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MIXED NATURE: AVENUES AND PATH(WAY)S TO INTERNATIONAL INVASIVE ALIEN SPECIES REGULATION

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I. INTRODUCTION

Our era is staging a sweeping exchange program not only in the education of students but also in the field of biology.[1] Rooted in a global society with the measureless benefits of trade and travel are the movements beckoning exotic organismal stowaways to tag along and occupy new environments.[2] Although organismal migration has always been a factor in the global ecosystem, humanity has accelerated the process and furnished otherwise impossible modes of migration.[3] Human-created methods of travel—terrestrial, marine, and aerial—fracture natural mountain ranges and oceans that forever had prevented migrations, merging all sides of the Earth.[4] These artificial modes of organism transport are termed *introduction pathways.*[5]

Unwelcome organisms use introduction pathways to invade new ecosystems.[6] Foreign species introductions become problematic when the bio-invader overruns an ecosystem.[7] Once established, control and eradication of Invasive Alien Species (IAS) is

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1. *See* DANIEL SIMBERLOFF, INVASIVE SPECIES: WHAT EVERYONE NEEDS TO KNOW 1-3 (2013) (providing examples of recent bioinvasions and their sources).

2. *See id.* at 2-3 (discussing man-made impact on organism migration from one ecosystem to another).

3. *See* CHRIS BRIGHT, LIFE OUT OF BOUNDS: BIOINVASION IN A BORDERLESS WORLD 17-19 (1998) (discussing traditional barriers to organism migration humanity has threatened).

4. *See id.* (comparing current organism exchange to prehistoric continent Pangaea).

5. *See* Gericke Cook ET AL., *Iterative Models for Early Detection of Invasive Species across Spread Pathways*, 10 FOREST 108, 109 (2019) (defining pathways).

6. *Pathways,* U.S. DEP'T OF AGRIC., https://www.invasivespeciesinfo.gov/subject/pathways (last visited Jan. 31, 2021) (describing man-made pathways invasive organisms use in entering new environments).

7. *See* David Pimentel, *Environmental and Economic Costs Associated with Alien Invasive Species in the United States*, *in* BIOLOGICAL INVASIONS: ECONOMIC AND ENVIRONMENTAL COSTS OF ALIEN PLANT, ANIMAL, AND MICROBE SPECIES 423 (David Pimentel ed., 2nd ed. 2011) (calculating dollar amount of IAS impacts in United States).

nearly impossible.[8] Additionally, unilateral state quarantine measures frequently conflict with international trade agreements promoting free trade between countries.[9] Trapped in this conundrum, environmental advocates have turned to international regulations to cleanse introduction pathways and avert organism introductions.[10] The lone pathway-specific treaty in force is the International Convention for the Control and Management of Ships Ballast Water and Sediments (Ballast Water Management Convention or BWMC).[11] The BWMC requires ships to limit organisms in ballast water emissions through chemical or mechanical means.[12] Although the BWMC's regulations are not yet in full effect and the practical benefits of its operation remain unseen, the BWMC, in theory, closed a significant introduction pathway.[13] While this international cooperation provides optimism for closing other introduction pathways, the international community must realize that other pathways are not so easily regulated.[14]

For readers unfamiliar with these critters, Part II of this Article introduces IAS, limitations of local control efforts, and the reason for global concern.[15] In Part III, this Article essays pre-2004 international IAS management, with its strengths and limitations.[16] Part

8. *See, e.g.*, D. C. Le Maitre ET. AL, *The Economic Consequences of the Environmental Impacts of Alien Plant Invasions in South Africa*, *in* BIOLOGICAL INVASIONS: ECONOMIC AND ENVIRONMENTAL COSTS OF ALIEN PLANT, ANIMAL, AND MICROBE SPECIES 314 (David Pimentel ed., 2d ed. 2011) (describing labor-intensive programs as being unsustainable solution to IAS outbreaks).

9. *See* Sophie Riley, *Invasive Alien Species and the Protection Of Biodiversity: The Role of Quarantine Laws in Resolving Inadequacies in the International Legal Regime*, 17 J. ENVTL L. 323, 344 (2005) (describing twentieth-century resistance to quarantine measures under GATT when countries suspect those engaging in quarantine measures are merely using said measures to limit international trade).

10. *See id.* at 323-24 (noting recent attention of IAS problem at international level).

11. International Convention for the Control and Management of Ships' Ballast Water and Sediments, Feb. 16, 2004, U.N. Doc. BWM/CONF/36 [hereinafter BWMC].

12. *See id.* at art. 1(3), art. 2(5) (requiring use of mechanical or chemical agent to significantly reduce biotic material in ballast-water emissions).

13. *See Effective Ballast Water Monitoring in 3 Easy Steps*, HELLENIC SHIPPING NEWS (Feb. 6, 2020), https://www.hellenicshippingnews.com/effective-ballast-water-monitoring-in-3-easy-steps/ (noting BWMC D-2 regulations do not fully enter into force until 2024).

14. *See, e.g.*, Matteo Marchioro ET AL., *Light Traps in Shipping Containers: A New Tool for the Early Detection of Insect Alien Species*, 113 J. OF ECON. ENTOMOLOGY 1718 (2020) (describing threat of alien arthropod transfer via containerized shipping).

15. For a further discussion of the biological and global underpinnings of this invasive conundrum, see *infra* notes 20-92 and accompanying text.

16. For a further discussion of the pre-2004 international IAS legal regime, see *infra* notes 93-127 and accompanying text.

IV of this Article examines international law's first foray into introduction pathway regulation in the Ballast Water Management Convention of 2004.[17] With some regulation under the world's belt, Part V suggests potential new approaches in pathway-specific management, both in controlling specific species predicted to cause damage and in the regulation of the pathways themselves.[18] Lastly, this Article will summarize realities of the IAS issue and difficulties in management.[19]

II. INVASIVE ALIEN SPECIES (IAS)

A. Pathways and Biological Background

Introduction pathways are the man-made "mechanisms or routes by which species arrive at new regions or ecosystems."[20] Introduction pathways take manifold forms.[21] Some introductions of foreign species occur deliberately, such as the release of exotic pets or the stocking of foreign fish in rivers.[22] Many introduction pathways, however, are unintentional.[23] Invasion can occur through the shipment of containerized goods or on the muddy heels of an unsuspecting tourist's shoe.[24] Identifying these accidental introduction pathways can be more challenging because, unlike intentional introductions, the initial transfer of the organism from its native environment is unanticipated.[25]

Although not every introduced species has the potential to survive and proliferate in a new environment, organisms prove remark-

17. For a further discussion of the BWMC, see *infra* notes 128-230 and accompanying text.

18. For a further discussion of new approaches to introduction pathway regulation, see *infra* notes 231-93 and accompanying text.

19. For a further discussion of the realities of international IAS pathway management, see *infra* notes 278-83 and accompanying text.

20. Cook ET AL., *supra* note 5, at 109.

21. *See Pathways of Introduction*, GA. INVASIVE SPECIES TASK FORCE, https://www.gainvasives.org/what-is/pathways-of-introduction/ (last visited November 9, 2020) (describing numerous types of introduction pathways in Georgia).

22. *See* Philip E. Hulme, *Trade, Transport and Trouble: Managing Invasive Species Pathways in an Era of Globalization*, 46 J. APPLIED ECOLOGY 10, 14 (2009) (noting deliberate introductions of exotics constitute one category of IAS introductions).

23. *See id.* (noting existence of accidental IAS introductions, referred to as "escapes").

24. *See id.* (describing forms of accidental introduction pathways).

25. *See id.* (stating deliberate introductions are in theory easier to regulate than accidental introductions); *see also* Kate Brierley, *Murder Hornets Made Their Way Into the U.S. — And What It Means for Us*, GREEN MATTERS, https://www.greenmatters.com/p/how-did-murder-hornets-get-to-the-us (last visited Nov. 26, 2020) (describing accidental transmission of Asian Giant Hornets to Northwestern United States).

ably adaptive when necessary.[26] The initial introduction to the environment is only one step in the IAS invasion.[27] After this, establishing a population is difficult and may require multiple introductions before an introduced species can become firmly entrenched in a new ecosystem.[28] The strength of this introduction effort, referred to as propagule pressure, is an essential predictor in determining the probability of a successful invasion.[29] Once a human-introduced species presents itself in this new environment, the organisms become an established alien species.[30]

A coherent and consistent definition of IAS eludes biologists and treaty drafters alike.[31] Scientific observations suggest not all alien species become invasive in that they cause economic or environmental harm to their new environments.[32] Indeed, some biological introductions, deliberate or accidental, provide benefits to an area's human inhabitants.[33] Unfortunately, these beneficial introductions are typically limited to the introduction of previously domesticated organisms.[34] Introduced undomesticated plants and animals frequently become uncontrolled and overrun the ecosys-

26. *See* Petr Pyšek & David M. Richardson, *Invasive Species, Environmental Change and Management, and Health*, 35 ANN. REV. ENVTL. RES. 25, 27 (2010) (discussing ability of introduced species to evolve through genetic differentiation to invade ecosystem).

27. *See* Robert E. Ricklefs, *Taxon Cycles: Insights From Invasive Species*, SPECIES INVASIONS: INSIGHTS INTO ECOLOGY, EVOLUTION, AND BIOGEOGRAPHY 179 (DOV F. SAX ET AL. ed., 2005) (describing IAS's initial colonization of novel environment only first step in invasion process).

28. *See id.* (noting many alien-species colonists with insufficient propagule pressure fail to become established despite dearth of evidence for failed alien-species colonization).

29. *Id.* (emphasizing importance of propagule pressure in determining probability of successful invasion).

30. Pyšek & Richardson, *supra* note 26, at 29 (defining alien species as organisms transported with human intervention to new ecosystems).

31. *See, e.g.*, Karin Klein, *Opinion: Is America's wild horse an invasive species, or a reintroduced native?*, L.A. TIMES (July 3, 2014, 12:50 PM), https://www.latimes.com/nation/la-ol-wild-horse-endangered-20140703-story.html (discussing whether wild horses, which were extinct on North American continent and reintroduced, should be considered invasive species).

32. *See* Simberloff, *supra* note 1, at 25-26 (stating many introduced species fail to become invasive).

33. KEN THOMPSON, WHERE DO CAMELS BELONG? 196 (2014) (noting 98% of all food produced in United States comes from introduced crops and livestock).

34. *See Introduction, in* BIOLOGICAL INVASIONS: ECONOMIC AND ENVIRONMENTAL COSTS OF ALIEN PANT, ANIMAL, AND MICROBE SPECIES (David Pimentel ed.) (detailing introduced species who help with livestock and food production).

tem.[35] Still, not all alien species become invasive.[36] Precise numbers vary, but research approximates that only ten percent of all established alien species become invasive.[37] Factors determining the likelihood of an alien species becoming an IAS remain a matter of scientific debate, but likely include the evolutionary pressure these organisms face in their native environment compared to their new ecosystem.[38] Even if an alien species does become invasive, ecologists will only classify it as such in its non-native ecosystem.[39] For example, ecologists consider the spotted lanternfly to be an IAS in North America but not in the spotted lanternfly's native Asian habitat.[40]

Although onlookers typically perceive bioinvasions to be a local problem, IAS invasions cause environmental distress to every continent in the world.[41] For example, in Antarctica—a continent casual observers might view as inhospitable and perhaps immune to IAS invasion—IAS are arriving with the recent influx in tourists.[42] These Antarctic IAS, which include the common housefly, typically arrive through camera bags or mud on tourists' shoes.[43] International law has long recognized the threat IAS pose to Antarctica's pristine environment, and in 1966, the Agreed Measures for the Conservation of Antarctic Fauna and Flora restricted the importa-

35. *See, e.g.*, Bright, *supra* note 3, at 157 (stating how Leidy's comb jelly overran Black Sea ecosystem).

36. *See* Simberloff, *supra* note 1, at 25-26 (noting substantial number of introduced organisms do not become invasive).

37. *See id.* at 25-27 (describing scientific estimates of average introduced organism's invasiveness potential in environment).

38. *See* Pyšek & Richardson, *supra* note 26, at 27 (summarizing factors relating to invasive potential of species and invasiveness of given ecosystem).

39. *See* Riley, *supra* note 9, at 327 (stating definitions of "alien species" found in IUCN Guidelines and CBD Guiding Principles limit application to species found outside native range).

40. *See Spotted Lanternfly: Introduction, Native Range, and Current US Range*, N.Y. STATE INTEGRATED PEST MGMT., https://nysipm.cornell.edu/environment/invasive-species-exotic-pests/spotted-lanternfly/spotted-lanternfly-ipm/introduction-native-range-and-current-range-us/ (last visited Mar. 3, 2021) (describing spotted lanternfly as native to China, India, and Vietnam but "infest[ing]" southeastern Pennsylvania).

41. *Introduction, in* BIOLOGICAL INVASIONS: ECONOMIC AND ENVIRONMENTAL COSTS OF ALIEN PANT, ANIMAL, AND MICROBE SPECIES 6-7 (David Pimentel ed.) (providing brief overview of economic and environmental damage to various regions throughout globe); Robin McKie, *The latest threat to Antarctica: an insect and plant invasion*, THE GUARDIAN (June 17, 2017, 4:54 PM), https://www.theguardian.com/world/2017/jun/17/antarctica-insect-plant-invasion-house-flies-mosses-warmer-climate (discussing IAS presence in Antarctica).

42. McKie, *supra* note 41 (explaining impact of IAS invasions in Antarctica).

43. *Id.* (describing introduction pathways relevant to Antarctica's IAS conundrum).

tion of non-indigenous animals.[44] Yet changes in visitation, especially from non-scientist visitors, have increased propagule pressure and made even Antarctica vulnerable to bioinvasion.[45] The IAS issue is best considered an international ailment, with symptoms appearing locally.[46]

1. *Environmental and Economic Impact*

Only human population growth outweighs IAS invasions in impact on global biodiversity.[47] IAS invasions have broad environmental effects, most apparently through interspecies interaction.[48] IAS compete with native species for resources either through intimidation of native species or by reducing the supply of a shared resource.[49] When an IAS is more efficient at foraging or hunting for resources, the IAS will overrun the native species and mercilessly usurp its role in the ecosystem.[50] IAS predation of native species can also lead to extinction, with the impact of rat and feral cat introductions on the world's island species being prominent examples.[51] Parasite and pathogen introduction will also threaten native organisms because native organisms lack the necessary inherited or

44. Riley, *supra* note 9, at 331 (detailing history of IAS regulations relating to Antarctica).

45. *See* McKie, *supra* note 41 (discussing IAS presence in Antarctica).

46. *See id.* (detailing IAS introductions in Antarctica); *Introduction*, *in* BIOLOGICAL INVASIONS: ECONOMIC AND ENVIRONMENTAL COSTS OF ALIEN PANT, ANIMAL, AND MICROBE SPECIES 6-7 (David Pimentel ed.) (providing brief overview of economic and environmental damage to various regions throughout globe).

47. *Introduction*, *in* BIOLOGICAL INVASIONS: ECONOMIC AND ENVIRONMENTAL COSTS OF ALIEN PLANT, ANIMAL, AND MICROBE SPECIES 2 (David Pimentel ed.) (writing human population growth and impacts of invasive species are two largest threats to biodiversity).

48. *See id.* at 144-46 (discussing interspecies interactions between native species and IAS through consumption of other species and interspecific competition).

49. Simberloff, *supra* note 1, at 61 (stating invasive organisms can affect fitness of native organisms through fighting, intimidation, or reducing resource supplies available to native organisms).

50. *See id.* at 62 (describing example of North American grey squirrel in outcompeting native squirrel populations and replacing them through resource competition).

51. *Id.* at 64-65 (using examples of rats and feral cats in world's island environments to describe IAS's impact on ecosystems through predation). Another prominent example of IAS predation is the bee-eating Asian Giant Hornet, more infamously feared as the "Murder Hornet." Mike Baker, *'Murder Hornets' in the U.S.: The Rush to Stop the Asian Giant Hornet*, N.Y. TIMES (last updated Nov. 13, 2020), https://www.nytimes.com/2020/05/02/us/asian-giant-hornet-washington.html (describing Asian Giant Hornet as threat to native bee populations).

acquired immune response to detect and respond sufficiently to these previously unseen pathogens.[52]

Bioinvasions also modify habitats.[53] IAS may affect the chemical makeup of an ecosystem by introducing new substances or by eliminating fundamental ecosystem species, subsequently altering natural carbon, nutrient, and hydrologic cycles.[54] In North America, the introduction of the periwinkle snail along the northeastern coast removed mudflats and salt marshes from the coast as the snails consumed the vegetation necessary for these features.[55] In Florida, the introduction of Australian paperbark trees, with their flammable leaves and litter, has increased the regularity of wildfires and displaced native Floridian plants ill-suited for perdition-like flames.[56] In New Zealand, the introduction of single-celled invasive algae layered rocks and streambeds, causing disruption to native insects and "treacherous footing for fishermen."[57] Globally, the presence of invasive species can reduce an ecosystem's carbon sequestration potential, leading to increased atmospheric temperature.[58]

Island ecosystems are particularly vulnerable to IAS invasions.[59] Island land masses are isolated from the rest of the world, causing native species to adapt to niche ecological pressures and evolve with little external influence.[60] Unlike the native species of Afro-Eurasia

52. *See* Simberloff, *supra* note 1, at 61 (detailing problems that arise when alien species introduce foreign microbial pathogens to native species without proper immune response to those pathogens).

53. *See* Simberloff, *supra* note 1, at 56 (describing periwinkle snail's impact on North American shores); *see, e.g.*, Pyšek & Richardson, *supra* note 26, at 28-29 (discussing invasive insects' effect on biocycles in new ecosystems).

54. *See* Pyšek & Richardson, *supra* note 26, at 28-29 (noting effects of invasive insect causing disruptions in natural cycles).

55. Simberloff, *supra* note 1, at 56 (describing periwinkle snail's impact on North American shores).

56. *Id.* at 58 (noting example Australian paperbark trees' ability to increase frequency of forest fires through highly flammable leaves, litter, and bark).

57. *Id.* (illustrating Northern Hemisphere diatom's impact on New Zealand stream environments through habitat modification and subsequent impacts on organisms not directly competing for resources with Northern Hemisphere diatom).

58. David A. Strifling, *An Ecosystem-based Approach to Slowing the Synergistic Effects of Invasive Species and Climate Change*, 22 DUKE ENVTL. L. & POL'Y F. 145, 158-59 (2011) (noting indirect impact IAS have on ecosystem's carbon sequestration and potential to increase global carbon dioxide levels).

59. Dena R. Spatz ET AL., *Globally threatened vertebrates on islands with invasive species*, 3 SCI. ADVANCES 9 (2017), https://advances.sciencemag.org/content/advances/3/10/e1603080.full.pdf (discussing threat IAS pose to fragile island ecosystems).

60. *Id.* at 1 (noting highly-adapted island species with small population sizes render these populations vulnerable to extirpation from external invaders).

that evolves under significant pressure from natural invaders, the vast expanse of the ocean protected against foreign bioinvasions in islands before human contact.[61] Australia and New Zealand are notable for their unique ecological composition, with Australia being almost entirely populated by marsupial (as opposed to placental) mammals and New Zealand being previously populated only by birds and reptiles.[62] Indigenous and European settlers brought IAS with them that contributed to the quick extinction of local, unique fauna, namely the megafauna.[63] Native organisms that have survived the initial onslaught remain threatened by previously introduced IAS and new potential introductions.[64] In smaller island ecosystems, IAS pose threats to native species that have similarly evolved specifically to an ecological niche without external pressure. Birds are the most conspicuous of these island extinctions, with most known bird extinctions after 1500 A.D. being island species.[65]

Economic damage of IAS comes in the form of IAS control and agricultural damage. Numbers vary widely, depending usually on what species are included in the calculation and whether microbial damage is included in the estimates.[66] In New Zealand, the cost of IAS is estimated to be 3.4 billion dollars per year, or 1.93 percent of New Zealand's GDP.[67] The United States faces IAS damage of 219

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61. Simberloff, *supra* note 1, at 30 (discussing evolutionary pressure species of Afro-Eurasia experienced when evolving in diverse environments with human-introduced species).

62. *See Humans, not climate change, wiped out Australian megafauna*, PHYS.ORG (Jan. 20, 2017), https://phys.org/news/2017-01-humans-climate-australian-megafauna.html (describing existence of large marsupial animals on Australia prior to human arrival); M. N. Clout, *Ecological and Economic Costs of Alien Vertebrates in New Zealand*, *in* BIOLOGICAL INVASIONS: ECONOMIC AND ENVIRONMENTAL COSTS OF ALIEN PLANT, ANIMAL, AND MICROBE SPECIES 283 (David Pimentel ed., 2d ed. 2011) (describing flora and fauna of New Zealand prior to human arrival approximately 730 years ago).

63. *See, e.g.*, Clout, *supra* note 62, at 284 (detailing impact IAS has had in New Zealand since human arrival).

64. *Invasive Species in Australia*, NAT. HERITAGE TRUST (2004), https://www.environment.gov.au/system/files/resources/2bf26cd3-1462-4b9a-a0cc-e72842815b99/files/invasive.pdf (describing continuing threats of IAS to Australian ecosystem).

65. *See* Tim M. Blackburn & Kevin J. Gaston, *Biological Invasions and the Loss of Birds on Islands: Insights Into the Idiosyncrasies of Extinction*, *in* SPECIES INVASIONS: INSIGHTS INTO ECOLOGY, EVOLUTION, AND BIOGEOGRAPHY 91 (Dov F. Sax ET AL. ed. 2005) (describing characteristics and non-randomness of recent bird extinctions).

66. *See* Thompson, *supra* note 33, at 196 (criticizing use of microbial infections in factoring IAS costs).

67. *See* Clout, *supra* note 62, at 289 (discussing costs of alien species invasions in New Zealand).

billion dollars per year.[68] In India, a 2001 estimate calculates the economic cost of IAS amounts to ninety-one billion USD each year.[69] Additionally, some suggest actual IAS economic costs could be higher if environmental impacts, including those associated with "habitat damage, loss of rare and endangered species, extinctions, and/or ecosystem or environmental services" were factored into determinations.[70]

B. Limitations of State Control and Regulation

Controlling IAS once an IAS has invaded an ecosystem is difficult, and complete eradication is rare.[71] Labor-intensive control programs, including the pulling of IAS weeds and hunting IAS vertebrates, present problems.[72] Labor-intensive eradication efforts in curtailment of IAS plants have substantial costs and are of limited efficacy.[73] Rehabilitation of previously IAS-infested areas is normally temporary; the removal of weeds alone does not prevent the IAS from reinvading the rehabilitated area.[74] To add another complication, extermination of IAS vertebrates will frequently draw the ire of animal rights groups that oppose efforts to exterminate vertebrate populations, especially when the species is human-introduced.[75] For example, an animal rights lawsuit halted an Italian campaign to eradicate the North American eastern gray squirrel in Italy.[76] Without the eradication campaign, the eastern gray squirrel will continue to outcompete and potentially eradicate native squirrel species.[77]

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68. Pimentel, *supra* note 7, at 423 (calculating dollar amount of IAS impacts in United States).

69. David Pimentel ET AL., *Economic and Environmental Threats of Alien Plant Animal and Microbe Invasions*, 84 AGRIC., ECOSYSTEMS, & ENV'T 3 (Table 2) (2001).

70. Daizy R. Batish ET AL., *Invasive Plants in the Indian Subcontinent*, *in* BIOLOGICAL INVASIONS: ECONOMIC AND ENVIRONMENTAL COSTS OF ALIEN PLANT, ANIMAL, AND MICROBE SPECIES 254 (David Pimentel ed., 2nd ed., 2011).

71. *See Invasive Species in Australia*, *supra* note 64 (stating complete and permanent removal of IAS is impractical because of high likelihood of reinvasion from contiguous land).

72. *See, e.g.*, Simberloff, *supra* note 1, at 22-23 (explaining animal-rights opposition to IAS vertebrate exterminations).

73. Le Maitre ET AL., *supra* note 8, at 314 (describing labor-intensive programs as being unable to provide sustainable solution to IAS outbreaks).

74. *See id.* (discussing need for labor-intensive programs to prevent reinvasion of IAS weeds after rehabilitation).

75. *See* Simberloff, *supra* note 1, at 22-23 (explaining animal-rights opposition to IAS vertebrate exterminations).

76. *See id.* at 62-63 (discussing animal-rights lawsuit that ended Italian campaign to eradicate North American eastern gray squirrel).

77. *See id.* (noting failure of eradication campaign could lead to replacement of native squirrel by invasive squirrel).

A more cost-effective eradication method is through the biological control of IAS.[78] Biological control options introduce alien organisms to prey on the IAS, therefore adding a biological check to IAS growth.[79] This fighting-fire-with-fire approach, however, is controversial.[80] The newly introduced alien species could itself become invasive and cause similar ecological and economic damage.[81] Some studies suggest that the risk of introducing alien organisms to control other alien species is too great to be considered a viable option.[82] Control programs attempt to avoid this risk by introducing specialist organisms—that is, organisms that only prey on the IAS.[83] One example is the introduction of a specialist wasp to combat the brown marmorated stink bug in North America.[84] Determining whether the proposed biological control organism would become invasive can be a lengthy process, allowing the IAS to grow further uncontrolled.[85] Others oppose the introduction of these biological specialists altogether, citing the precautionary principle.[86]

Local efforts to control IAS introductions are further hampered when state-led quarantine programs limiting the importation of shipped goods violate international law. These efforts come into contention with treaties and conventions supporting free trade.[87] Under the Agreement on the Application of Sanitary and

78. *See* Le Maitre ET AL., *supra* note 8, at 314 (introducing biological control options as cost-effective alternatives to labor-intensive control options).

79. *See id.* (defining biological control methods used to reduce IAS impacts).

80. *Id.* (stating introduction of biological controls is controversial).

81. *See id.* at 315 (noting opponents to biological control agents discuss uncertainties and unintended consequences potentially stemming from release of alien organisms to combat other alien organisms).

82. *Id.* (listing studies suggesting risk of unwanted outcome in biological control too great to render method effective).

83. *See* Le Maitre ET AL., *supra* note 8, at 315 (distinguishing generalist herbivores and specialist feeders).

84. Jack Charles Nissen, *Scientists want to use the Samurai Wasp to fight Michigan's invasive stink bug problem*, FOX2 (Aug. 7, 2019), https://www.fox2detroit.com/news/scientists-want-to-use-the-samurai-wasp-to-fight-michigans-invasive-stink-bug-problem (proposing introduction of specialist wasp native to Asia to combat brown marmorated stink bug).

85. *See Biological Control*, U.S. FOREST SERV., https://www.fs.fed.us/research/invasive-species/control/biological.php (last updated Apr. 29, 2014) (describing careful process researches must take before releasing biological control agents into environment).

86. *See* Le Maitre ET AL., *supra* note 8, at 315 (noting opponents to biological specialist introductions to combat IAS argue impact of specialist introduction can never be understood fully before actual introduction).

87. *See* Bright, *supra* note 3, at 202-03 (outlining WTO's quarantine regulations and its potential conflicts with efforts to limit flow of goods into one country or state).

Phytosanitary Measures (SPSA), members of the World Trade Organization (WTO) cannot reject imports without providing a rational scientific link between the quarantine and the potential for bioinvasion.[88] The purpose for this presentation of a rational scientific link is to ensure states do not dress economic protectionism in the robes of environmental concern.[89] This approach to free trade, however, is incompatible with environmental law's precautionary principle and, from an environmental standpoint, an unworkable standard.[90] In a trading system with thousands of biological hitchhikers, one author described the current SPSA requirements analogous to "deciding to fight off a military invasion by letting in the enemy soldiers and then polling each one to determine individual levels of hostility."[91] The attempts of international litigants to avoid this requisite scientific link by arguing that the environmental precautionary principle had become customary law has been unsuccessful.[92] Members of the WTO, therefore, are severely limited in their unilateral restriction of introduction pathways.

III. PRE-2004 PATHWAY REGULATIONS

Prior to the 2004 Ballast Water Management Convention, international IAS regulation was sparse and did not thoroughly regulate one specific pathway.[93] Most treaties discussing IAS only focused on specific regions of the world, such as the Agreed Measures for the Conservation of Antarctic Fauna and Flora limiting organism introductions in Antarctica.[94] Instruments operating under an international scope struggled with "inconsistent level[s] of commitment and obligation, the patchy application of the instru-

88. *See* Riley, *supra* note 9, at 344-45 (stating countries must rationally link their appropriate level of protection to risk assessments with degree of scientific certainty).

89. *Id.* at 344 (stating SPSA arose out of concern that quarantine measures based on environmental regulations were instead disguises for economic protectionism).

90. *See* Bright, *supra* note 3, at 202-03 (discussing logistical issues in evaluating potential risk posed by each exotic organism entering country as is required by WTO's commitment to free trade).

91. *Id.* (describing practical difficulties in current SPSA execution).

92. *See* Riley, *supra* note 9, at 348-49 (discussing two international cases before WTO's Appellate Body where parties unsuccessfully argued environmental precautionary principle had become customary law and therefore permitted local quarantine regulations).

93. *See, e.g.*, Convention on Biological Diversity, art. 8(h), *open for signature* June 5, 1992, 1760 U.N.T.S. 79 [hereinafter CBD] (requiring states to prevent introduction of alien species but failing to specify how this prevention should proceed).

94. Riley, *supra* note 9, at 331.

ments and the need for an acceptable definition of an IAS."[95] This Section will describe the operation and limitations of pre-2004 international IAS introduction pathway treaties.

A. Convention for Biological Diversity (1992)

Article 8(h) of the 1992 Convention for Biological Diversity (CBD) requires signatories of the convention to "[p]revent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species."[96] This broad mandate, which signatory nations are to follow "as far as possible and as appropriate," covers introductions throughout the globe.[97] In the CBD's preamble, the CBD embraces the precautionary principle, stating, "lack of full scientific certainty should not be used as a reason for postponing measures" related to conservation.[98] One advantage to the CBD is its broad membership; 193 nations have signed it, with the United States being the main non-participator.[99] The mandate is symbolic for its recognition of the IAS issue and expresses a desire to close introduction pathways.[100]

The IAS portion of the treaty has its detractors, however, and is not a comprehensive, workable solution to introduction pathways.[101] In a global trade system with many introduction pathways and numerous exotic organisms being transported intentionally or accidentally, one sentence in a treaty will be insufficient to close pathways.[102] The CBD provides no methods or mechanisms to achieve the stated objective and it is the role of the individual parties to establish the entire introduction pathway control regime.[103] At best, this mandate causes inconsistent regulations and, at worst,

95. *Id.* at 334 (explaining problems with international nature of problem related to IAS elimination).

96. CBD, *supra* note 93, at art. 8(h). (quoting Article 8(h) of 1992 Convention for Biological Diversity signatory requirements).

97. *See id.* at art. 4, art. 8 (stating provisions of CBD apply in jurisdictions of contracting parties and in jurisdictions outside of those covered if outside jurisdictions may be affected by activities of contracting parties).

98. *Id.* at preamble.

99. Simberloff, *supra* note 1, at 160 (describing number of parties that have ratified CBD and lack of United States as participator).

100. *See id.*

101. *See* Bright, *supra* note 3, at 204 (criticizing CBD for vagueness and inbuilt limitations of contracting party commitments).

102. *See* Riley, *supra* note 9, at 335 (noting CBD's lack of specific instructions to contracting parties).

103. *Id.* at 335-36 (discussing CBD's failure to furnish parties with guidance on how to achieve ambitious outcomes).

inaction.[104] Other commentators have criticized the CBD's vague "as far as possible and as appropriate" verbiage in mandates.[105] According to these commentators, this language reduces the CBD's potentially binding provision to a mere acknowledgement of IAS infestations.[106] Yet, to its credit, the CBD has released non-binding regulatory guidelines for its members through Conference of Parties (COP) decisions.[107] The guidelines distinguish intentional and unintentional introductions and favor an "ecosystem approach" that views the range of an ecosystem, rather than a state's jurisdiction, as the decisive factor in regulation.[108] Nonetheless, the guidelines fail to identify specific pathways and fail to address conflicts with international trade law.[109]

B. International Plant Protection Convention (1951)

The International Plant Protection Convention (IPPC) requires signatories to take "common and effective action" to limit "pests and diseases" appurtenant to plant shipments.[110] Further, the preamble of the IPPC acknowledges that contracting parties should consider international environmental laws when assembling proper phytosanitary measures.[111] Parties to the IPPC must maintain inspection procedures and attempt to eradicate pest outbreaks.[112] Although the IPPC was originally created for agricultural reasons, commentators note it also has important applications in the consideration of IAS infestations by determining proper proce-

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104. *See id.* at 335 (arguing CBD only describes preferred outcome and fails to create comprehensive IAS regime).

105. *See, e.g.*, CBD, *supra* note 93, art. 8; *see* Bright, *supra* note 3, at 204 (stating "as far as possible and appropriate" language of CBD removes CBD's power to control IAS infestations).

106. *See* Bright, *supra* note 3, at 204 (stating "as far as possible and appropriate" language of CBD removes CBD's power to control IAS infestations).

107. *See, e.g.*, *Alien species that threaten ecosystems, habitats or species*, COP 6 DECISION VI/23, https://www.cbd.int/decision/cop/?id=7197 (last visited Jan. 15, 2021) (displaying non-binding guidelines on CBD's treatment of IAS by "urg[ing]" rather than requiring parties to complete IAS prevention protocols).

108. *Id.* (stressing analysis through "ecosystem approach" in "[g]uiding principle 3").

109. *See id.* (declining to address specific IAS pathways and potential conflicts).

110. International Plant Protection Convention, art. 1, Dec. 6, 1951, 1945-2021 T.I.A.S. No. 05-1002, 150 U.N.T.S. 67.

111. *Id.* at preamble (noting contracting parties take into account "internationally approved principles governing" environment).

112. *See* Bright, *supra* note 3, at 202 (discussing generally commitments of IPPC).

dures in the shipping of plant species.[113] A 2003 IPPC workshop stressed the IPPC's role in limiting some IAS introductions, particularly when considering the legal mandate of the CBD.[114] The convention itself does not specifically identify pathways, but the IPPC permits side agreements between contracting parties concerning forms of shipping.[115]

Although initially signed in 1951, a 1997 amendment greatly altered the IPPC to comply with the 1995 SPSA.[116] The SPSA, binding on all members of the WTO, mandates requirements for signatories before they can take protectionary measures that "protect human, animal or plant life or health" in shipping and commerce.[117] The impetus for the SPSA occurred when nation states began using quarantine measures to avoid tariff restrictions under the General Agreement on Tariffs and Trade.[118] The SPSA established new requirements of an accepted scientific link between commodity importation and the threat to biodiversity.[119] The SPSA limits application of the precautionary principle and suggests the need for different international introduction pathway regulations.

C. Cartagena Protocol (2000)

The Cartagena Protocol, a limited but important treaty relating to IAS introductions, controls the introduction of genetically modified organisms.[120] The goal of the Cartagena Protocol is to limit intentional introductions of Living Modified Organisms (LMOs) into the environment for fear that the genetic enhancement would cause the LMO to outcompete native organisms.[121]

113. *See id.*; Riley, *supra* note 9, at 325 (describing how IPPC parties have noted relationship between IAS and IPPC).

114. Riley, *supra* note 9, at 325 (noting 2003 workshop).

115. *See* Bright, *supra* note 3, at 202 (noting IPPC allows for side agreements between contracting parties to potentially regulate introduction pathways).

116. *Id.* (stating amendments to IPPC intended to comport IPPC with WTO standards has enfeebled IPPC as IAS prevention tool).

117. Agreement on the Application of Sanitary and Phytosanitary Measures, preamble, Jan. 1., 1995, 1945-2021 T.I.A.S. No. 06-222.1, 1867 U.N.T.S. 493.

118. *See* Simberloff, *supra* note 1, at 161-62 (discussing, generally, "phytosanitary measures" adopted by various conventions in response to limitations of quarantine measures).

119. *See id.* (noting efforts to reduce risk of IAS by regulating incoming shipments from other nations).

120. *See* Cartagena Protocol on Biosafety to the Convention on Biological Diversity art. 1, Jan. 29, 2000, 39 I.L.M. 1027, [hereinafter Cartagena Protocol] (using precautionary principle to limit transfer of potentially harmful modified organisms).

121. Riley, *supra* note 9, at 334 (describing ambit and general goals of Cartagena Protocol).

Before transferring an LMO outside of its jurisdiction, the contracting party must contact a relevant authority of the importer and allow the importer to review the proposed importation for hazards to biodiversity.[122] This contact is termed an "advance informed agreement."[123] Again evincing the precautionary principle, the lack of scientific certainty of an LMO's invasive potential does not require the importing party to allow for importation.[124] Contracting parties also must alert other parties if an LMO is unintentionally transferred to another contracting party.[125] While it addresses an emerging issue in IAS circles, the Cartagena Protocol does not answer the issues traditional bio-invaders present.[126] Still, the Protocol's advance informed agreement could provide an archetype to create a treaty about intentional transfers of traditional alien species.[127]

IV. THE BALLAST WATER MANAGEMENT CONVENTION (2004)

A. Background

With the current inadequacies in international law and states facing difficulty in controlling IAS outbreaks, recent attention has turned to international control of introduction pathways.[128] The first international attempt to regulate invasive species through introduction pathways occurred in 2004 with the BWMC.[129] The BWMC is within the domain of the International Maritime Organization (IMO) and entered into force in 2017.[130]

122. *Id.* (describing advance informed agreement procedure requiring first-time exporters to contact authority of importing state to review importation for environmental threats of LMOs).

123. Cartagena Protocol, *supra* note 120, at art. 7 (discussing application of advance informed agreement procedure).

124. *Id.* at art. 11(8) (stating lack of scientific certainty of LMO's potential environmental impact cannot be used to reject quarantine regulation when LMO is directly used for food, feed, or processing).

125. *Id.* at art. 17(1) (describing necessity of notifications of unintentional transfer and required information to be included in notification).

126. *See id.* at art. 1 (addressing only treatment and transfer of "living modified organisms resulting from modern biotechnology" in international treaty).

127. *See* Albert G. McCarraher, IV, *The Phantom Menace: Invasive Species*, 14 N.Y.U. ENVTL. L.J. 736, 753-54 (2006) (suggesting use of Cartagena Protocol as archetype in creating robust IAS introduction pathway treaty).

128. *See, e.g.*, BWMC, *supra* note 11 (noting spread of IAS through introduction pathway of ballast water transfers).

129. *See id.* (desiring to limit spread of IAS through ballast water transfers)

130. *See Ballast Water Convention to Enter into Force in 2017*, MAR. EXEC. (Sept. 9, 2016), https://www.maritime-executive.com/article/ballast-water-convention-to-enter-into-force-in-2017 (reporting on Finland's recent accession causing BWMC to enter into force).

B. Ballast Water and IAS

Ballast is material used in ships to weigh down the vessel and provide stability against ocean currents.[131] Without ballast, for example, the propeller and rudder might be unable to function because they would not be consistently submerged in water.[132] Ballast can consist of any material that will weigh down a vessel and, prior to 1880, usually consisted of solid material like gravel or dirt.[133] In the context of shipping, ballast is used when the ship is empty with cargo and traveling to a port to obtain new cargo.[134] Once a ship arrives at the destination port to acquire new cargo, the ship dumps the ballast at the port.[135] Technological developments in the late nineteenth century allowed for the use of water as ballast.[136] Currently in the shipping industry, water is almost exclusively used as ballast because "it is more readily available, much easier to load on and off a ship, and therefore more efficient and economical than solid ballast."[137] Ships acquire ballast water through gravity or by pumping water into ballast water tanks located near the hull of the ship.[138] Before the BWMC, the ballast water acquisition process allowed many organisms living in the water to survive the transfer and reside in ballast water tanks.[139] The ballast water acquisition process also allows for ocean sediment and organisms within that sediment to enter the ballast water tanks.[140]

From an IAS perspective, the transfer of ballast between two disparate locations has always been troubling. For example, the dumping of ballast soil into destination ports allowed for the trans-

131. Cory Hebert, *Ballast Water Management: Federal, States, and International Regulations*, 37 S.U. L. REV. 315, 316 (2010) (describing purpose of ballast water in context of shipping industry).

132. *Ballast water as a vector*, GLOBALLAST PARTNERSHIPS, http://archive.iwlearn.net/globallast.imo.org/ballast-water-as-a-vector/index.html (last visited May 9, 2020) (stating ballast is required to ensure proper functioning of rudder and propeller).

133. *Id.* (noting switch from solid material to water as ballast in 1880).

134. *See id.* (stating ships must be weighed down when ships are free of cargo).

135. *See id.* (noting vessel discharges ballast when loading new cargo at port).

136. Simberloff, *supra* note 1, at 38 (stating technological advancements permitting vessels to be ballasted with water precipitated wave of bioinvasions).

137. *See Ballast water as a vector*, *supra* note 132.

138. Cole Atlin, *Aquatic Invasive Alien Species and the Evolution of Canadian and U.S. Ballast Water Regulations in the Great Lakes-Rowing in Tandem or Muddying the Waters?*, 24 IND. INT'L & COMP. L. REV. 65, 69 (2014) (describing ballast water acquisition process).

139. *See id.* (stating ballast water is common pathway for IAS introduction).

140. *See id.* (explaining relationship between ballast water and ocean sediments).

fer of insects, seeds, and other organisms to a new ecosystem if parts of the ballast soil floated to shore.[141] The potential transfer of aquatic species into an aquatic environment only increased the magnitude of the problem.[142] Additionally, the increase in shipping volume and speed raises propagule pressure and the likelihood of species introduction. In the modern shipping industry, "[three to five] billion tonnes of ballast water is transferred throughout the world each year"[143] and thousands of organisms can be transported in the ballast water of shipping vessels.[144] Some consider ballast water to be one of the most dangerous marine introduction pathways.[145]

IAS introduced through ballast water transport have caused ecological and economic damage to their new ecosystems.[146] The most cited example is that of the zebra mussel in the North American Great Lakes.[147] Originally a native of Russia and Ukraine, the species was likely introduced as a ballast water passenger to North America in the 1980s.[148] The zebra mussel subsequently invaded the ecosystems across the country, outcompeting local species for resources and reducing phytoplankton levels.[149] With its ability to attach to many surfaces, including other zebra mussels, the critter has caused billions of dollars in damage by clogging pipes and damaging hulls.[150] For their part, Russia and Ukraine have found their own ballast-water foe with the North American Leidy's comb jelly-

141. *See* Simberloff, *supra* note 1, at 140 (identifying North American appearance of Cornwall beetle species early in European colonization of North America as likely ballast soil passenger).

142. Atlin, *supra* note 138, at 69 (discussing increase in bioinvasion caused by increased use of water as ballast).

143. *See Ballast water as a vector*, *supra* note 132.

144. Herbert, *supra* note 131, at 317 (stating estimates of number of organisms that might be transferred through ballast water transfers).

145. *See* Suzanne Bostrom, *Halting the Hitchhikers: Challenges and Opportunities for Controlling Ballast Water Discharges and Aquatic Invasive Species*, 39 ENVTL. L. 867, 872 (2009) (stating ballast water is leading vector for IAS introductions).

146. *See, e.g.*, Bright, *supra* note 3, at 157 (stating presence of Leidy's comb jelly in Black Sea).

147. Tony George Puthucherril, *Ballast Waters and Aquatic Invasive Species: A Model for India*, 19 COLO. J. INT'L ENVTL. L. & POL'Y 381, 388 (2008) (stating zebra mussel invasion of North American Great Lakes is among the "most publicized" examples of ballast water IAS).

148. *See id.* (describing supposed introduction pathway of zebra mussel to North America).

149. *See id.* (explaining ecological effects of zebra mussel invasion in North American Great Lakes).

150. *Id.* (describing zebra mussels' ability to attach onto objects and their relation to economic and ecological damage).

fish.[151] Also a 1980s arrival, the jellyfish invaded the Black Sea and precipitated a near-total collapse of the Black Sea ecosystem.[152] At the invasion's height, "a single cubic meter of Black Sea water could contain as many as [five hundred] of the little jellies."[153] Unlike the many pollution events of the 1980s, these two bio-invaders cannot be remediated and remain a disturbance to their non-native environments.[154]

C. History of the Ballast Water Management Convention

The international community's recognition of the ballast water introduction pathway long predates the BWMC.[155] In 1982, the United Nations Convention on the Law of the Sea instructed its members to limit the spread of marine IAS through intentional or accidental means.[156] Later, in 1988, introduction pathways received more global recognition when Canada brought the invasion of the zebra mussel and Leidy's comb jellyfish to the IMO's attention.[157] Although nations could regulate ballast water in their own waters, the international aspect of shipping and the need for consistent standards prompted an international solution.[158] After issuing non-mandatory guidelines regulating the use of ballast water, the IMO began "draft[ing] a new global treaty in 1999."[159] In 2004, the IMO adopted the Ballast Water Convention, and with Finland's accession to the treaty in 2016, the BWMC entered into force on Sep-

151. *See* Bright, *supra* note 3, at 157 (stating presence of Leidy's comb jelly in Black Sea).

152. *Id.* (analyzing impact Leidy's comb jellyfish had on already fragile Black Sea ecosystem).

153. *Id.*

154. *See* Bostrom, *supra* note 145, at 873 (noting rarity of total IAS eradication in ballast water context).

155. *See* Puthucherril, *supra* note 147, at 391 (noting pre-BWMC mention of IAS in maritime treaty).

156. *Id.* (stating one mandate of United Nations Convention on Law of Sea).

157. *See* Rajeev Jassal, *Ballast Water Management: What We Need to Know and How to Comply*, MYSEATIME: BLOG (Oct. 13, 2018), https://www.myseatime.com/blog/detail/ballast-water-management (discussing Australia and Canada's initial push for international ballast water regulation to combat invasive species).

158. Barbara Werschkun ET AL., *Emerging risks from ballast water treatment: The run-up to the International Ballast Water Management Convention*, 112 CHEMOSPHERE 256, 258 (2014), *available at* https://www.sciencedirect.com/science/article/pii/S0045653514005268 (discussing need of global response in tackling ballast water IAS introduction pathway).

159. Puthucherril, *supra* note 147, at 394 (stating when Ballast Water Working Group of MEPC began drafting process of comprehensive ballast water regulation treaty).

tember 8, 2017.[160] The BWMC currently regulates 91.12% of the world's merchant fleet's gross tonnage.[161]

D. Structure, Operation, and Enforcement

1. *Goals and Application*

Parties to the BWMC endeavor "to prevent, minimize and ultimately eliminate the transfer of Harmful Aquatic Organisms and Pathogens through the control and management of ships' Ballast Water and Sediments."[162] The term "Harmful Aquatic Organisms and Pathogens" includes organisms that, if introduced to the disparate location, "*may* create hazards to the environment, human health, property or resources, impair biological diversity or interfere with other legitimate uses of such areas."[163] This definition embraces the precautionary principle by defining IAS to broadly encompass potentially harmful organisms, not just those previously shown to be harmful.[164] This definition could arguably include any alien species to an environment instead of only scientifically-demonstrated IAS, evidencing the BWMC's embrace of the precautionary principle.[165]

The BWMC applies to ships "entitled to fly the flag of a Party" or ships "operat[ing] under the authority of a Party."[166] The BWMC does not apply to warships, naval auxiliaries, ships with permanent supplies of ballast water, and ships only operating within the waters of one Party or international waters.[167] Non-contracting parties to the BWMC can still be subject to the BWMC's terms when

160. *See Ballast Water Convention to Enter into Force in 2017*, MAR. EXEC. (Sept. 9, 2016), https://www.maritime-executive.com/article/ballast-water-convention-to-enter-into-force-in-2017 (reporting on Finland's recent accession to BWMC and eventual entry into force of BWMC).

161. *Status of IMO Treaties*, INT'L MARITIME ORG. (Jan. 7, 2021), https://wwwcdn.imo.org/localresources/en/About/Conventions/StatusOfConventions/StatusOfTreaties.pdf (listing countries and gross tonnage BWMC regulates as of January 7, 2021).

162. BWMC, *supra* note 11, at art. 2.

163. *Id.* at art. 1(8) (emphasis added) (defining Harmful Aquatic Organisms and Pathogens).

164. *See* Puthucherril, *supra* note 147, at 402 (noting precautionary principle and its use in BWMC).

165. *See* McCarraher, *supra* note 127, at 744.

166. BWMC, *supra* note 11, at art. 3(1) (discussing generally ships of contracting parties that must adhere to BWMC). This language is frequently used in maritime treaties. *See, e.g.*, International Convention for the Prevention of Pollution from Ships, Nov. 2, 1973, 12 I.L.M. 1319 (using "entitled to fly the flag of a Party" language to establish Convention's applicability).

167. BWMC, *supra* note 11, at art. 3(2) (providing exemptions to BWMC application to ships).

visiting a Party's port so that they do not receive favorable treatment.[168] For example, if a ship of the United States, a non-contracting party, visited a port in Finland, a Party to the BWMC, Finland would subject the United States ship to the terms of the BWMC as necessary to avoid giving ships of the United States a regulatory advantage.[169] This provision broadly expands the demands of the treaty to those wishing to ship goods to or from contracting Parties.

2. Operation

The BWMC limits IAS intake and release of ballast water through two regulatory standards, D-1 and D-2.[170] The D-1 standard requires ships to exchange their ballast water before reaching their destination port while the D-2 standard requires ships to implement filtering and sterilizing technology to reduce biotic presence in ballast water.[171] Currently, the applicable standard depends on a ship's size and date of construction.[172] Ships constructed after September 8, 2017 must comply with the D-2 standard, and all ships constructed before September 8, 2017 must comply with the D-2 standard by September 8, 2024.[173]

a. D-1 Standard - Ballast Water Exchange Standard

Ships following the D-1 standard are required to exchange their ballast water in the open ocean before reaching their destination port.[174] Regulation D-1 mandates that a ninety-five percent volumetric change in the ballast water constitutes a sufficient ex-

168. *Id.* at art. 3(3) (stating parties must apply some requirements of BWMC to ensure no favorable treatment is afforded to BWMC non-parties).

169. *See* Puthucherril, *supra* note 147, at 396 (using similar example in case of India).

170. *See* BWMC, *supra* note 11, at reg. B-3 (describing vessels must follow requirements of D-1 or D-2 regulations).

171. *See id.* at reg. D-1 (stating efficiency requirements for ballast water exchanges); *id.* at reg. B-4 (requiring ballast water exchanges to be "at least [two hundred] nautical miles from the nearest land and in water at least [two hundred] metres in depth"). *Id.* at reg. D-2 (outlining requirements for ballast water discharges).

172. *Id.* at reg. B-3 (delineating different mandates for vessels under 1500 meters of cubic ballast water capacity, vessels between 1500 and 5000 meters, and vessels with over 5000 cubic meters of ballast water capacity).

173. *See Effective Ballast Water Monitoring*, *supra* note 13; *Industry gets more time to comply with IMO's ballast water management regulation*, IBIA (July 14, 2017), https://ibia.net/2017/07/14/industry-gets-more-time-to-comply-with-imos-ballast-water-management-regulation/.

174. BWMC, *supra* note 11, at reg. B-4(1.1) (requiring ships under D-1 standard to conduct ballast water exchanges at substantial distance and depth).

change.[175] Ships with the ability to actively pump water into their ballast water tanks—as opposed to letting water flow into the ballast water tanks aided by gravity—must pump "three times the volume of each Ballast Water tank" in order to satisfy the standard.[176] The exchanges must occur "at least [two hundred] nautical miles from the nearest land and in water at least [two hundred] metres in depth," if possible.[177] Scientists find the probability of IAS intake at this depth and distance from the coast to be low, making open exchange useful.[178] Similarly, the potentially invasive coastal organisms retrieved at the ship's origin port are unlikely to survive in this open ocean environment.[179] If the ship is not traveling through an area meeting the coastal distance or marine depth requirements, ships can perform their exchange either fifty nautical miles from the shore or in another location the port state and adjacent states agree would satisfy the purposes of the exchange.[180] All exchanges must be recorded in a ballast water record book that can be inspected by a Party at reasonable times.[181]

While the D-1 standard helps to decrease the probability of IAS intake, it has its drawbacks. As noted earlier in this section, ships lacking cargo require ballast water to maintain proper functioning.[182] Emptying a ship's ballast water can be potentially disastrous if done in tempestuous weather conditions.[183] If the exchange is done pursuant to the BWMC during a storm, the severe ocean currents could prevent the rudder and propeller from being submerged and potentially cause the ship to capsize.[184]

175. *Id.* at reg. D-1 (stating sufficient exchanges require exchange of ninety-five percent of ballast water).

176. *Id.* (mandating requirements for ships with ballast water pumping technology).

177. *Id.* at reg. B-4 (stating location requirements for ballast water exchanges).

178. McCarraher, *supra* note 127, at 744-45 (stating species collected in open ocean are unlikely to become invasive).

179. *Id.* (noting scientists find organisms from coast will be unlikely to survive in open ocean environment).

180. BWMC, *supra* note 11, at reg. B-4(1.1), (2) (providing for deviation from requirements when vessel's path does not pass through requisite ocean distance or depth).

181. *Id.* at reg. B-2(5) (describing exchange recording requirements in Ballast Water record book).

182. For a discussion of ballast water's utility in ships free of cargo, see *supra* notes 134-43.

183. *See Ballast water as a vector*, *supra* note 132 (stating ballast is required to ensure proper functioning of rudder and propeller).

184. *See id.* (noting importance of keeping rudder and propeller fully submerged).

Acknowledging this possibility, the BWMC allows ships to avoid the ballast water exchange if the exchange "would threaten the safety or stability of the ship, its crew, or its passengers because of adverse weather, ship design or stress, equipment failure, or any other extraordinary condition."[185] Deviations from BWMC protocol due to an emergency or accident must be recorded in a record book available for inspection by contracting parties.[186] The safety hazards of exchange and the exception permitting ships to avoid exchanging ballast water present a limitation to ballast water exchanges and the need for a safer, more consistent approach found in the D-2 standard.

b. D-2 Standard - Ballast Water Performance Standard

The D-2 standard requires contracting parties to limit the amount of microscopic and non-microscopic living material in their ballast water discharges.[187] Although some living material is permitted to survive discharge, this amount is low and minimizes an IAS's propagule pressure in an environment.[188] To comply with this standard, contracting parties must require the implementation of a Ballast Water Management System (BWMS) on applicable ships to treat ballast water.[189] A BWMS destroys living mollusks, fish, algae, and other ballast-water denizens through mechanical, physical, or chemical means.[190] Treatment can occur through filtration, heat, chemical treatment, electric sterilization, or the use of biocides.[191]

Mariners must be mindful of the potential problems a BWMS can pose.[192] For example, treating ballast water with chemicals can lead to potential pollution concerns when that water is dumped at the destination port.[193] Other treatment methods can be unsafe

185. BWMC, *supra* note 11, at reg. B-4(4).

186. *Id.* at reg. B-4(5) (stating requirements for recording when exchange fails to occur).

187. BWMC, *supra* note 11, at reg. D-2(1) (displaying living organism requirements of ballast water discharges).

188. *See* Atlin, *supra* note 138, at 73 (explaining regulations allowing certain volume of living material to be discharged with ballast).

189. *See* BWMC, *supra* note 11, at reg. D-3 (describing regulations for Ballast Water Management Systems).

190. *See* Atlin, *supra* note 138, at 73-74 (noting methods of BWMS operation).

191. *Id.* at 74 (describing methods of chemical treatment).

192. *See id.* (warning of potential dangers of BWMS systems to crew and environment).

193. *See id.* (noting potential environmental impact of BWMS on environment).

for the ship's crew or damaging to the ship itself.[194] To ensure the ship's BWMS poses no threat to the environment, ship, or crew, the BWMC instructs contracting parties to approve the BWMS if it uses chemicals to destroy organisms.[195]

Contracting parties are responsible for monitoring the discharges of ships within their jurisdictions and ensuring the discharge meets the requirements of the D-2 standard.[196] Ship inspectors must verify the ship does not release its ballast water discharges until they confirm the discharges would satisfy the D-2 standard.[197] The BWMC prohibits using this sampling process, however, to "unduly delay[ ] the operation, movement or departure of the ship."[198] This provision can be problematic if sampling and testing require a large amount of time.[199] The "unduly delay" provision conflicts with enforcement of the provision, preventing inspectors from allowing a ship to discharge ballast water without first ensuring the ballast water satisfies BWMC requirements.[200] Further exacerbating this issue, states that unduly delay ships must pay additional costs, disincentivizing proper sampling and perhaps weakening the enforcement of the treaty.[201] Ultimately, the "unduly delay" provision conflicts with enforcement of the provision preventing inspectors from allowing a ship to discharge ballast water without first ensuring the ballast water satisfies BWMC requirements.[202]

The D-2 standard is expected to be gradually implemented for existing ships within the next four-and-a-half years.[203] Manufacturers have partially alleviated initial concerns that the technology did not exist for an effective BWMS by meeting market demand for the

194. *Id.* (noting potential safety impacts of BWMS on crew and ship).

195. BWMC, *supra* note 11, at reg. D-3 (stating IMO must approve use of active substances used to treat ballast water prior to implementation).

196. *See id.* at art. 9(1) (stating enforcement requirements of contracting parties).

197. *Id.* at art. 9(3) (stating vessels must not release ballast water until inspection confirms operational BWMS).

198. *Id.* at art. 9(1)(c).

199. *See* Puthucherril, *supra* note 147, at 403 (finding "unduly delay[ ]" provision to be major weakness of BWMC).

200. BWMC, *supra* note 11, at art. 9(3) (stating contracting parties must prevent release of ballast water until inspection confirms operational BWMS).

201. *Id.* at art. 9 (delineating enforcement requirements for contracting parties).

202. *See* Puthucherril, *supra* note 147, at 403-04 (criticizing "unduly delay[ ]" provision as potentially limiting enforcement abilities of emergent countries without technological infrastructure to quickly test ballast water for microorganisms).

203. *See Industry Gets More Time*, *supra* note 173 (stating timeline for implementation for of BWMC regime).

systems.[204] Still, costs for a BWMS are high.[205] Installation costs alone can be up to five million dollars per ship, with operational costs of the BWMS potentially running much higher over the ship's lifetime.[206]

3. *Enforcement and Violations Punishment*

The contracting parties to the BWMC are responsible for inspections and sanctioning violators.[207] Contracting parties are required to investigate violations reported by the inspectors of other BWMC parties.[208] After an investigation, if the contracting party determines a violation occurred and there is enough evidence to enforce the BWMC in legal proceedings, then the contracting party is required to sanction the violating party in its own courts.[209] The strength of the sanctions and whether they take criminal or civil form is for the contracting party to determine.[210] Both the party doing the inspection at the port and the party "whose flag the ship is entitled to fly" can enforce the BWMC violating party.[211] There are no described sanctions imposed on parties who fail to enforce the BWMC against violators.[212]

E. Analysis

From a real-world-impact perspective, it is too early to determine the efficacy of the BWMC because implementation of D-2 standard technology is incomplete.[213] Still, commentators have

204. *See* Werschkun ET AL., *supra* note 158, at 258 (discussing initial concern with BWMS and later technological developments allowing shipping industry to meet D-2 standard).

205. *Counting the Cost of Ballast Treatment*, RIVIERA NEWSLETTERS (Mar. 7, 2016), https://www.rivieramm.com/opinion/counting-the-cost-of-ballast-treatment-33924 (suggesting BWMS could cost up to five million dollars per ship and operational costs over one ship's lifetime being higher).

206. *Id.* (suggesting monetary costs of BWMS).

207. BWMC, *supra* note 11, at art. 8 (describing enforcement requirements of contracting parties); *id.* at art. 9 (describing inspection requirements of contracting parties).

208. *Id.* at art. 8(1) (mandating contracting parties report vessels of other states occurring within contracting party's port).

209. *Id.* at art. 8(2) (stating enforcement requirements of party detecting violations).

210. *See id.* at art. 8 (requiring contracting parties prohibit BWMC violations but failing to specify whether sanctions are criminal or civil).

211. *Id.* at art. 10(2) (stating both flagship party and inspecting party may take enforcement actions against violating vessel).

212. *See, e.g.*, BWMC, *supra* note 11, at art. 8 (failing to discuss sanctions for parties failing to enforce BWMC).

213. *See Effective Ballast Water Monitoring, supra* note 13 (noting complete implementation will not occur until 2024).

noted the BWMC's strengths and weaknesses.[214] A contracting party's inability to unduly delay a ship leaves a potential gap that allows ships to evade inspection.[215] Testing procedures could vary depending on the nation and port, and there is concern this vague language could cause some ports to have little inspection power if they cannot test discharges as quickly as other nations.[216] Signatories to the BWMC differ in overall wealth and, because there is no provision distributing funds to emergent nations for ensuring compliance, one commentator suggested emergent nations could have difficulty properly testing ballast water.[217] Much of the rationale for an international treaty was to harmonize international ballast water regulation, but the BWMC allows for nations to create more stringent regulations.[218] The current standards do not provide for complete annihilation of living organisms, leaving the introduction pathway narrow but viable.[219] Additionally, BWMS generally use chemicals to eliminate IAS from ballast water, leading to potential pollution concerns for both natural biota and human life.[220]

Despite these perceived weaknesses, the BWMC is a practical and important first step in limiting IAS infestations through introduction pathway control. Previous binding instruments lacked the detail to provide meaningful regulation to complex introduction pathways.[221] The BWMC is also an implicit embrace of the precautionary principle, providing a tool for the destruction of all alien organisms, not only those scientifically demonstrated to be invasive at the target port.[222] This is in stark contrast with other treaties

214. *See, e.g.*, Puthucherril, *supra* note 147, at 402-05 (weighing strengths and weakness of BWMC); Werschkun ET AL., *supra* note 158, at 259 (explaining usage of active substances in BWMS and their potential role as environmental hazard).

215. *See* Puthucherril, *supra* note 147, at 403-04 (finding "unduly delay" provision to be major weakness in BWMC that might hamper enforcement of BWMC in certain countries).

216. *See id.* (noting not all countries may have infrastructure required to quickly test ballast water samples).

217. *See id.* (criticizing BWMC for lacking provision that would transfer funds from developed nations to emergent nations to ensure proper enforcement of BWMC).

218. *See id.* (stating BWMC allows for nations to adopt more stringent regulations than those required by BWMC).

219. *See* BWMC, *supra* note 11, at reg. D-2 (failing to require complete eradication of indicator organisms to pass BWMC standards).

220. *See* Werschkun ET AL., *supra* note 158, at 259 (explaining usage of active substances in BWMS and their potential role as environmental hazard).

221. For a discussion of previous international attempts to regulate introduction pathways, see *supra* notes 93-127 and accompanying text.

222. *See* Puthucherril, *supra* note 147, at 402 (celebrating BWMC's break from previous legal regimes in embracing environmental precautionary principle by not requiring definitive scientific link between species and potential for harm).

focusing on trade, which tend to favor unfettered trade over environmental precaution.[223] With this, the BWMC possibly foreshadows the precautionary principle's role in future trade regulation. Although there are no sanctions for states who fail to inspect and enforce the standards of the treaty properly, enforcement is split between the port state and the state "whose flag the ship is entitled to fly," decreasing the probability of lax enforcement.[224] Expenses of enforcement, between personnel training and scientific lab equipment, should only run to the tens of thousands of dollars range, which is probably manageable for all contracting parties.[225] Requiring more stringent standards for ballast water treatment would have greatly increased BWMS costs and likely decreased the number of contracting parties.

The BWMC provides reason for optimism for future international IAS regulation, particularly from an introduction pathway perspective.[226] The environment had to wait fourteen years, however, for the treaty to enter into force; this wait is considered long for the maritime industry.[227] One could go back even further, with Canada raising the issue with the IMO in 1988, to compute a wait time of twenty-nine years between the problem being raised at the international stage and the execution of a working solution.[228] This lag time is problematic.[229] Invasions become uncontrollable quickly, and introduction pathways must be closed before other alien organisms have the opportunity to establish themselves in disparate environments.[230]

223. *See, e.g.*, Riley, *supra* note 9, at 7 (stating free trade is usually seen as "end in itself" and not coincident with ecological sustainability).

224. BWMC, *supra* note 11, at art. 10(2).

225. *See, e.g.*, *BW700 Ballast Water Validation Kit*, HACH, https://www.hach.com/bw700-ballast-water-validation-kit/product?id=15808016252 (last visited Apr. 4, 2020) (selling ballast water test kit for $6,253 as of February 12, 2021)).

226. *See* Puthucherril, *supra* note 147, at 402 (celebrating BWMC's regulation of notable introduction pathway through precautionary principle application).

227. *Ballast Water Management Convention: Fifteen years in the making*, LLOYD'S LIST (Aug. 9, 2019), https://lloydslist.maritimeintelligence.informa.com/LL1128592/Ballast-Water-Management-Convention-Fifteen-years-in-the-making (noting considerable wait between BWMC's adoption and entry into force).

228. *See* Jassal, *supra* note 157 (stating Australia and Canada's initial raising of ballast water IAS issues).

229. *See, e.g.*, Riley, *supra* note 9, at 323 (describing explosion of invasive rabbit population in Australia).

230. *See id.* (noting eradication may become impossible once destructive potential of IAS is appreciated).

V. POTENTIAL FUTURE AVENUES FOR REGULATION

Although the BWMC has brought international law one step closer to effective and harmonized introduction pathway regulation, the international treatment of IAS introductions still resembles chaos more than coherence.[231] Marine IAS introductions remain a threat, and the threat of non-Marine IAS introductions is unchanged.[232] This Section discusses and critically analyzes further steps the international community could take to quell introductions.

A. Comprehensive IAS Treaties

With one pathway regulation achieved, one might be tempted to *up the ante* and attempt to regulate numerous pathways in one comprehensive treaty focused on similarities between known pathways. Introducing a treaty narrowing all introduction pathways, instead of a pathway-by-pathway approach, would simplify the IAS issue by establishing controls that would not need to change if a new pathway appeared. This approach would repeat the mistakes of the CBD and is not technical enough to appreciate the complexity of introduction pathways.[233] Even if the convention later promulgated soft law regulations, these would not be binding and countries would have no detailed, technical obligations under the treaty.[234] At best, this approach is superfluous; the CBD currently performs similar functions.[235]

In contrast, one could address each known introduction pathway in one treaty and detail technical obligations for each pathway.[236] This approach would have the benefit of allowing all countries to sign the treaty at once instead of undertaking the treaty process for every single pathway known.[237] Yet, with the com-

231. *See id.* at 322 (admonishing inconsistencies and shortcomings in international IAS legal regime).

232. *See* BWMC, *supra* note 11, at reg. D-2 (failing to require complete eradication of indicator organisms to pass BWMC standards).

233. *See* Riley, *supra* note 9, at 334-37 (criticizing CBD for failure to furnish parties with guidance on how to achieve ambitious outcomes).

234. For a discussion of the CBD's shortcomings in introduction pathway regulation, see *supra* notes 96-109.

235. *See Alien species that threaten ecosystems, habitats or species*, CONVENTION ON BIOLOGICAL DIVERSITY, https://www.cbd.int/decision/cop/?id=7197 (last visited Jan. 31, 2021) (discussing guiding principles for CBD members in combatting introduction and spread of IAS).

236. *See* McCarraher, *supra* note 127, at 757 (suggesting adoption of comprehensive IAS treaty focusing on multiple introduction pathways).

237. *See id.* (suggesting use of one treaty covering multiple pathways).

plexity of the introduction pathways and the amount of known and unknown pathways, a comprehensive treaty managing all major pathways simultaneously is impossible.[238] One commentator suggests such a treaty could contain a provision requiring the parties to address introduction pathways as they become known to scientific understanding.[239] Whether this provision would actually cause the international community to reconvene and limit biological transport through these new pathways is unclear; similar broad instructions in international IAS law are ineffective.[240]

A more practical issue with a comprehensive treaty addressing all introduction pathways arises when considering the broad technical aspects the treaty would cover.[241] Pathways occur in the shipping, pet, and tourism industries, with forms of travel including marine, terrestrial, and aerial mechanisms.[242] Finding a solution to each of these problems in one treaty would require a vast array of technical consultations that would perhaps be unwieldy, even for an international convention. Additionally, one point of contention by an industry could hold up all of the pathway regulations, significantly delaying implementation of pathway regulations. The time gap between the BWMC's adoption and its entry into force was fourteen years.[243] If a treaty attempted to address five pathways at once, it could require even more time to become adopted and then enter into force.[244] With this acknowledged, it would be more expedient to treat each of the major introduction pathways separately rather than attempt to draft one comprehensive multilateral treaty.

Despite the limitations of a comprehensive approach to technical aspects of introduction pathways, the field could benefit from some comprehensive treaties.[245] One major deficiency in the IAS

238. *See, e.g.*, *Pathways of Introduction*, *supra* note 21 (describing numerous types of introduction pathways in Georgia).

239. *Id.* (advocating for provision in comprehensive IAS treaty requiring contracting parties to reconvene and regulate pathways not explicitly managed in initial treaty).

240. *See, e.g.*, CBD, *supra* note 93, at art 8(h) (instructing broadly to prevent alien species introductions).

241. *See, e.g.*, BWMC, *supra* note 11, at reg. D-2 (detailing technical requirements for ballast water emissions).

242. *See* Pathways of Introduction, *supra* note 21 (describing numerous types of introduction pathways in Georgia).

243. *See* Ballast Water Management Convention, *supra* note 227 (stating thirteen-year wait for BWMC to enter into force was unusually long for maritime industry).

244. *See id.* (describing BWMC as among most delayed maritime requirements in memory).

245. *See, e.g.*, Riley, *supra* note 9, at 334-37 (noting inconsistent definitions in international law).

international regime is the lack of a consistent definition of IAS.[246] A term so multitudinously defined presents challenges in drafting and complying with international regulations.[247] For example, some definitions focus mainly on the economic impacts of IAS rather than their impact on global biodiversity.[248] As the commercial sector and environmentalism have different objectives, an emphasis on economic impacts appears in trade agreements while environmental agreements stress biodiversity.[249] Similarly, industries have variable terms for IAS and non-IAS to fit their own objectives, including "exotic, alien, indigenous, native, non-indigenous, nonnative, as well as 'invasive alien.'"[250] Establishing a single definition and term that would consider all consequences of IAS introductions could help harmonize enforcement and guide future treaties.[251]

A comprehensive liability system for parties causing IAS introductions could also be treated in a single treaty. One criticism of the BWMC was the lack of a liability system that would compel "polluters" to pay for their IAS introductions.[252] In theory, developing a liability system would encourage contracting parties and their industries to police their own introduction pathways, and an IAS liability regime could complement the existing IAS pathway framework.[253] Importers and exporters could buy insurance to protect against the economic cost of a large-scale bioinvasion.[254]

Creating a liability regime, however, has its drawbacks. First, determining liable parties is exceedingly difficult because there is typically a substantial lag time between species introduction and a

246. *See id.* (stating lack of acceptable IAS definition is major deficiency in international IAS regime).

247. *See id.* at 326-27 (encouraging international community to settle on single definition for IAS).

248. *See id.* (noting conflict between commercial and environmental interests when one species is termed resource by commercial sector but IAS by environmental sector).

249. *See, e.g.*, CBD, *supra* note 93, at art. 8(h) (prohibiting introduction of alien species that threaten ecosystem and ecosystem's native species).

250. *See* Riley, *supra* note 9, at 331-34.

251. *See id.* at 326-27 (encouraging international community to find single definition for IAS).

252. *See* Puthucherril, *supra* note 147, at 403 (discussing lack of mitigation and liability for entities who accidentally introduce IAS into foreign ecosystems).

253. *See* Bright, *supra* note 3, at 207 (arguing polluter-pays approach is core principle that should govern accidental IAS introductions).

254. *See* Simberloff, *supra* note 1, at 173 (noting one method to compensate victims of species invasions would require importers and others using introduction pathways to purchase liability insurance for potential introductions).

bioinvasion.[255] Second, negligence is not the sole cause of IAS introductions.[256] For example, a party complying with the BWMC could theoretically still transfer organisms in its ballast water because standards permit BWMS that do not completely sterilize water.[257] Holding a compliant party strictly liable would hinder international cooperation by creating significant financial disincentives to join IAS-control regimes.[258]

Costs of invasion control due to accidental introductions could be addressed through other methods that are proactive and do not necessarily place liability on one party. For example, a treaty could levy taxes on all importers and exporters as a class and the revenue from this tax could be distributed to countries currently attempting to control a bioinvasion.[259] As this would apply to the industry as a whole, however, it would not necessarily encourage individual importers and exporters to close introduction pathways.[260] This tax system could also constitute a tariff because it would be placing a tax on foreign shipping but not domestic shipping.[261] A proactive tax system, therefore, could run afoul of the GATT and WTO.[262] All in all, these comprehensive ideas, while well-intentioned, will alone not sufficiently ameliorate introductions.

B. Pathway-Specific Treaties

The BWMC is evidence the international community can unite and narrow individual introduction pathways. One conspicuous marine pathway that could be regulated in a method similar to ballast water is hull fouling.[263] Hull fouling occurs when organisms

255. *Cf.* Riley, supra note 9, at 323 (describing explosion of invasive rabbit population in Australia).

256. *See id.* at 330 (stating accidental introductions are "at best, motiveless or, at worst, negligent").

257. *See* BWMC, *supra* note 11, at reg. D-2 (failing to require complete eradication of indicator organisms to pass BWMC standards).

258. *See id.* (suggesting bioinvasion still possibility even when conforming to requisite standard of care).

259. *See* Simberloff, *supra* note 1, at 173 (suggesting tax on importers could compensate those controlling IAS outbreaks).

260. *See* Bright, *supra* note 3, at 207 (arguing polluter-pays approach is core principle that could discourage introductions).

261. *See Tariff*, WEBSTER'S NEW COLLEGIATE DICTIONARY (1977) (defining tariff as duties "imposed by a government on imported or in some countries exported goods").

262. *See* Riley, *supra* note 9, at 334 (noting general restriction on tariffs and trade restrictions).

263. *See* Simberloff, *supra* note 1, at 37. The hull is the watertight enclosure around a ship, protecting the ship from the outside water. *See What Is The Hull Of A Ship?*, MARITIME MANUAL (last updated July 5, 2019), https://

accumulate on a ship's hull and are transported with the ship as it enters into a new environment.[264] For example, the sea lamprey was transferred on a ship's hull to the North American Great Lakes in the nineteenth century, causing the extinction of three native fish species.[265] Anti-fouling the vessel is possible with the use of chemicals, paints, and treated surfaces that interfere with an organism's ability to attach to the hull.[266] The need to encourage anti-fouling through an international treaty, however, is potentially unnecessary because fouled hulls reduce fuel efficiency and speed.[267] Shippers are economically encouraged to anti-foul their hulls in order to improve ship performance.[268] The 2001 International Convention on the Control of Harmful Anti-fouling Systems on Ships also addresses hull fouling, but the treaty is mainly concerned with controlling anti-fouling chemicals that could threaten marine life.[269] 2011 IMO Guidelines present a more sophisticated approach to controlling fouling of niche vessel areas, like propellers and shafts, that shippers are not inclined to clean for economic reasons, which could narrow this IAS pathway more if made mandatory.[270]

Intentional introductions, like those in the exotic pet or agriculture industries, could also be regulated through an international framework.[271] Modeling IAS treaties after the Cartagena Protocol—the previously-discussed treaty regulating the transport of organisms with artificially-adjusted genetics—would establish a regime requiring importers to contact a relevant authority of the exporter so that they could review the proposed importation for

www.maritimemanual.com/hull-of-a-ship/ (defining hull and explaining hull's purpose in vessel).

264. James Kraska & Daniel Rittschof, *Toward a Global Regime of Vessel Anti-Fouling*, 26 DUKE ENVTL. L. & POL'Y F. 53, 54 (2015) (describing hull fouling generally).

265. *See* Simberloff, *supra* note 1, at 37 (stating sea lamprey traveled to North American Great Lakes on fouled hull and caused extinction of several local fish species).

266. *See* Kraska & Rittschof, *supra* note 264, at 55 (stating methods used to limit organism attachment to hulls.

267. *See id.* at 54 (stating hull fouling's effect on vessel's drag on fuel performance).

268. *See id.* (noting economic disadvantages of fouled hull).

269. *See id.* at 59-60 (describing purposes and history of IMO's Anti-Fouling Convention).

270. *See id.* at 63 (describing aims of 2011 IMO hull fouling guidelines).

271. *See* McCarraher, *supra* note 127, at 751 (noting potential role of international regulation in controlling intentional releases of IAS).

hazards to biodiversity.[272] If the importer believes the attempted export could cause harm to biodiversity, the exporter could reject the proposed importation of the exotic species.[273] Using the precautionary principle, the exporter could reject the importation if the lack of scientific certainty of an LMO's invasive potential is insufficient to determine the potential for invasiveness.[274] This proposed Cartagena-Protocol-like intentional introduction treaty differs from instruments focused on unintentional introduction pathways because the organism is not a hitchhiker but the commodity itself.[275] An intentional introduction pathway treaty, therefore, must be mindful of the requirements of the WTO.[276] Using the environmental precautionary principle in an intentional introduction pathway setting could be impossible unless the SPSA were renegotiated to include an exception for exotic organisms.[277]

Unfortunately, the BWMC could give the international community a false sense of optimism. Finding solutions to other notorious pathways is significantly more difficult.[278] One major introduction pathway, containerized shipping, presents a quandary for IAS regulation.[279] Hitchhiking organisms in sealed shipping containers remain concealed for long periods of time, making it challenging for inspectors to determine the organism's presence.[280] Inspectors could open containers randomly or routinely, but this is considered a time-consuming, laborious, and inefficient process.[281] Inspectors currently use imaging techniques, but these typically

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272. *See* Riley, *supra* note 9, at 331-34 (delineating requirements of Cartagena Protocol).

273. *See* McCarraher, *supra* note 127, at 753-54 (suggesting use of Cartagena Protocol as template for intentional introduction pathway regulation).

274. *See id.* (noting Cartagena Protocol's embrace of environmental precautionary principle).

275. *See* Hulme, *supra* note 22, at 14 (describing forms of intentional and accidental introduction pathways).

276. *See* McCarraher, *supra* note 127, at 754-55 (noting potential conflicts with WTO's trade requirements).

277. *See* Bright, *supra* note 3, at 211 (discussing conflicts between WTO, SPSA, and IAS pathway controls).

278. *See* Marchioro ET AL., *supra* note 14, at 1718 (describing threat of alien arthropod transfer via containerized shipping).

279. *See* Brierley, *supra* note 25 (suggesting package shipping caused accidental transmission of Asian giant hornets to Northwestern United States).

280. Amitrajeet A. Batabyal & Seung Jick Yoo, *Some Statistical Properties of a Generic Container Inspection Policy in Invasive Species Management*, 60 ECOLOGICAL ECON. 1, 1-2 (2006) (describing difficulties related to detection of alien hitchhikers in containerized shipping).

281. Vadim Simonenko & George Stanford, Nuclear Shadowboxing: Legacies and Challenges, APPENDIX VE-2 (2004).

only detect material contraband, not biological hitchhikers.[282] A full treatment of potential containerized shipping inspection methods to narrow this introduction pathway is outside the scope of this Article, but the conundrum suggests previously applied solutions are not available for all pathways.[283]

C. Species-Specific

Another alternative non-comprehensive approach to introduction pathway management is to focus on eliminating specific species in an introduction pathway that authorities believe might become invasive if introduced into an ecosystem. As stated at the outset, not all alien species will become invasive in an introduced environment.[284] Magnifying the effort on potentially-invasive organisms could be useful in clearing introduction pathways. For example, instead of attempting to remove all insects from containers, inspectors could spray containers with specialized pesticides designed only to harm the potentially invasive organisms. A species-specific approach, in theory, would allow the regulation of introduction pathways without resorting to active substances that could pose a threat to native organisms or human life.

Although biologists once bemoaned the unpredictability of bioinvasions, modern science has made invasion biologists optimistic.[285] In one instance, species that become invasive in one ecosystem are likely to become invasive in other similar ecosystems.[286] Biologists can also use traits of the species themselves, such as "size, means of dispersal, or rate of reproduction" to determine a species's potential for becoming invasive.[287] New Zealand and Australia already use an assessment program to determine the likelihood that certain species will become invasive.[288] Establishing an inter-

282. *See id.*

283. *See* Marchioro ET AL., *supra* note 14, at 1723 (using novel light trap technique to attempt to catch hitchhiking arthropods in shipping containers). *See also* Brierley, *supra* note 25 (suggesting package shipping caused accidental transmission of Asian giant hornets to Northwestern United States).

284. *See* Simberloff, *supra* note 1, at 26-27 (stating approximately ten percent of introduced species become invasive in new environment).

285. *See id.* at 145 (extolling recent increase in scientific analyses in determining potential of invasiveness and suggesting reason for optimism).

286. *See id.* at 147 (noting scientists expected one pine species to become invasive in environment when pine species was observed to be invasive in other ecosystems).

287. *See id.* at 146 (explaining use of species traits in determining probability of invasion for given alien organism).

288. *Id.* at 149-51 (detailing Australian and New Zealand risk assessment tools used in defending against pests and IAS).

national system or communication with countries with similar ecosystems will assist states in targeting organisms for elimination.

Limitations in modern understanding, however, prevent this strategy from being a universal solution to comprehensive IAS pathway reform.[289] Lag times between the introduction of a species and the species becoming invasive in some invasions will limit the application of this preventive species-specific system.[290] By the time a species becomes invasive in one ecosystem, the species might already have a foothold in another ecosystem. Species distribution prediction models have also sustained scientific criticisms for focusing too much on certain climatic factors while ignoring the harder-to-quantify interspecies interactions.[291]

Another contention with a species-specific approach is that these approaches are short-term solutions that distract from the long-term introduction pathway problem.[292] In particular, a species-specific approach is unhelpful when the threat of invasion or the species itself is unknown.[293] Despite scientific improvement in invasion biology, biologists cannot reasonably compile the potential invaders in every ecosystem internationally. Similar to comprehensive and pathway-specific approaches, species-specific approaches cannot provide a complete solution.

VI. CONCLUSION

Increasing trade and travel between nations has led to the deliberate and inadvertent introduction of organisms into novel environments. While some of these introductions are harmless or beneficial, others lead to negative impacts on biodiversity and the economy. With the international scope and cause of the issue, there have been attempts to find international solutions through treaties regulating introduction pathways. The first of these pathway regulations was the BWMC, focusing on exchanging and man-

289. Pyšek & Richardson, *supra* note 26, at 27 (summarizing scientifically disputed factors relating to invasive potential of species).

290. Simberloff, *supra* note 1, at 148 (noting one major limitation of invasive species predictions is lag time between alien species arrival and invasion).

291. *See id.* at 154-55 (noting factors usually ignored by species invasiveness potential assessments and difficulty in quantifying these environmental and species traits).

292. *See* Riley, *supra* note 9, at 342-43 (criticizing species-based approaches as failing to address existence of introduction pathways and necessity of limiting organism introductions through pathways).

293. *See id.* (noting species-based approaches fail to adequately tackle unknown species or species with unknown invasion potential).

aging ballast water to ensure organisms in the ballast water do not enter new environments.

This Article critically analyzed the BWMC. Although fourteen years elapsed between its adoption and entry into force, the BWMC is indisputably a step forward in narrowing introduction pathways. Standards requiring the exchange of ballast water are currently in force, ensuring a limited transfer of organisms into novel environments. In the next few years, standards will require the installation of technology that will cleanse ballast water and destroy most ballast water organisms without causing harm to the environment, ship, or crew. While the BWMC is promising, other pathways have less intuitive tactics for control, and there are limitations to other proposed control regimes that are not specific to pathways.

The total elimination of species introductions is impossible. Agreements intent on quashing the introduction pathway problem will inevitably disappoint. In the present age, with our travels, commerce, and industry, some species will migrate using human-made mechanisms. Nonetheless, introduction pathway regulation remains more than a Sisyphean endeavor. This Article advises the international community to continue the search for a solution to organism introductions. Only with a sense of science and pragmatism will the international community confront these globe-trotting foes.