 2018), http://www.miamidade.gov/releases/2018-10-23-portmiami-record-year.asp [https://perma.cc/C5Z7-P3F7].

81. *See* Roshan Nebhrajani, *The Dredge Report*, NEW TROPIC (Mar. 27, 2016), https://thenewtropic.com/the-dredge-report/ [https://perma.cc/MKU9-HLA8].

82. *See, e.g.*, THRILLER MIAMI SPEEDBOAT ADVENTURES, http://thrillermiami.com/ [https://perma.cc/5XWD-T9Z9].

83. Miami-Dade Reef-Guard Association's Statement of Material Facts in Support of Motion for Partial Summary Judgment Regarding Defendant's Liability Under the Endangered Species Act ¶ 2, Biscayne Bay Waterkeeper, Inc. v. U.S. Army Corps of Eng'rs, No. 14-23632-CIV (S.D. Fla. Sept. 30, 2016) [hereinafter Statement, *Biscayne Bay Waterkeeper*].

84. *See id.* ¶ 14.

85. *See id.* ¶¶ 14–15.

86. *See Corps Commits to Conduct New Environmental Studies Before Port Everglades Expansion Dredging Begins*, *supra* note 73.

87. *See, e.g.*, Statement, *Biscayne Bay Waterkeeper*, *supra* note 83 (identifying Biscayne Bay Waterkeeper, now known as Miami Waterkeeper, as one of the plaintiffs); *Miami Waterkeeper*, GUIDESTAR, https://www.guidestar.org/profile/27-3627697 [https://web.archive.org/web/20200621211028/https://www.guidestar.org/profile/27-3627697].

blanketing of thousands of corals. After years of litigation, the parties reached a settlement to cultivate 10,000 staghorn corals to restore the reef.[88]

While the settlement benefitted the listed staghorn corals, the *Acropora prolifera* and other unlisted corals in the same reefs did not receive the same protections. Listing under the ESA provides a legal hook for advocacy groups to file suit to protect listed species by way of the Act's robust citizen suit provision.[89] But listing is only permitted for endangered or threatened species,[90] leaving otherwise vulnerable hybrid corals unprotected. The listing of the hybrid *Acropora prolifera*'s parent species, the elkhorn and staghorn corals, indicates the past and present threats facing both species—threats that naturally extend to their hybrid.

Between the 1980s and 2000, 93 percent of Caribbean elkhorn corals and 98 percent of staghorn corals died.[91] Once the dominant reef-builders in the Caribbean, elkhorn and staghorn corals were so ravaged by white-band disease, a bacterial infection that produces necrotic tissue, that they were designated "threatened" under the ESA,[92] and the International Union for Conservation of Nature listed them as "critically endangered."[93]

The elkhorn and staghorn corals were the first corals to receive ESA protection in the act's thirty-plus year history.[94] In 2014, the National Oceanic and Atmospheric Administration (NOAA) listed twenty more corals under the ESA, a pared-down group from the sixty-six species proposed for listing under a 2012 proposed rule.[95] At the time of this writing, just twenty-four coral species

88. *See Lawsuit Over Dredging Achieves Restoration of Over 10,000 Threatened Corals*, MIAMI WATERKEEPER (Aug. 6, 2018), https://www.miamiwaterkeeper.org/portmiami_settlement_enews [https://perma.cc/83C3-HR96]; *see also* Joint Status Report, Miami-Dade Reef Guard Ass'n v. U.S. Army Corps of Eng'rs, No. 1:14-cv-23632 (S.D. Fla. May 15, 2018).

89. 16 U.S.C. § 1540(g)(1) (2018) (stating that "any person may commence a civil suit" to enforce the ESA, subject to certain time and redundancy provisions); *see also* Kirsten Nathanson et al., *Developments in ESA Citizen Suits and Citizen Enforcement of Wildlife Laws*, NAT. RESOURCES & ENV'T, Winter 2015, at 15, 15 (providing a history of enforcement under the ESA's citizen suit provision).

90. 16 U.S.C. § 1533(a)(1) (providing five factors agencies consider when listing a species as endangered or threatened, including destruction and modification of habitat and "other natural or manmade factors affecting [the species'] continued existence").

91. *See* JACK E. DAVIS, THE GULF 462 (2017).

92. *See* 50 C.F.R. §§ 223.102, .208 (2019).

93. *See* KOLBERT, *supra* note 54, at 141.

94. Sarah Heberling, *Finding a New Future for Corals*, U.S. FISH & WILDLIFE SERV. (Aug. 28, 2012), https://www.fws.gov/endangered/news/bulletin-summer2009/finding-a-new-future-for-corals.html [https://perma.cc/BSY5-ZCTV].

95. *See id. Compare* 50 C.F.R. § 223.102 (enumerating threatened coral species), *with* Proposed Listing Determinations for 82 Reef-Building Coral Species, 77 Fed. Reg. 73,219, 73,219 (Dec. 7, 2012) (codified at 50 C.F.R. pts. 223–24).

are protected under the ESA, including the threatened elkhorn and staghorn corals.[96]

D. Hybridization as a Response to Threats

Over the last four decades, corals such as the elkhorn and staghorn have declined by more than 90 percent in Florida's coral reef system.[97] However, hybrid *Acropora prolifera* have flourished along the man-made cuts of PortMiami, the neighboring port to Fisher Island. These naturally-occurring urban "super corals,"[98] along with lab-grown "super corals," may be key for the survival of corals in the coming generations.[99] The term "super corals" is used to describe coral interventions, including hybridization, that may be more resilient to anthropogenic change.[100] Some find the term problematic because of its subjective, non-scientific nature and its implication that any one "super coral" will certainly save coral reefs.[101] This Note argues that such corals, "super" or otherwise, should not be excluded from legal protection mechanisms given the threats facing corals reefs at large. To exclude a coral species that shows resilience in the face of climate change from legal protection merely because of its hybrid nature forecloses the possibility for that coral to help reef longevity. This Note largely focuses on naturally occurring hybrid corals such as *Acropora*

96. *See Environmental Conservation Online System: Generate Species List*, U.S. FISH & WILDLIFE SERV., https://ecos.fws.gov/ecp0/reports/ad-hoc-species-report-input [https://perma.cc/AE9K-VFHW] (select "Corals" under Taxonomic Groups and "Endangered (E)" and "Threatened (T)" under Federal Listing Status, then click "Submit") [hereinafter *ECOS*]; *see also* Press Release, Nat'l Oceanic & Atmospheric Admin., NOAA Lists 20 New Corals as Threatened Under the Endangered Species Act (Aug. 26, 2014), https://www.noaa.gov/media-release/noaa-lists-20-coral-species-as-threatened-under-endangered-species-act [https://perma.cc/ZME5-P7H9] [hereinafter NOAA Press Release].

97. *See* DAVIS, *supra* note 91, at 462–63; *see also* Marco Rubio & Michael P. Crosby, *We Have the Resources to Save Florida's Dying Coral Reefs. Now, We Just Need the Will*, MIAMI HERALD (Sept. 5, 2018), https://www.miamiherald.com/opinion/op-ed/article217873600.html [https://perma.cc/9JAF-5PMK] (indicating widespread, bipartisan appeal for saving corals in Florida).

98. *See* Colin Foord, *On Super Corals and Where to Find Them (A Closer Look at Miami's Urban Coral Ecosystem) — Part 2*, MEDIUM (Aug. 14, 2018), https://medium.com/@coralmorphologic/on-super-corals-and-where-to-find-them-a-closer-look-at-miamis-urban-coral-ecosystem-part-2-45a1ee2fa729 [https://perma.cc/HL32-3NXV]; *see also Accelerating Evolution: Mass Die-offs Are Driving Efforts to Create Hardier Corals*, ECONOMIST (May 15, 2018), https://www.economist.com/science-and-technology/2018/03/15/mass-die-offs-are-driving-efforts-to-create-hardier-corals [https://perma.cc/W635-5H3G]; Riane Roldan & Claire Thornton, *'Coral Whisperers' Look for Genetic Clues in Their Quest to Save Reefs in Biscayne Bay*, WLRN (July 30, 2018), https://www.wlrn.org/post/coral-whisperers-look-genetic-clues-their-quest-save-reefs-biscayne-bay [https://perma.cc/N3EY-29HC].

99. Hybrids and lab-grown corals may also be among the keys to coral resiliency around the globe. *See* NAS RESEARCH REVIEW, *supra* note 7, at 3–4. However, this Note focuses specifically on corals in Florida.

100. *See* Foord, *supra* note 98.

101. *See id.*

prolifera, given the experimental nature of lab-grown super corals and their genetically engineered zooxanthellae.[102]

The National Academies committee identified a suite of potential genetic and reproductive interventions for corals, including managed selection (detection of corals with above-average stress tolerance); managed breeding (artificial propagation of diverse coral reef populations); genetic manipulation (direct alteration of genomes); and environmental interventions such as shading, mixing of cool water, and ocean acidification interventions.[103] These resiliency interventions are crucial for the longevity of coral reefs.

Hybridization between species, a form of managed breeding, is one intervention that may increase coral reefs' durability.[104] Coral hybridization has been replicated in a laboratory environment,[105] and hybridization across coral species is one way to create "novel genotypes that are more fit than the parental species that were used to create the hybrids."[106] Some hybrid corals have also been observed spawning.[107] First-generation hybrids are known as "F1 hybrids," but evaluation and study of hybrids over generations (beyond F1) is paramount to assessing the value of hybrids as productive members of reef ecosystems.[108] The question remains whether hybrids are viable beyond F1; if they are, they may offer a long-term intervention for corals.

Hybridization contributes to the resiliency of coral reefs in two ways: through infertile hybrids that resurrect degraded reefs and repair coral reef infrastructure, and through fertile hybrids that "may provide an opportunity to create new genotypes that are more capable of adapting to a changing environment."[109] Natural hybridization already has played a role in the evolution of several coral taxa. Because coral hybrids naturally occur, such hybrids require little human action to be viable as a coral reef resiliency intervention.[110] In

102. *See* NAS RESEARCH REVIEW, *supra* note 7, at 69–70 (noting the experiments used for gene editing).

103. *See id.* at 2–5, 130–32.

104. *See id.* at 40.

105. *See id.* at 56 (noting that hybridization of *Montipora* and *Platygyra* species in artificial environments was viable, while hybridization of *Ctenactis* species was not viable).

106. *See id.* at 51.

107. Lisa Carne & Iliana Baums, *Demonstrating Effective Caribbean Acroporid Population Enhancement: All Three Nursery-grown, Out-planted Taxa Spawn August 2015 & 2016 in Belize*, REEF ENCOUNTER, Dec. 2016, at 42, 42 (stating that nursery-grown *Acropora prolifera* planted out in a reef have been observed spawning); Telephone Interview with Nicole D. Fogarty, Assistant Professor, Univ. of N.C. Wilmington (Apr. 15, 2019) [hereinafter Fogarty interview] (noting that further research needs to be done as to whether hybrid *Acropora prolifera* can mate with itself).

108. *See* NAS RESEARCH REVIEW, *supra* note 7, at 54.

109. *Id.*

110. *See id.* at 57; *see also* William F. Precht et al., *Fossil Acropora Prolifera (Lamarck, 1816) Reveals Coral Hybridization Is Not Only a Recent Phenomenon*, 132 PROC. BIOLOGICAL SOC'Y WASH. 40, 40 (2019) ("It is becoming apparent that hybrid taxa likely play an important but underappreciated role in coral reef ecology and reef-building more generally.").

essence, a naturally occurring coral hybrid is a natural volunteer against the stressors caused by climate change and humans.

Acropora prolifera is one of the prime examples the National Academies cites as a viable coral hybrid.[111] While staghorn and elkhorn corals have experienced dramatic population declines in the Caribbean, their hybrid spawn *Acropora prolifera* has shown an increase in population.[112] A 2012 study confirmed "anecdotal evidence that hybrid densities are equivalent or greater than one or both of the parental species at some sites."[113] In addition, F1 *Acropora prolifera* has shown comparable fitness with its parent species across life stages, and higher settlement and growth rates in shallow environments.[114] The 2012 study did not find any evidence that F1 hybrids were inferior to the parent *Acropora* species; instead, hybrid density was often equivalent to or greater than the parental species.[115]

The shallow-water preference of *Acropora prolifera* indicates that these Caribbean hybrids "adapted to withstand high temperature and UV irradiance associated with extremely shallow environments."[116] Typically, shallower water means that UV exposure and water temperatures are higher, which should result in a higher rate of coral paling and bleaching. However, *Acropora prolifera* did not display a higher incidence of paling and bleaching, even in shallow-water environments.[117] This suggests that "[a]s sea temperatures rise, it is likely that the hybrid will be more tolerant than the parental species."[118]

With hybridization, if a hybrid has equal or superior viability compared with its parent species, it is known as "dominant" or "super-dominant."[119] A hybrid is additive if it is intermediate, i.e., it performs better than one parent and worse than the other. If the hybrid is inferior to both parent species, it is known as "under-dominant." *Acropora prolifera*, at the very least, is additive relative to its two parent species, and is thus more likely than at least one of them to survive disease and rising temperatures.[120]

Given the pressing threat of climate change and ocean warming, attention to coral reef resiliency should be prioritized as a short-term fix to ensure the

111. *See* Foord Interview, *supra* note 79; Fogarty Interview, *supra* note 107.

112. *See* NAS RESEARCH REVIEW, *supra* note 7, at 56–57.

113. Nicole D. Fogarty, *Caribbean Acroporid Coral Hybrids Are Viable Across Life History Stages*, 446 MARINE ECOLOGY PROGRESS SERIES 145, 155 (2012).

114. *See id.*; *see also* NAS RESEARCH REVIEW, *supra* note 7, at 56 (citing Fogarty, *supra* note 113).

115. *See* Fogarty, *supra* note 113, at 157.

116. *See id.* at 155.

117. *See id.*

118. *Id.; see also* Bette L. Willis, et al., *The Role of Hybridization in the Evolution of Reef Corals*, 37 ANN. REV. ECOLOGY EVOLUTION & SYSTEMATICS. 489, 510 (2006) ("[T]he evolutionary potential of hybridization is important to conserve, thus hybrids like *A. prolifera* represent important reservoirs of novel genetic diversity . . . .").

119. *Id.*

120. *See* Fogarty, *supra* note 113, at 157.

survival of coral species into the next century. A major fear of pushing hybrid interventions is that the hybrid will destroy genetics of the parent species on an evolutionary time scale.[121] And while a valid concern, coral reefs are facing extinction today—not because of hybrids, but because of anthropogenic stressors. If humans value corals and coral reefs, a short-term intervention is required.

In addition to hybrids, genetically manipulated corals provide another possible pathway for improving reef resiliency. While these genetic manipulations are not currently feasible for use in the field,[122] further research may result in heat-tolerant and/or disease-tolerant corals.

Unlike hybrids, genetically modified corals—created either through altering coral genes for new function or altering symbiont genes for new function—must occur first in a laboratory.[123] This added level of removal from coral reefs may affect how lab-manipulated corals are valued overall by society in the abstract and more concretely by existing legal regimes. In addition to genetically modifying corals, some researchers are exploring changing algal symbiont communities through uptake in the field.[124] However, much work is needed before genetically engineered algal symbionts are ready for the oceans. The National Academies has noted that manipulation of algal symbionts may be less feasible than manipulations of corals themselves.[125] While man-made genetic interventions may also be needed, coral reefs are already innovating for resilience by propagating natural hybrid corals, in situ.

But despite the promise of *Acropora prolifera*, the coral is unprotected because its hybrid status prevents it from meeting the definition of a species under the ESA.[126] The lack of support and legal recognition of these climate-adapted hybrids puts the future survival of Florida's corals, and possibly the whole world's corals, in jeopardy.

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121. Fred Bosselman, *A Dozen Biodiversity Puzzles*, 12 N.Y.U. ENVTL. L.J. 364, 455 (2004) (citation omitted).

122. *See* NAS RESEARCH REVIEW, *supra* note 7, at 10–13 (providing charts summarizing feasibility of various field experiments). *See generally* Andrew C. Baker et al., *Corals' Adaptive Response to Climate Change*, 430 NATURE 741, 741 (2004) (describing laboratory results of adaptation measures).

123. *See* NAS RESEARCH REVIEW, *supra* note 7, at 70 (stating that "CRISPR/Cas9 is the only tool to date that has been used to directly alter a coral genome").

124. *See id.* at 167–69.

125. *See id.* at 71–72.

126. RAFE BOULON ET AL., NATIONAL MARINE FISHERIES SERVICE ET AL., ATLANTIC *ACROPORA* STATUS REVIEW 9 (2005), https://sero.nmfs.noaa.gov/protected_resources/coral/elkhorn_coral/document/Key_Docs/2004_status_review.pdf [https://perma.cc/N4X4-YJ38].

II.
EXISTING LEGAL AND POLITICAL MECHANISMS TO PROTECT CORALS

Although protecting corals is vital to ensure their survival, existing legal regimes are insufficient to protect resilient hybrid species. Coral reefs are protected by a number of local, state, national, and international acts and initiatives. Unfortunately, the patchwork-like nature of these safeguards undercuts their effectiveness.[127] In addition, existing legal structures do not adequately address the ecosystem needs or benefits of corals and coral reefs.[128] This Section reviews protections for corals under federal and state law, which implement operative international laws.[129]

Broadly, protections for corals and coral reefs operate under two frameworks: species-specific protections such as the ESA, and geographic protections like marine protected areas. Each framework adopts components of and overlaps with the other, such as the ESA's critical-habitat considerations.[130] However, there are several key differences between species-specific and primarily spatial protections. For example, species-specific protections can extend beyond geographic boundaries.[131] Geographic protections such as marine protected areas are specifically bounded areas where human activities are regulated and/or prohibited. And while such areas can produce a halo of protective effects, such protections are spatially limited.

This Note suggests that a species-specific protection similar to the ESA's is a better fit for *Acropora prolifera* than a geographic protection, given the coral's location in South Florida. Because *Acropora prolifera* appears in and

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127. *See* Natalie Harrison, Note, *Rent a Reef? How the Privatization of Florida Coral Reefs May Advance Local Conservation Efforts*, 68 U. MIAMI L. REV. 189, 192 (2013).

128. *See id.* at 201.

129. International laws include the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the United Nations Convention Concerning the Protection of the World Cultural and Natural Heritage (WCNH). *See* Marjorie Mulhall, *Saving the Rainforest of the Sea: An Analysis of International Efforts to Conserve Coral Reefs*,19 DUKE ENVTL. L. & POL'Y F. 321, 334, 343 (2009) (outlining CITES and WCNH). In the United States, the ESA implements CITES. PERVAZE A. SHEIKH & M. LYNNE CORN, CONG. RESEARCH SERV., RL32751, THE CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES OF WILD FAUNA AND FLORA (CITES) 2 (2016); *see also* 16 U.S.C. § 1531(a)(4)(F) (2018) (codifying United States' commitment to CITES); Davidson, *supra* note 77, at 534–35 (noting that the United States was the first state to ratify CITES). A consideration of domestic law such as the ESA and local laws is particularly germane to the protection of corals in the United States.

130. For example, critical habitat appears both when the ESA discusses species listing, *see* 16 U.S.C. § 1533(a)(3)(A) (2018) (noting that critical habitat should be designated upon listing), and in a species-independent manner, *see* 16 U.S.C. § 1532(5)(A)(i)–(ii) (2018) (defining "critical habitat" as areas occupied by a listed species "on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection" and "specific areas outside the geographical area occupied by the species at the time it is listed . . . upon a determination by the Secretary that such areas are essential for the conservation of the species").

131. *See* 16 U.S.C. § 1538(a)(1) (2018) (prohibiting the import, export, "take," possession, sale, and more of endangered species with no geographic limits).

around the port, cruise terminals, marinas, and beaches of Miami Beach, Miami, and Fisher Island, where human activity is extensive, another marine protected area is unrealistic. A species-specific protection would complement existing marine protected areas. In order to protect Florida's vital reef ecosystems, while allowing for human economic activity, hybrid corals should benefit from species-specific protections. If successful, such a protection could provide a model to safeguard other hybrid corals in other areas of the country.

A. Existing Protections in the United States

Hybrid corals are an important tool to ensure reef resiliency in the face of a changing climate. While there are numerous overlapping laws and executive orders that seek to protect corals and coral reefs domestically, they are inadequate to protect hybrids and may ultimately be ineffective at protecting "natural" coral species and reefs as a whole. To address gaps in hybrid coral protection, agencies should alter existing hybrid policy under laws like the ESA, reconsider the "best available science"[132] in protecting hybrid corals as either threatened or endangered, or work with Congress to establish a new legal regime that protects coral reef resiliency interventions like hybrid corals.

1. The Endangered Species Act of 1973 and the Hybrid Dilemma

The ESA is the dominant federal statute[133] used to protect individual species.[134] Congress passed the ESA after finding that "various species . . . in the United States have been rendered extinct as a consequence of economic growth and development untempered by adequate concern and conservation," with the intention of "provid[ing] a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved."[135] The ESA is a powerful piece of legislation: shortly after its enactment, the U.S. Supreme Court stated that "Congress has spoken in the plainest of words, making it abundantly clear that the balance has been struck in favor of affording endangered species the highest of priorities."[136]

The ESA flows as a waterfall, starting first with the "listing" of a species under the Act as either "endangered" or "threatened" by federal agencies. From the listing decision flows protections against physical threats and requirements regarding consultation between federal agencies. The operative agencies under the statute are the U.S. Fish and Wildlife Service (FWS) and NOAA's National Marine Fisheries Service (NMFS, also known as "NOAA Fisheries"), which determine whether a species is designated as "endangered" or "threatened,"

132. *See* 16 U.S.C. § 1533(b)(1)(A).

133. *See* Benson, *supra* note 1, at 2 ("The ESA is the strongest federal statute in the United States against species loss.").

134. *See* 16 U.S.C. § 1531(c)(1) (2018).

135. *See id.* § 1531(a)(1), (b).

136. Tenn. Valley Auth. v. Hill, 437 U.S. 153, 194 (1978).

based on five factors.[137] If the agency determines a species is either endangered or threatened, that species is then considered "listed" under the respective category.[138] Once a species is listed as endangered or threatened, federal agencies and persons are typically barred from action that would "take,"[139] i.e., harass or harm,[140] an individual organism of the designated species. In addition, listing under the ESA triggers agency consultation to ensure that governmental action, such as dredging by the Army Corps, "is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species which is determined . . . to be critical, unless such agency has been granted an exemption for such action."[141] Thus, while the ESA functions as a specific species-level protection, some habitat and spatial protections flow from designation.[142]

While the ESA has strong species-level protections, the fact that no coral species were listed for its first three decades hints at agency hesitance to use statutory tools to safeguard corals, even though NMFS considered protecting corals under the act as early as 1991.[143] Finally, in 1999, *Acropora cervicornis* (staghorn coral) and *Acropora palmata* (elkhorn coral) were both added to the ESA candidate species list based on contemporary analysis and public

137. *See* Robin Kundis Craig, *Coral Reefs, Fishing, and Tourism: Tensions in U.S. Ocean Law and Policy Reform*, 27 STAN. ENVT'L L.J. 3, 17–18 (2008); *see also* 16 U.S.C. § 1533(a)(1) (2018) (listing five factors for the Secretary of the Interior or the Secretary of Commerce to consider in listing decisions, including "present or threatened destruction . . . of . . . habitat," "disease or predation," "the inadequacy of existing regulatory mechanisms," or "other natural or manmade factors affecting [a species'] continued existence"). In general, FWS, which is part of the Department of the Interior, makes determinations regarding terrestrial and freshwater species, while NOAA and NMFS, which are part of the Department of Commerce, address marine species and anadromous fish.

138. *See ECOS*, *supra* note 96 (providing a database of all listed animals under the ESA, as of writing).

139. 16 U.S.C. § 1538(a)(1)(B). Section 1538 is also commonly known as Section 9, its location in the session laws.

140. *See id.* § 1532(19).

141. *See id.* § 1536(a)(2).

142. Under 16 U.S.C. § 1533, known as Section 4 of the ESA, the responsive Secretary (either the Secretary of Commerce or Secretary of the Interior) "shall . . . designate any habitat . . . considered to be critical habitat" at the time of listing a species as either threatened or endangered. 16 U.S.C. § 1533(a)(3)(A)(i). Critical habitat designations are to be based on "the basis of the best scientific data available" and, unlike a listing decision, may also include considerations of "economic impact, the impact on national security, and any other relevant impact, of specifying any particular area as critical habitat." *Id.* § 1533(b)(2). Unless failure to designate critical habitat will result in the extinction of a listed species, "any area" can be excluded from critical habitat if "the benefits of such exclusion outweigh the benefits of specifying such area as part of the critical habitat." *Id*. In an economically important area such as an international port, economic factors may weigh against designation of critical habitat.

143. *See* Identification of Candidate Species for Listing Under the Endangered Species Act, 56 Fed. Reg. 26,797, 26,798 (June 11, 1991); *see also* Final Listing Determinations for Elkhorn Coral and Staghorn Coral, 71 Fed. Reg. 26,852, 26,852 (May 9, 2006) (discussing 1991 candidates and removal from list in 1997).

comment.[144] In 2004, the nonprofit environmental group Center for Biological Diversity (the Center) petitioned NOAA and NMFS to list staghorn, elkhorn, and "fused-staghorn" corals as threatened or endangered.[145] The agencies published a final rule in 2006 listing the staghorn and elkhorn as threatened under the ESA, because the "corals were likely to become endangered within the foreseeable future throughout their entire ranges."[146] Though it faced identical threats and similar declines, the "fused-staghorn" coral did not qualify for listing under the ESA because the agencies determined it was a hybrid; that hybrid was *Acropora prolifera*.[147]

In 2014, federal agencies bulk-listed twenty corals as threatened, at the same time noting that the ESA permits local activities to move forward and "no prohibitions exist relating to the newly listed species."[148] The Center was integral, again, to the listing of the additional corals: in 2009, the organization petitioned federal agencies to list eighty-three reef-building corals as endangered or threatened under the ESA.[149] Today, there are twenty-four corals listed as "endangered" or "threatened" under the ESA.[150]

Although recognized as a resilient species adaptable to climate change, *Acropora prolifera*'s status as a hybrid means it is unlistable.[151] To be listable under the ESA, the first inquiry is whether the organism meets the statutory and

144. *See* Final Listing Determinations for Elkhorn Coral and Staghorn Coral, 71 Fed. Reg. at 26,852.

145. *See id.*; *see also* CTR. FOR BIOLOGICAL DIVERSITY, PETITION TO LIST ACROPORA PALMATA (ELKHORN CORAL), ACROPORA CERVICORNIS (STAGHORN CORAL), AND ACROPORA PROLIFERA (FUSED-STAGHORN CORAL) AS ENDANGERED SPECIES UNDER THE ENDANGERED SPECIES ACT i (2004), https://www.biologicaldiversity.org/species/invertebrates/staghorn_coral/pdfs/petition.pdf [https://perma.cc/78LB-WF4N].

146. *See* Final Listing Determinations for Elkhorn Coral and Staghorn Coral, 71 Fed. Reg. at 26,853.

147. *See id.* Regarding listing *Acropora prolifera* today under the ESA, Fogarty says: "I am on the fence at this point. It takes so long to get things listed[.] It would have been nice if they had wrapped the hybrid in there, but . . . with the information [researchers and agencies] had at the time[,] [I understand]. I would love to see it protected, [but] I don't think that's ever going to happen. Unless we see drastic declines in the parents and the hybrid is the only thing around." *See* Fogarty Interview, *supra* note 107.

148. NOAA Press Release, *supra* note 96 (stating that "new information provided . . . strengthened the body of species-specific information available to NOAA" and that the information improved "the agency's understanding of coral habitat diversity . . . and species-specific exposure to threats and their relative vulnerability or resilience").

149. CTR. FOR BIOLOGICAL DIVERSITY, PETITION TO LIST 83 CORAL SPECIES UNDER THE ENDANGERED SPECIES ACT (2009), https://www.biologicaldiversity.org/species/invertebrates/staghorn_coral/pdfs/Coral%20petition_10-20-09.pdf [https://perma.cc/8QD6-NQ6G]; *see also* Final Listing Determinations on Proposal to List 66 Reef-Building Coral Species and to Reclassify Elkhorn and Staghorn Corals, 79 Fed. Reg. 53,852, 53,852 (Sept. 10, 2014) (discussing the Center's petition).

150. *See ECOS*, *supra* note 96.

151. *See* NAS RESEARCH REVIEW, *supra* note 7, at 56.

regulatory definition of a "species."[152] This requires a taxonomic inquiry,[153] i.e., a consideration of how an organism is classified based on natural relationships.[154] Under the ESA, "species" is defined as "[a]ny species or taxonomic group of species,"[155] which includes "any species or subspecies . . . and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature."[156] Joint regulations adopted by FWS and NOAA provide as additional guidance the five factors enumerated in the ESA's text.[157]

The statutory definition of "species" sets a foundation that makes it more difficult to list coral species than charismatic terrestrial animals such as eagles or bears. To begin, the ESA only extends protections for "distinct population segment[s]" of *vertebrate* species,[158] excluding the possibility of listing distinct population segments of *invertebrate* species, including corals.[159] In practice, "the measure of biodiversity has tended to concentrate on the larger organisms and to ignore invertebrates, fungi, and bacteria."[160] Likewise, to determine whether an organism is a sufficient "species," agencies look to taxonomy. When dealing with wildlife that frequently hybridizes, taxonomic lines are blurred.

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152. Some researchers and academics suggest that corals and coral reefs should not even be bound by the framework of "species" or the "individual," but rather considered as "holobionts," which are "organism[s] plus [their] persistent communities of symbionts." *See, e.g.*, Scott F. Gilbert, *Holobiont by Birth: Multilineage Individuals as the Concretion of Cooperative Processes*, *in* ARTS OF LIVING ON A DAMAGED PLANET M73, M73–74 (Anna Tsing et al. eds., 2017). The framing of holobionts and holobiomes, or communities of holobionts, as applied to coral colonies and coral reefs is quite logical, given the vast overlapping symbiotic nature of both the individual coral colonies and coral reefs. *See, e.g.*, Donna Haraway, *Symbiogenesis, Sympoiesis, and Art Science Activisms for Staying with the Trouble*, *in* ARTS OF LIVING ON A DAMAGED PLANET M25, M35 (noting that corals and lichens "taught biologists to understand the parochialism of their ideas of individuals and collectives"). Although a legal regime based on holobiont or holobiome units is appealing and likely well suited for dealing with rapid anthropogenic change, the ESA bases listing on individual species, which excludes symbionts. *See* 16 U.S.C. §§ 1532(16), 1533(a)(1) (2018). This Note urges FWS and NOAA to push existing legal mechanisms to be more adaptive and flexible to address the exigencies posed by climate change.

153. 50 C.F.R. § 424.11(a) (2019).

154. *Taxonomy*, MERRIAM-WEBSTER, https://www.merriam-webster.com/dictionary/taxonomy [https://perma.cc/U58V-F8E9].

155. 50 C.F.R. § 424.11(a); *see also* § 424.02 (excluding "any species of the Class Insecta determined by the Secretary to constitute a pest," thereby providing a loophole for not listing certain insects).

156. *See* 16 U.S.C. § 1532(16); *see also* 50 C.F.R. § 424.02. Notably, corals are invertebrates. *See* Esther C. Peters, *Diseases of Coral-Reef Organisms*, *in* LIFE AND DEATH OF CORAL REEFS 114, 118 (Charles Birkeland ed., 1997). Their invertebrate status excludes corals from listing as a distinct population segment, a spatial protection available to threatened or endangered vertebrates, even if they interbreed when mature.

157. *Compare* 16 U.S.C. § 1533(a)(1)(A)–(E) (providing five factors for listing), *with* 50 C.F.R. § 424.11(a) ("[A]ny species or taxonomic group of species (e.g., genus, subgenus) . . . is eligible for listing . . . .").

158. 16 U.S.C. § 1532(16).

159. *See* Peters, *supra* note 156.

160. Bosselman, *supra* note 121, at 407.

Under statutory and regulatory guidelines, FWS and NOAA are required to utilize the "best available" scientific and commercial data to determine threatened, endangered, or taxonomic standing.[161] However, "best available scientific information" is left undefined, and is therefore open to interpretation—and potentially abuse.[162] In addition, uncertainty plagues listing decisions.[163] Taxonomists disagree about what constitutes a species,[164] and such disagreement or uncertainty negatively affects the listing of a species. Some liken the listing process to forcing FWS and NOAA into a "'science charade,' in which they must pretend to make non-scientific decisions entirely on the basis of science."[165] In the case of hybrid corals, rather than allowing uncertainty to act as an obstacle to listing, a conservation-minded agency should instead consider uncertainty in the context of other "esthetic, ecological, educational, historical, recreational, and scientific value[s]."[166]

Best available science did not help the *Acropora prolifera*. In 2006, NOAA and NMFS relied on taxonomic evidence to determine that *Acropora prolifera* was a hybrid, and therefore "[did] not meet the biological definition of species."[167] The agencies arrived upon *Acropora prolifera*'s hybrid status

161. 16 U.S.C. § 1533(b)(1)(A) (stating that listing determinations should be made on "the best scientific and commercial data available"); 50 C.F.R. § 424.11(b) (stating that listing should be determined "on the basis of the best available scientific and commercial information regarding a species' status").

162. *See, e.g.*, Holly Doremus, *Listing Decisions Under the Endangered Species Act: Why Better Science Isn't Always Better Policy*, 75 WASH. U. L.Q. 1029, 1032–36 (1997) (describing critiques of the "science" involved in listing species under the ESA and challenging "the assumption that better science alone can resolve the problems plaguing the ESA").

163. *Id*. at 1035–36 ("Because so little is known about so many disappearing species, the best available scientific evidence is often highly uncertain. Instead of pretending that uncertainty can be avoided, we must learn how best to factor it into decisions."); *see also* Oliver Frey, *When Science and the Statute Don't Provide an Answer: Hybrid Species and the ESA*, 26 DUKE ENVTL. L. & POL'Y F. 181, 181 (2015) ("The best scientific and commercial data available often reflect a series of studies that inherently contain assumptions, rates of error, and extrapolations, among other uncertainties.").

164. *See, e.g.*, Kevin D. Hill, *The Endangered Species Act: What do We Mean By Species?*, 20 B.C. ENVTL. AFF. L. REV. 239, 247–50, 252 n.99 (1993) (providing an overview of the historical progression of taxonomy from Aristotle to Ernst Mayr, with Mayr's definition requiring reproductive isolation, or the inability to interbreed with other species, and noting "three rival schools in modern taxonomy"). Hill highlights the hybrid dilemma under the ESA, noting that the ability to create fertile hybrids does not necessarily mean that two organisms are of the same species. *See id.* at 251. The fluidity of hybrids highlights that speciation is not static, and that "modern taxonomy is a dynamic biological science." *Id.* at 252 (footnote omitted).

165. Doremus, *supra* note 162, at 1035 (footnote omitted).

166. 16 U.S.C. § 1531(a)(3) (2018); *see also* Doremus, *supra* note 162, at 1131–32 (discussing the ill fit of category-focused taxonomy with the broader goal of protecting biodiversity). To counteract the "science charade," Doremus recommends a possible revision to the definition of "species": "includ[ing] any recognized taxonomic species, and any other identifiable group of fish or wildlife or plants which provides esthetic, ecological, educational, genetic, historical, recreational, scientific or other value significantly distinct from, or substantially additional to, that provided by other identifiable groups." *Id.* at 1137.

167. Final Listing Determinations for Elkhorn Coral and Staghorn Coral, 71 Fed. Reg. 26,852, 26,854 (May 9, 2006).

because of three data points: the coral displays a wide range of morphologies, or physical forms; all sampled coral individuals were F1 hybrids of *Acropora palmata* and *Acropora cervicornis*; and the coral did not produce successful offspring via sexual reproduction in a laboratory setting.[168] The agencies noted that although other *Acropora* species can reproduce sexually and asexually, *Acropora prolifera* "is not able to reproduce by both modes."[169] The agencies concluded that "the best available science shows it is a first generation hybrid and not a species."[170] Notably, the agency rejected listings based solely on ecological functions.[171] Therefore, *Acropora prolifera* was, and is, unlistable under the ESA.[172]

The agency deliberations reflect the fierce debate surrounding hybrids, with opponents arguing that hybrids disrupt ecosystem balance and imperil parental and other non-hybrid species, while proponents point to hybrids as an evolutionary step forward.[173] The case of the *Ambystoma californiense* (California tiger salamander) illustrates arguments against the protection of hybrids, including how hybridization threatens certain species. FWS listed the tiger salamander as threatened in 2004, citing threats of habitat loss and degradation, predation, inadequacy of existing protections, and "hybridization with non-native tiger salamanders."[174] The agency estimated that hybridized salamanders inhabited approximately 24 percent of protected salamander habitat, or that the salamanders in those habitats were threatened by hybridization.[175] FWS deemed hybridization of the native salamanders with non-native individuals a threat to the species because: hybridization may be the result of human interference through habitat destruction and introduction of non-native salamanders; hybridization has resulted in the extinction of other animal and plant taxa; and overall concerns of genetic contamination.[176] The agency wasn't alone in declaring hybridization a threat to the California tiger salamander: a district court affirmed the listing, stating that "hybridization poses a serious threat to Central California tiger salamanders."[177]

Despite arguments casting hybridization as harmful to a species, FWS itself acknowledged "[n]atural hybridization has only recently been recognized as an

168. *Id.*
169. *Id.*
170. *Id.*
171. *Id.*
172. *See id.*
173. *See* Holly Doremus, *The Endangered Species Act: Static Law Meets Dynamic World*, 32 WASH. U. J.L. & POL'Y 175, 222 (2010).
174. Determination of Threatened Status for the California Tiger Salamander, 69 Fed. Reg. 47,211, 47,219 (Aug. 4, 2004).
175. *Id.* at 47,231.
176. *Id.* at 47,238–39 (citations omitted).
177. Home Builders Ass'n of N. Cal. v. U.S. Fish & Wildlife Serv., 529 F. Supp. 2d 1110, 1118 (N.D. Cal. 2007), *aff'd*, 321 F. App'x 704 (9th Cir. 2009) (mem.).

important evolutionary mechanism for the origin of new species of animals."[178] For corals, which hybridize frequently and for which there is fossil evidence of hybrids including *Acropora prolifera* that are hundreds of thousands of years old, hybridization should be viewed as an important evolutionary mechanism.[179] *Acropora prolifera* do not produce hybridization threats like those imposed upon the California tiger salamander by hybridized salamanders. The hybrid is a F1 hybrid of two native parent species, not the product of human introduction of a non-native species. Thus, genetic contamination with a non-native species is not at issue. There is evidence of coexistence between the hybrid and its parents for hundreds of thousands of years, indicating that the hybrid has not resulted in the extinction of either parent. For corals, the hybrid-versus-species distinction is arbitrary and acts as an obstacle to protecting future coral reefs. The failure to list *Acropora prolifera* exemplifies a broader issue in listing: everything hinges on the rigid definition of a species. Agencies strongly weigh taxonomy when listing, but may undervalue an individual organism's broader conservation and ecosystem benefits, such as the potential resiliency characteristics of a hybrid coral.

2. The National Marine Sanctuaries Act and the Marine Protection, Research, and Sanctuaries Act

Another federal tool for protecting coral reefs is the National Marine Sanctuaries Act (NMSA). The National Marine Sanctuaries Act is an outgrowth of Title III of the Marine Protection, Research, and Sanctuaries Act (MPRSA).[180] The MPRSA is a geographic protection, in that it establishes specific marine protected areas. Thus, MPRSA is ill-suited for protecting *Acropora prolifera* along Government Cut, where it is unlikely that a marine sanctuary would be approved. The threats facing coral reefs are severe and unbounded; therefore, a nuanced tool that protects individuals beyond a certain location is necessary for robust resilience. Although marine protected areas such as sanctuaries are incredibly important in protecting biodiversity within their boundaries, for individual organisms colonizing urban areas, a nimble species-specific protection is needed.

178. Reconsidered Finding for an Amended Petition To List the Westslope Cutthroat Trout as Threatened Throughout Its Range, 68 Fed. Reg. 46,989, 46,991–92 (Aug. 7, 2003) (codified at 50 C.F.R. pt. 17) (declining to list the Westslope cutthroat trout as threatened or endangered, and articulating a case-by-case basis for evaluating the status of species "where introgressive hybridization may have occurred" and noting that "the issue of 'hybrids' is more properly a biological issue than a legal one"); *see also* Determination of Threatened Status for the California Tiger Salamander, 69 Fed. Reg. at 47,238 ("Natural hybridization can be an important component of evolutionary processes.").

179. Precht et al., *supra* note 110, at 46 (dating coral samples including accumulations of *Acropora prolifera* to 134 and 119 kiloanni).

180. *See* Davidson, *supra* note 77, at 510–11.

MPRSA was signed one hundred years after the creation of the National Park System.[181] Title III of MPRSA created the ability to designate national marine sanctuaries for the protection of oceanic parks.[182] The century-long delay between the creation of terrestrial parks and oceanic protected areas highlights one of the difficulties of oceanic legislating: what's under the surface, and out of sight, is out of mind. As originally enacted, Title III authorized the Secretary of Commerce to designate marine sanctuaries for "their conservation, recreational, ecological, or esthetic values."[183] Notably, the governor of the sanctuary state could reject the designation if in territorial waters.[184]

Title III of MPRSA was overhauled and rebranded as the National Marine Sanctuaries Act in 1992.[185] NMSA similarly provides that the Secretary of Commerce may designate an area of marine environment as a national marine sanctuary if the area is of "special national significance."[186] To date, thirteen national marine sanctuaries and one marine national monument have been designated, of which five are home to coral reefs, including the Florida Keys National Marine Sanctuary.[187] Once designated, criminal and civil penalties may be enforced against anyone who violates the NMSA, for example, by running a vessel aground in a national marine sanctuary.[188] Each sanctuary has a specific management plan, which includes fine-scale zoning that designates specific regions within the sanctuary with different protections based on local management priorities.[189] Although at first glance marine sanctuaries appear to be powerful tools, their strict geographical limits means their use is limited. For example, although close to PortMiami and Government Cut, where some

181. *See* Pub. L. No. 92-532, 86 Stat. 1052 (1972) (codified as amended in scattered sections of 16 U.S.C. and 33 U.S.C.); *Brief History of the National Parks*, LIBR. CONGRESS, https://www.loc.gov/collections/national-parks-maps/articles-and-essays/brief-history-of-the-national-parks/ [https://perma.cc/L8NA-RXGL].

182. *See* 16 U.S.C. § 1431 (2018); Office of Nat'l Marine Sanctuaries, *Legislative History of the National Marine Sanctuaries Act*, NAT'L OCEANIC & ATMOSPHERIC ADMIN., https://sanctuaries.noaa.gov/about/legislation/leg_history.html [https://perma.cc/6Z2Q-JUBM].

183. MPRSA § 302(a), 86 Stat. at 1061.

184. *Id.* § 302(b), 86 Stat. at 1061–62.

185. Oceans Act of 1992, Pub. L. No. 102-587, 106 Stat. 5039.

186. 16 U.S.C. § 1433(a)(2) (2018).

187. *See* Davidson, *supra* note 77, at 512–13; *see also* Florida Keys National Marine Sanctuary and Protection Act, Pub. L. No. 101-605, 104 Stat. 3089 (1990) (codified at 16 U.S.C. § 1433 note); *National Marine Sanctuaries Frequently Asked Questions*, NAT'L OCEANIC & ATMOSPHERIC ADMIN., https://sanctuaries.noaa.gov/about/faqs/ [https://perma.cc/YU5Y-DLV7] (confirming that, at the time of writing, there are thirteen national marine sanctuaries and the Papahānaumokuākea Marine National Monument).

188. *See* 16 U.S.C. § 1437 (2000).

189. *See generally* National Marine Sanctuary Program, National Ocean Service, Nat'l Oceanic & Atmospheric Admin., Florida Keys National Marine Sanctuary Revised Management Plan (2007), https://nmsfloridakeys.blob.core.windows.net/floridakeys-prod/media/archive/mgmtplans/2007_man_plan.pdf [https://perma.cc/2NKC-ELPH] (detailing science management, monitoring, enforcement, resource protection, and marine zoning in the Florida Keys National Marine Sanctuary).

Acropora prolifera coral colonies are located, the Florida Keys National Marine Sanctuary boundary falls to the south, and at the border, protection ends.[190]

Marine sanctuaries' protections end at the sanctuaries' borders. Certainly, within a sanctuary and other marine protected areas, coral reefs benefit from conservation measures, and the increased genetic diversity of reefs within such areas can produce benefits outside such areas' borders. In the Florida Keys National Marine Sanctuary, designation of certain "areas to be avoided" significantly decreased the number of ship groundings on coral reefs.[191] But for the corals beyond protected spaces, and for the smaller coral populations and individual colonies that grow in busy commercial areas like PortMiami, a marine sanctuary offers little protection against destruction or take if such a coral species is unprotected. It is unlikely a no-motor zone could be established in an area with a commercial port and robust recreation.[192] To better protect a hybrid species, a species-specific legal tool is needed. Such a tool would not supplement marine protected areas, but rather complement such areas to extend coral protections outside strict spatial bounds.

3. The Coral Reef Task Force, the Coral Reef Conservation Act of 2000, and the Antiquities Act

Coral reefs have been the subject of specific, tailored executive protections in the past couple decades. However, these additional federal protections for corals have proven less protective than the ESA. The U.S. Coral Reef Task Force and the Antiquities Act are examples of executive action to protect coral reefs and create monuments which function as marine protected areas.

In 2000, President Bill Clinton created the U.S. Coral Reef Task Force through Executive Order No. 13,089, in response to congressional stagnation on protecting coral reefs.[193] The order required federal agencies to ensure that "any actions they authorize, fund, or carry out will not degrade the conditions of [reefs]."[194] The Task Force was charged with developing and implementing research strategies to identify the major "causes and consequences of degradation of coral reef ecosystems."[195] However, neither the Executive Order nor the Task Force's resulting plan were directly enforceable.[196] The Coral Reef Conservation Act of 2000 (CRCA) was passed in support of the Coral Reef Task

190. National Marine Sanctuary Program, *supra* note 189, at 5.

191. *Id.* at 9.

192. *See, e.g.*, *id.* at 145 (describing multiple zoning accomplishments in the Florida Keys National Marine Sanctuary such as no-motor zones and a rule to protect living corals from anchor damage by freighters).

193. *See* Robin Kundis Craig, *The Coral Reef Task Force: Protecting the Environment Through Executive Order*, 30 ENVTL. L. REP. 10,343, 10,343 (2000).

194. Exec. Order. No. 13,089, 63 Fed. Reg. 32,701, 32,701 (June 11, 1998).

195. *See id.* at 32,702.

196. *See* Craig, *supra* note 193, at 10,343.

Force and gave NOAA primary authority over coral conservation.[197] Unfortunately, CRCA has been ineffective in protecting coral reefs, in part because of tensions between conservation and fishing goals.[198] NOAA notes that only 3 percent of U.S. waters are protected as no-take reserves, which encompasses removal of many resources, including corals, fish, and shells.[199]

Presidents Clinton and George W. Bush used the Antiquities Act of 1906 to create national monuments protecting coral reefs.[200] While the Antiquities Act had previously been used largely to preserve national monuments centered around "curiosities," President Clinton used the act to preserve "large ecosystems that are distinct and of significance," following in the footsteps of executives who had used the act to protect public lands like the Grand Canyon and Joshua Tree.[201] Notably, designation as a national monument under the Antiquities Act may allow for quicker protection than designation as a marine sanctuary under the NMSA, because the President can designate a national monument through unilateral executive decision.[202] As of writing, there are only four national monuments in Florida.[203] Given the specific location of *Acropora prolifera*, and its proliferation around economically valuable areas like PortMiami, a monument designation is unlikely. Monument designation may be an effective protection where unique geographically contiguous resources occur in areas where a president has political capital to designate. Unfortunately, this does not meet the protection needs of *Acropora prolifera* thriving in and around PortMiami, where an executive may be hard-pressed to muster such capital for large-scale conservation at the expense of a busy port. Such patches of coral reefs exist interspersed with areas of intense and diverse human use, and therefore a species-specific tool provides a more exacting protection.

Additionally, monument designation is not a definite path to long-term protection, either on land or in the oceans, because administration changes can result in changes to monuments. President Donald J. Trump reduced the Bears Ears National Monument and Grand Staircase-Escalante National Monument in the first year of his administration.[204] Both Bears Ears and Grand Staircase-

197. 16 U.S.C. §§ 6401–6409 (2018).

198. *See* Harrison, *supra* note 127, at 194.

199. *See id*.

200. *See* Davidson, *supra* note 77, at 514–15; Proclamation No. 8335, 74 Fed. Reg. 1555 (Jan. 6, 2009).

201. *See* Davidson, *supra* note 77, at 515 & n.137 (citations omitted)

202. *See id.* at 515–16; *see also* Jennifer C. White, *Conserving the United States' Coral Reefs: National Monument Designation to Afford Greater Protection for Coral Reefs in Four National Marine Sanctuaries*, 32 WM. & MARY ENVTL. L. & POL'Y REV. 901, 928 (2008) (concluding that the Antiquities Act "may afford greater protection to the four National Marine Sanctuaries with coral reefs in a number of ways").

203. *See* Archaeology Program, *Antiquities Act: Monuments List*, NAT'L PARK SERV., https://www.nps.gov/archeology/sites/antiquities/monumentslist.htm [https://perma.cc/R8TE-F7RS].

204. *See* Julie Turkewitz, *Trump Slashes Size of Bears Ears and Grand Staircase Monuments*, N.Y. TIMES (Dec. 4, 2017), https://www.nytimes.com/2017/12/04/us/trump-bears-ears.html [https://perma.cc/C2NG-L366].

Escalante were designated as national monuments by President Barack Obama.[205] In addition, monuments are often the subject of legal challenges. The Northeast Canyons and Seamounts Marine National Monument in the Atlantic, also designated by President Obama, was the subject of a recent legal challenge.[206] Although a U.S. District Court rejected the plaintiffs' arguments that the Antiquities Act did not allow for the creation of such a marine monument, it is yet to be seen if future monuments will survive additional scrutiny.

B. Existing Protections in Florida

Florida has a suite of laws and regulations covering coral reefs. However, these laws fail to protect hybrids and "are generally ineffective, inefficient, or both."[207] This is in part due to gaps in jurisdiction between state agencies, and a strong public trust doctrine protecting the right to fish over conservation efforts.[208]

As a result, hybrid corals such as *Acropora prolifera* are insufficiently protected under the Florida legal regime. Additionally, given the overlapping jurisdiction of both federal and state agencies in an area like PortMiami and Government Cut, protection under state law alone would still be insufficient. However, an exploration of Florida law is useful for understanding the legal landscape that has so far left hybrids unprotected. Similarly to federal law, the Florida legal regime has an endangered species act, general coral-minded protection acts, and geographically specific legal protections. What follows is a discussion of Florida's Endangered Species Act, coral-focused statutes like the Florida Coral Reef Protection Act, and spatial protections like the John Pennekamp State Park Protection Act.

1. Florida's Endangered Species Act

Florida has its own ESA: the Florida Endangered and Threatened Species Act (ETSA), enacted by the legislature in recognition of the "wide diversity of fish and wildlife" within the state.[209] As noted by the text of the statute, the Sunshine State is home to "more endangered and threatened species than any other continental state."[210] But greater biodiversity does not equate to increased legal protections.

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205. *Id.*

206. *See generally* Mass. Lobstermen's Ass'n v. Ross, 349 F. Supp. 3d 48, 51, 58–60 (D.D.C. 2018) (granting the government's motion to dismiss commercial fishing associations' challenge of President Obama's designation of Northeast Canyons and Seamounts Marine National Monument, holding that the Antiquities Act was not repealed by implication by the National Marine Sanctuaries Act), *aff'd*, 945 F.3d 535 (2019).

207. *See* Harrison, *supra* note 127, at 200.

208. *See id.*

209. FLA. STAT. § 379.2291(2) (2019).

210. *See id.*

The substantive difference between Florida's ETSA and the national ESA is that the ETSA prohibits taking of state-listed threatened species, while the ESA does not automatically extend such protections.[211] However, the ETSA currently only lists seven corals, all of which are listed under the ESA as threatened.[212] Notably, the hybrid *Acropora prolifera* is not included on Florida's list.

Listing species as either threatened or endangered under the ETSA would be one way to protect *Acropora prolifera* in Florida. However, Florida's listing process for corals may be more burdensome than the ESA's listing process for two reasons: listing petitions are only accepted during the first half of the year;[213] and biological standards are based on a 1990 system developed "[t]o prioritize Florida's *vertebrate* fauna."[214] First, petitions for listing a species under ETSA can only be submitted between January 1 and June 30, to allow for evaluation by Florida's Fish and Wildlife Commission (FWC), which administers ETSA.[215] Under the ESA, anyone can petition to list a species, at any time.[216] This provides the public twice as much time annually to petition for listing. Second, FWC requests scientific and commercial listing data based on a framework developed for vertebrate conservation.[217] A vertebrate-centered process for listing does not necessarily disadvantage invertebrates. However, certain aspects of the vertebrate-centered process do, such as relying on "only those taxa that could be easily identified in the field using morphological characteristics."[218] For corals species that appear physiologically similar and grow next to one another, a listing based on form (morphological) and location (spatial) is not ideal.

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211. *See* Harrison, *supra* note 127, at 200. FWS adopted a regulation automatically extending take prohibitions under Section 9 of the ESA to threatened wildlife, applicable unless "a species-specific rule" is promulgated or an employee or agent of FWS or NMFS takes a species "acting in the course of official duties." 50 C.F.R. § 17.31(a)–(c) (2019). NOAA and NMFS, which list corals, did not adopt such a regulation, and instead issue species-specific regulations extending take prohibitions to threatened species. *See, e.g.*, 50 C.F.R. § 223.203(a) (extending prohibitions related to take to a salmon and steelhead with an intact adipose in specific populations); 50 C.F.R. § 223.210(a) (extending prohibitions related to take to a distinct population segment of threatened green sturgeon).

212. *See* FLA. FISH & WILDLIFE CONSERVATION COMM., FLORIDA'S ENDANGERED AND THREATENED SPECIES 8 (2018), https://myfwc.com/media/1945/threatend-endangered-species.pdf [https://perma.cc/PLX7-HNGE].

213. FLA. ADMIN. CODE ANN. r. 68A-27.0012(2)(b)(1) (2017).

214. Brian A. Millsap et al., *Setting Priorities for the Conservation of Fish and Wildlife Species in Florida*, 111 WILDLIFE MONOGRAPHS 1, 6 (1990); *see also* FLA. ADMIN. CODE ANN. r. 68A-27.0012(2)(b)(2)(c) (providing that evaluations for listing a species must accord with the priorities described in the Millsap et al. article).

215. FLA. ADMIN. CODE ANN. r. 68A-27.0012(2)(b)(1).

216. *See* 16 U.S.C. § 1533(b)(3)(A) (2018).

217. FLA. ADMIN. CODE ANN. r. 68A-27.0012(2)(b)(2)(c); *see also* Millsap et al., *supra* note 214.

218. *See* Millsap, *supra* note 214, at 9.

Finally, any protections under the ETSA beyond what the federal ESA allows might be deemed preempted in the face of federal action.[219] Under the ESA, "[s]tate law or regulation which is intended to conserve migratory, resident, or introduced fish or wildlife" is expressly *not voided*.[220] Likewise, state laws may be *more* restrictive regarding take of endangered or threatened species.[221] However, a protection under the ETSA for a hybrid coral may fall under a preemption analysis, whether express, implicit, or conflict preemption. A court might deem a hybrid coral to not be "resident" wildlife, and view additional protection to be outside what is expressly permitted by the ESA.

As it currently stands, the ETSA does not offer any more protection than its federal peer law for currently listed corals, and it is unclear whether Florida's listing process would be more accepting of a hybrid coral.

2. The Florida Coral Reef Protection Act, the Florida Coastal Management Act, and Areas of Particular Concern

In addition to the ETSA, Florida law purports to protect corals under the Florida Coral Reef Protection Act (FCRPA). But the act only protects reefs from "vessel groundings and anchoring-related injuries."[222] FCRPA provides for recovery of damages from such actions.[223] While fiscal penalties may encourage responsible boating, they are difficult to enforce and thus insufficient for protecting coral reefs.

The Florida legislature adopted the Florida Coastal Management Act (FCMA) in 1978,[224] under the structure set out by the U.S. Coastal Zone Management Act (CZMA).[225] The FCMA codified the Florida Coastal Management Program (FCMP), and was approved by the Secretary of NOAA in 1981.[226] Under the FCMP, as under the CZMA, "areas of particular concern" warrant preservation and special attention.[227] Such areas include coral and other

219. *See* 16 U.S.C. § 1535(f) (providing a conflict of laws section between the ESA and state law); *see also* Robin Kundis Craig, *Does the Endangered Species Act Preempt State Water Law?*, 62 KAN. L. REV. 851, 877–80 (2014) (providing an overview of federal preemption under the Supremacy Clause of the U.S. Constitution for the purpose of analyzing state water laws, and stating that "Courts have concluded that this section constitutes an express declaration of congressional intent to have the ESA preempt state law"); Amanda Pearson, Comment, Viva! International v. Adidas*: Preemption in the Realm of Endangered Species Protection*, 31 ENVIRONS: ENVTL. L. & POL'Y J. 297, 310 (2008) (detailing preemption under the ESA and theorizing that a California ban on alligator product imports might fail under a preemption challenge).

220. 16 U.S.C. § 1535(f).

221. *Id.*

222. *See* FLA. STAT. § 403.93345(4) (2019).

223. *See id.* § 403.93345(6).

224. FLA. STAT. § 380.20 (2019).

225. 16 U.S.C. § 1451.

226. FLA. DEP'T OF ENVTL. PROT., FLORIDA COASTAL MANAGEMENT PROGRAM GUIDE 6 (2017), https://floridadep.gov/sites/default/files/FCMP-Program-Guide-2017_0.pdf [https://perma.cc/65Q3-WNTT].

227. *See id.* at 23.

reefs.[228] The Florida Keys is one of five areas designated as an "Area of Critical State Concern."[229] This area largely overlaps with the boundaries of the Florida Keys National Marine Sanctuary. Neither overlap with PortMiami.

In addition, Florida's Department of Environmental Protection designates aquatic preserve systems in or near areas of increasing urbanization.[230] These preserves "provide an essential natural habitat for various living resources."[231] This can translate into fishing and boating regulations to decrease impact to natural resources, visitation limits, or limits on types of permitted activities. Certain aquatic preserves overlap with coral areas in the state, including the Biscayne Bay–Cape Florida to Monroe County Line Aquatic Preserve, Lignumvitae Key, and Coupon Bight in Southeast Florida.[232] Similar to federal spatial protections, Florida's aquatic preserves are likewise insufficient for protecting corals outside of the boundaries of the aquatic preserves, as evidenced by the steep declines in coral within and outside their boundaries.[233]

3. Regional Protection Acts, such as the John Pennekamp State Park Protection Act

In addition to aquatic preserves, Florida law also specifically protects corals from take or damage in designated regional areas. While such protections are useful in certain areas, they are insufficient to protect corals that grow on the wrong side of a boundary, such as on the side of a seawall.

One example of a regional protection act is the John Pennekamp State Park Protection Act. It is statutorily prohibited for "any person, firm, or corporation" to take or damage coral in the John Pennekamp Coral Reef State Park.[234] Such action is a second-degree misdemeanor.[235] When enforcement works, the Park Protection Act suffices to protect the corals within the park's boundaries. However, these marine protection areas—such as aquatic preserves, national monuments, and marine sanctuaries—are insufficient to protect corals in areas outside park borders.

III.
A PROPOSAL TO CREATE SPECIES-LEVEL PROTECTIONS FOR HYBRID CORALS

Given the scale and force of the threats facing coral reefs, from climate change to more localized human activities such as dredging and recreational and commercial boat traffic, hybrid corals with promising resiliency characteristics

228. *See id.*
229. *See id.* at 25.
230. *See id.* at 27.
231. *See id.*
232. *See id.* at 27–30.
233. DAVIS, *supra* note 91, at 462.
234. FLA. STAT. § 258.083(2) (2019); *see also id.* § 253.90 (covering other submerged lands and state waters in Southeast Florida).
235. *See id.* § 258.083(3).

should be protected. Although it is impossible to predict the species composition of future coral reefs, to forego protecting a coral species resilient to certain stressors such as increasing ocean temperatures would be to foreclose a way forward for coral reefs. "[W]ho but a fool would"[236] limit the viability of coral reefs, when there are current legal mechanisms in place which could be expanded to protect resilient hybrid corals?

Instead of excluding hybrid corals from protection under the ESA, implementing agencies should take a more holistic approach in considering the importance of, and threats facing, hybrid corals. There are several possible solutions. First, NOAA and NMFS could adopt a regulation regarding the listing of hybrid corals, and structure the listing consideration of hybrid corals around such species' "esthetic, *ecological*, educational, historical, recreational, and *scientific* value[s]" as permitted by the text of the ESA.[237] Such a regulation would emphasize the ecological and scientific value of hybrid corals to coral reef resiliency in the face of global and local threats. Alternatively, instead of adopting a regulation, NOAA and NMFS could simply reevaluate the existing body of "best available scientific and commercial information" regarding *Acropora prolifera*.[238] In the fifteen years since the agencies declined to list *Acropora prolifera*, a volume of research has become available revealing potentially listable qualities of the hybrid coral.[239] Finally, other protections could be created, such as geographic protections, programmatic cultivation in certain protected areas, or bans on practices that harm corals.

Broadly, hybrid corals would benefit from both species-specific protections under legal mechanisms such as the ESA, and geographic protections such as a marine sanctuary or monument designation. Existing legal structures could better protect hybrid corals with a species-specific tool under the ESA, such as developing a hybrid coral listing policy, listing *Acropora prolifera* under the existing ESA structure, or creating geographic protections for certain coral reefs with hybrid coral individuals. But given the location of some *Acropora prolifera* in the highly-trafficked PortMiami, a species-level protection is better suited to South Florida's urban areas, where a marine protected area is infeasible. It is simply unlikely that a busy commercial port will be shut or slowed down and converted into a monument, or that traffic in and out of a port will be significantly

236. Leopold, *supra* note 1.

237. *See* 16 U.S.C. § 1531(a)(3) (2018) (emphasis added).

238. 50 C.F.R. § 424.11(b) (2019).

239. *See, e.g.*, NAS RESEARCH REVIEW, *supra* note 7, at 56–57; Fogarty, *supra* note 113, at 155; Adele Irwin et al., Age and Intraspecific Diversity of Resilient *Acropora* Communities in Belize, 36 J. INT'L CORAL REEF SOC'Y 1111, 1118 (2017) (concluding that Belize populations of Acropora either have low genotypic diversity and are therefore susceptible to environmental threats, or the populations have "veteran genets" capable of survival and recovery); Precht et al., *supra* note 110, at 40.

reduced on account of a single species.[240] While a total solution to the ESA's hybrid dilemma[241] is beyond the scope of this Note, protections for hybrids under laws such as the ESA would further the overall goal of sustaining local reefs in certain regions imperiled by climate change.

A. The Need for a Hybrid Species Policy Under the ESA

The path to an ESA hybrid policy is already littered with stalled attempts and vigorous critiques. But such a history should not dissuade agencies from attempting to adopt a regulatory policy today. Rather, a review of past attempts at a hybrid policy is helpful in proposing a coral-specific hybrid policy today.

An ESA hybrid policy was proposed in 1996 and published in the Federal Register, but has not been accepted or rejected by the FWS or NMFS.[242] The proposed policy described three possible categories of hybrids for inclusion under the ESA: first, intercross progeny, described as progeny resulting from a cross between an individual in a listed taxonomic group, such as a species, and a taxon that is not listed; second, species of hybrid origin, i.e., species originated from the intercrossing of two or more other species, but that are stable and self-sustaining; and third, intercross progeny produced in captivity.[243] *Acropora prolifera* could be included in the second category, in that the coral species originated from two other species and is stable and self-sustaining.

The proposal intended to provide listing agencies "with the necessary flexibility to deal with diverse intercross situations to allow for . . . protection and conservation.[244] Additional ancillary benefits flowed from the proposal, including that funds would be freed for conservation of threatened and endangered species instead of being devoted to complex genetic analysis.[245] Although promising, the policy was never accepted, and agencies now consider hybrids on an ad hoc basis.[246] Unfortunately, a case-by-case decision-making

240. However, large-scale federal projects have been halted pre-completion due to a listed species. *See, e.g.*, Tenn. Valley Auth. v. Hill, 437 U.S. 153, 194 (1978) (affirming reversal and remand of denial of a permanent injunction, halting the construction of a near-complete dam). PortMiami is distinguishable from the dam at issue in *Tennessee Valley Authority v. Hill*, because the port has long been active.

241. *See* Frey, *supra* note 163, 182–83, 192 (proposing a solution to the dilemma hybrid species pose to the ESA whereby agencies look to the purpose of the ESA when deciding whether or not to list hybrids and consider threats of listing the hybrid to the conservation of the hybrid's parent species).

242. *See* Proposed Rule on the Treatment of Intercrosses and Intercross Progeny (the Issue of "Hybridization"), 61 Fed. Reg. 4710, 4710 (Feb. 7, 1996) (codified at 50 C.F.R. § 424); Robert K. Wayne & H. Bradley Shaffer, *Hybridization and Endangered Species Protection in the Molecular Era*, 25 MOLECULAR ECOLOGY 2680, 2681 (2016); *see also* Doremus, *supra* note 162, at 1110 (noting that FWS's proposed hybrid policy "marks a welcome retreat from . . . excessive emphasis on genetic distinctness").

243. Proposed Rule on the Treatment of Intercrosses and Intercross Progeny (the Issue of "Hybridization"), 61 Fed. Reg. at 4711.

244. *Id.* at 4712.

245. *See id*.

246. *See* Doremus, *supra* note 173, at 189.

scheme lacks the reliability that a formal policy would provide.[247] As indicated by the listing decision for *Acropora prolifera*, the hybrid issue persists.

The hybrid dilemma is not limited to coral species, and the promulgation of a coral-specific hybrid regulation may lead to broader hybrid policies. The broad inclusion of many different hybrid species under the ESA would likely raise alarm, given concerns about competition between hybrids and parent species, and the muddling of genetic integrity. The California tiger salamander and hatchery salmon are examples of the hybrid problem, with vocal proponents on both sides.[248]

The hybrid nature of the Florida panther,[249] the red wolf, and the Yellowstone National Park grey wolf highlights tensions between the desire to conserve and protect hallmark "species" and genetic data that reveal these very species are mixes of others.[250] The Florida panther provides a useful parallel to corals, as an example of when hybridization was embraced to save an imperiled species. When the Everglades Florida panther population faced decreasing genetic health, eight Texas cougars were released in South Florida in 1995 to restore genetic variability as part of the larger "South Florida Multi-Species Recovery Plan."[251] The plan was drafted by FWS to restore native plant and animal species, and utilized tools such as land acquisition, conservation efforts, and the introduction of genetically diverse individuals.[252] Although the problems facing coral reefs differ from those facing the panther—coral reefs are threatened by global warming and human activity, while the panther suffered from inbreeding as well as human stressors[253]—the solution could be the same: hybridization.

Critics of hybrid species argue that hybrids muddle the genetic integrity of species populations, and even result in genetic extinction.[254] Likewise, critics of a policy for hybrid corals under the ESA might worry that such a policy would be expanded to permit protection of other hybrids. But such opponents overlook the potential ecosystem benefits of hybrid corals like *Acropora prolifera*. If other hybrids offer such benefits to imperiled ecosystems, protection may be

247. Frey, *supra* note 163, at 189.

248. Wayne & Shaffer, *supra* note 242, at 2687.

249. *See* Doremus, *supra* note 162, at 1112 (concluding that the "welcome retreat from genetic fetishism in the proposed hybrid policy seems to be driven by political pressure to list the Florida panther").

250. *See* Andrew E. Wetzler, *The Ethical Underpinnings of the Endangered Species Act*, 13 VA. ENVTL. L.J. 145, 147–48 (1993).

251. Stacy A. Barker, Comment, *Use of the South Florida Multi-Species Recovery Plan to Restore Threatened and Endangered Species*, 9 DICK. J. ENVTL. L. & POL'Y 507, 525–26 (2000).

252. *See id.* at 512–13, 525.

253. *See* Andrew Long, *Defining the Nature Protected by the Endangered Species Act: Lessons from Hatchery Salmon*, 15 N.Y.U. ENVTL. L.J. 420, 475 (2007) (noting that hybridization to increase genetic diversity is the only way to save the Florida panther from extinction)

254. Bosselman, *supra* note 121, at 455 (describing the genetic extinction of a duck species after hybridization with introduced mallards); *see also supra* Part II.A.1 (discussing arguments against protection and utility of hybrids).

warranted. Proponents of hybrid protection note that hybridization can enhance species fitness.[255] In the case of *Acropora* corals, hybrids could expand the parent species' range by colonizing previously adverse environments and provide the opportunity for "ecological persistence" over time.[256]

As proposed in 1996, agencies should adopt a hybrid listing policy under the ESA. However, such regulation should be tailored specifically for hybrid corals. Instead of the wholesale inclusion of hybrids under the ESA, a narrow regulation permitting the listing of hybrid corals based on their risk of extinction and ecological value may be more palatable for critics of hybrid species. Such a regulation would not relax taxonomic requirements for an individual species, but rather would more heavily weight the ecological and scientific value of hybrid corals in making listing determinations. Given corals' unique biology and reproductive history, corals species should not be held to a strict species frame better fit for animal species that do not reproduce in the same manner.

NOAA and NMFS, the agencies with jurisdiction over corals, should adapt the stalled 1996 policy and adopt a formal policy permitting the listing of hybrid corals such as the *Acropora prolifera* as threatened or endangered. The second category of hybrids described in the 1996 policy, stable and self-sustaining species originated from the intercrossing of two or more other species,[257] provides a good starting point. Knowledge of hybrid corals, their viability, and their potential value in resiliency to climate change has advanced considerably since 1996 (when the hybrid policy was proposed) and 2006 (when NOAA and NMFS declined to list *Acropora prolifera*).[258]

B. A Holistic Approach to Listing Coral Hybrids

There is an alternative to adopting a new coral hybrid-specific listing regulation: reconsideration of NOAA's and NMFS's decisions not to list *Acropora prolifera* under the ESA. Unlike creating a new policy, allowing an exception for a single species could be more acceptable for critics of hybrid inclusion under the ESA because of the species-limited nature of listing. Upon petition, the agencies could approve a listing decision of a hybrid coral species, noting recent research has revealed that the coral hybrid *Acropora prolifera* has the ability to reproduce. However, this case-by-case listing approach to hybrid

255. Bosselman, *supra* note 121, at 455.

256. *Id*. at 457–58 (stating "many of the hybrid corals are sterile," but noting that "[c]oral diversity appears to be enhanced by these long-lived asexual hybrids, . . . which again raises the issue of the extent to which evolutionary potential should be an important component of any definition of biodiversity"). Since Bosselman published, additional research has indicated that *Acropora prolifera* hybrids may sexually reproduce. *See, e.g.*, Carne & Baums, *supra* note 107; Fogarty Interview, *supra* note 107 (indicating the *Acropora prolifera* has been observed spawning).

257. Proposed Rule on the Treatment of Intercrosses and Intercross Progeny (the Issue of "Hybridization"), 61 Fed. Reg. 4710, 4711 (Feb. 7, 1996).

258. *See generally* NAS RESEARCH REVIEW, *supra* note 7 (discussing hybrid corals as a potential resiliency intervention).

corals would not establish the formal, reliable process for protecting hybrid corals that might prove important for protecting other similarly resilient hybrids.

In the 2006 listing decision for the elkhorn and staghorn corals, NOAA and NMFS rejected comments calling for the listing of the elkhorn-staghorn hybrid, *Acropora prolifera*.[259] NMFS noted that "*A. prolifera* is a hybrid and, therefore, not considered a species for listing."[260] The agency gave several reasons for its decision not to list *Acropora prolifera* because it is a hybrid, such as a wide range of morphologies, the fact that all sampled individuals were hybrids, and the apparent inability to sexually reproduce.[261] NMFS relied on its own agency regulations [262] directing it to apply standard taxonomic distinctions and biological expertise within the agency and scientific community.[263]

Today, NMFS could consider such reports as the National Academies' coral intervention study, which finds at least some evidence that *Acropora prolifera* can sexually reproduce. In reconsidering the listing decision, NMFS could bring a hybrid coral under the ESA's protective wing. Treatment of coral hybrids today addresses taxonomic uncertainty by distinguishing between a "good species" with a hybrid history (genetic signatures of interbreeding in its evolutionary history) and a "hybrid species," composed entirely of hybrids.[264]

In a time of rapid environmental change, when the vast majority of coral reefs are facing imminent extinction, a static system of laws that rejects natural interventions such as hybrids may further doom imperiled ecosystems. In the case of *Acropora prolifera*, a coral hybrid that may prove more environmentally viable for coral reefs in the future, "natural" hybridization should not prohibit its protection under the ESA.[265]

The current structure for listing hybrids under the ESA excludes corals such as *Acropora prolifera*, which have value as potential resilient corals of the future. This is in addition to a historic bias towards listing terrestrial and freshwater species over marine species.[266] Regardless, protection under the ESA or a similar species-specific protection is likely the best fit for hybrid corals like the *Acropora prolifera* along Fisher Island. A reconsideration of listing may appear more tolerable for critics of hybrid inclusion in the ESA, but it would only be a

259. *See* Final Listing Determinations for Elkhorn Coral and Staghorn Coral, 71 Fed. Reg. 26,852, 26,854 (May 9, 2006).

260. *Id*.

261. *See id*.

262. *See id.*; *see also* 50 C.F.R. § 424.11(a) (2019).

263. Final Listing Determinations for Elkhorn Coral and Staghorn Coral, 71 Fed. Reg. at 26,854.

264. Final Listing Determinations on Proposal To List 66 Reef-Building Coral Species and To Reclassify Elkhorn and Staghorn Corals, 79 Fed. Reg. 53,851, 53,877 (Sept. 10, 2014).

265. *See* Doremus, *supra* note 162, at 1098 ("Although grounded in the natural world, the species concept is a tool rather than a natural phenomenon. Species are not immutable entities separated from one another by clear biological or morphological lines."). Doremus's observation about the man-made category of a "species" is in contrast to that of a naturally occurring hybrid.

266. *See* Craig, *supra* note 137, at 18.

one-off fix and would not create a path to protecting other potentially resilient coral hybrids.

Unfortunately, listing under the ESA may not do much to protect hybrid corals. As seen in PortMiami, listing is not an absolute guard against harm.[267] However, listing provides a legal hook for advocacy groups to seek coral restoration and rehabilitation. Protection under the ESA arguably failed coral colonies damaged by the PortMiami 2013–2015 dredging.[268] But because staghorn corals are listed under the ESA, advocates were able to file suit and eventually reach a settlement to attempt to restore the reef.[269] *Acropora prolifera* are denied the protections afforded non-hybrids, and therefore no one can bring legal actions that could benefit these hybrids. Given the potential for reef resiliency due to hybrids like *Acropora prolifera*, and the demonstrated ability of such hybrids to survive in areas around Government Cut, the lack of protection may be a fatal mistake. *Acropora prolifera*, and its human-cultivated peers, should be valued in the same way as listed coral species.

C. Other Possible Paths to Protecting Hybrid Corals

In addition to species-specific protections under the ESA, there are other methods available to protect hybrid corals. Such options include designating marine protected areas and enacting local bans on practices harmful to coral reefs. As discussed above, geographic protections such as marine protected areas alone are insufficient to protect a hybrid coral species that grows beyond a designated area. And although local bans on certain practices such as boat traffic and regulation of coastal development and agricultural pollution are helpful, such methods should be viewed as complementary, rather than supplementary, to a species-specific protection.

Geographic protections such as national marine sanctuaries, national monuments, state aquatic preserves, and regional protection acts certainly help to protect coral reefs and colonies within area borders. Such protected areas offer fertile—and safe—sea floor for coral restoration programs, such as asexual coral propagation.[270] Coral gardening nurseries can be helpful in reef restoration, and such a practice has been used with *Acropora prolifera*.[271] Coral nurseries have proven to be successful, and coordination between conservation groups and

267. *See supra* Part I.C.A.

268. *See* Ross Cunning et al., *Extensive Coral Mortality and Critical Habitat Loss Following Dredging and Their Association with Remotely-sensed Sediment Plumes*, 145 MARINE POLLUTION BULL. 185, 186, 196 (2019) (analyzing the impacts of sedimentation on corals, with a focus on the PortMiami dredging and noting that whole colony mortality was five times higher near the dredged channel compared to nine kilometers away).

269. *See Corps Commits to Conduct New Environmental Studies Before Port Everglades Expansion Dredging Begins*, *supra* note 73.

270. *See, e.g.*, FRAGMENTS OF HOPE, http://fragmentsofhope.org/ [https://perma.cc/352M-CSCL] (providing an example of a conservation group engaged in coral gardening and coral nurseries).

271. *See* Carne & Baums, *supra* note 107 (noting the success of transplanting coral in Belize).

regulatory agencies have led to success stories in countries like Belize. In June 2018, The United Nations Educational, Scientific, and Cultural Organization (UNESCO) removed the Belize Barrier Reef Reserve System from its list of World Heritages Sites in danger.[272] In addition to providing a safe space for reef restoration activities, such protected areas limit potentially harmful activities such as boat traffic and development.

However, spatial protections are bound by hard borders, and in the marine space, where organisms can move freely with the flow of coastal waters, such protections are limited by nature. For a hybrid coral such as *Acropora prolifera*, which can grow on the side of seawalls in highly developed areas, a more exacting tool such as a species-level protection is a better fit.

For those localities which value coral reefs, municipal bans on practices that harm corals are another option for protecting vulnerable corals. In the Florida Keys, the City of Key West City Commission voted in early 2019 to ban sunscreens containing certain chemicals harmful to coral reefs.[273] But municipal action can be in tension with, and at times preempted by, state law. In June 2020, the Florida Legislature enacted a law overriding local ordinances and laws prohibiting over-the-counter sales of "proprietary drugs and cosmetics,"[274] effectively blocking Key West's sunscreen ban.[275]

Geographic protections and local and state bans on practices harmful to corals and coral reefs, although helpful, should not replace species-specific protections under the ESA. Listing under the ESA provides relatively strong legal protections for threatened and endangered organisms. In the face of escalating anthropogenic threats, such protections should be extended to corals which show promising resiliency, regardless of hybrid status.

CONCLUSION

Colin Foord, marine biologist and co-founder of Miami-based art-science collective Coral Morphologic,[276] wasn't searching for a hybrid coral when he first saw *Acropora prolifera*.[277] It was 2009, and Foord was searching for soft

272. *See* Press Release, UNESCO, Belize Barrier Reef Reserve System Removed from the List of World Heritage in Danger (June 26, 2018), https://whc.unesco.org/en/news/1838/ [https://perma.cc/E8QR-QQB3].

273. Lindsey Bever, *'We Have One Reef': Key West Bans Popular Sunscreens to Help Keep Coral Alive*, WASH. POST (Feb. 6, 2019), https://www.washingtonpost.com/climate-environment/2019/02/06/we-have-one-reef-key-west-bans-popular-sunscreens-help-keep-coral-alive/ [https://perma.cc/EF28-DXSQ].

274. FLA. STAT. ANN. § 499.002(7) (West 2020).

275. Ana Ceballos, *Florida Senate Blocks Cities like Key West from Banning Sunscreens*, MIAMI HERALD (Jan. 30, 2020), https://www.miamiherald.com/news/local/community/florida-keys/article239755248.html [https://perma.cc/Z45Z-XF98]. *But see* Haw. Rev. Stat. § 342D-21 (2019) (providing an example of a successfully adopted statewide sunscreen ban).

276. *About*, CORAL MORPHOLOGIC, http://www.morphologicstudios.com/index.php?/about/ [https://perma.cc/5RJ4-HDEK].

277. *See* Foord Interview, *supra* note 79.

corals, commonly found in a shallow coastal environment.[278] He was swimming off Government Cut when he first saw it: a bright, out-of-place *Acropora prolifera*, clinging to the side of a Fisher Island seawall.[279] And yet, more than a decade after Foord's discovery, *Acropora prolifera* is still without protection.

Hybrid corals such as *Acropora prolifera* may be a key to reef resiliency. But these corals are dangerously unprotected relative to their parent species. The current legal regime does not adequately protect hybrid corals in South Florida or across the United States. Under NOAA's current position, hybrids are not listable under the ESA, and as such are at risk relative to their listed peers. The resistance to listing hybrids such as *Acropora prolifera* is a static position in a world undergoing rapid change due to global warming, ocean acidification, and increasing human activity. More must be done, either at the federal level by listing these hybrids as threatened or endangered under the ESA, or at the local level, through protection efforts by municipalities and counties. Given the threats facing coral today, every cog and wheel in the reef must be protected, especially those best equipped to survive in the face of global climate change.

278. *Id.* Foord notes that he "was there looking for soft corals. I was looking for corals that you are more likely to find living in a coastal environment. I was not expecting to find many stony corals, and certainly not the *Acropora*. I was doing a soft coral survey and lo and behold, I stumbled across a stony coral." *Id*.

279. *See id.*