ARTICLES

A COMPREHENSIVE SOLUTION TO THE BIOFOULING PROBLEM FOR THE ENDANGERED FLORIDA MANATEE AND OTHER SPECIES

BY

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Biofouling is the undesirable accumulation of microorganisms, plants, algae, arthropods, or mollusks on a surface, such as a ship's hull, when it is in contact with water for a period of time. Biofouling and its traditional remedies pose serious environmental consequences, including 1) the transportation of nonindigenous aquatic species that can outcompete with native species for space and resources, thereby reducing biodiversity and threatening the viability of fisheries or aquaculture, 2) the accumulation of zinc- or copper-based toxins that can harm mollusk and marine mammal populations, and 3) the increase in weight, decrease in flexibility and mobility, and topical damage of marine mammals hosting biofouling organisms. There are a number of existing legal mechanisms that address biofouling under international law. However, due to the complexity of biofouling, we argue that existing mechanisms are inadequate for comprehensively regulating the problem, leaving aquatic species susceptible to numerous negative effects from biofouling. Specifically, the existing mechanisms fail to recognize the optimal factors for biofouling development

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*and adhesion, make recommendations to manage biofouling through design standards for marinas and harbors, provide standards for biofouling removal, or detail measures to treat high-risk vessels. To address these inadequacies, we recommend biofouling also be mitigated under the federal Endangered Species Act (ESA). First, we consider the Florida manatee (*Trichechus manatus latirostris*) as a case study species, and suggest that Florida's Resource Conservation and Development (RC&D) areas develop a Safe Harbor umbrella agreement under section 10 of the ESA to create a new generation of ecological harbors that are safe from the dangers of biofouling. The agreement would include a Habitat Conservation Plan (HCP) that incorporates a combination of behavioral and infrastructural biofouling mitigation techniques to be applied regionally across estuary, freshwater, and saltwater ecosystems. Second, we suggest that both public and private owners of existing, proposed, and expanding marina developments be encouraged to voluntarily sign Safe Harbor Agreements under the RC&D areas' umbrella agreement to avoid owners having to navigate the long and strenuous process of obtaining individual HCPs. The comprehensive biofouling management strategy proposed as a model here would require RC&D areas to carry out a range of biofouling best management practices that would protect species and the habitats on which they depend from the adverse effects of biofouling. It would also encourage public and private landowners to follow suit, while maintaining efficiency and rewarding participating landowners for voluntarily implementing additional species conservation practices. In addition, there are several implications for the urban planning processes surrounding marina construction and expansion. If implemented, urban planners and land use attorneys will be expected to proactively lead interdisciplinary collaborations between developers, engineers, biologists, and municipal and state representatives during the marina site selection phase to an unprecedented degree. Planners and land use attorneys will then bring together information obtained from all parties to determine which site is the most economically, biologically, legally, and structurally feasible for the client, and has the greatest potential to minimize the negative effects of biofouling on surrounding ecosystems.*

I. INTRODUCTION

The purpose of the federal Endangered Species Act of 1973 (ESA)[1] is "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, to provide a program for the conservation of such endangered species and threatened species, and to take such steps as may be appropriate to achieve the purposes" of a number of international conservation treaties and conventions.[2] This language highlights the interconnection between ecosystems and species; in order to conserve a listed species, we must protect the critical bionetwork on which it depends.[3] Therefore, the ESA incidentally protects endangered *ecosystems* through its focus on listed species that, if destroyed, will result in a disastrous loss of biodiversity.[4] In essence, listed species have become indicators for the health of entire endangered ecosystems.[5] For instance, given the purposes of the ESA, endangered species like the Florida manatee (*Trichechus manatus latirostris*)[6] are a barometer for the degrading health of estuary, freshwater, and saltwater ecosystems.[7]

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1 16 U.S.C. §§1531–1544 (2006 & Supp. IV 2010).

2 *Id.* § 1531(b).

3 *See* Craig Segall, Taking Evolution Seriously: Species Concepts, the Endangered Species Act, and the Future of Biodiversity Law 11 (May 8, 2004) (unpublished B.S. thesis, University of Chicago) (on file with the University of Chicago's Program on the Global Environment).

4 *Id.* at 3 (citing SHANNON PETERSEN, ACTING FOR ENDANGERED SPECIES: THE STATUTORY ARK 30–35 (2002)).

5 *Id.* at 1; SHANNON PETERSEN, ACTING FOR ENDANGERED SPECIES: THE STATUTORY ARK 123 (2002).

6 Florida manatees are marine mammals and primarily herbivores. U.S. Fish & Wildlife Serv., *Species Profile: West Indian Manatee (*Trichechus Manatus*)*, http://ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=A007 (last visited Apr. 7, 2012). Florida manatees are commonly found in coastal waters, estuaries, and freshwater bodies. *Id.* Their low metabolic rate does not protect them in cold water. FLA. FISH & WILDLIFE CONSERVATION COMM'N, FLORIDA MANATEE MANAGEMENT PLAN: TRICHECHUS MANATUS LATIROSTRIS 2 (2007), *available at* http://www.myfwc.com/media/415297/Manatee_MgmtPlan.pdf. Therefore, in the cold fall and winter months, Florida manatees migrate to shallow water, warm river springs, and areas near power plants

Specifically, this Article contends that the Florida manatee and other bellwether aquatic species have become "canaries in a coal mine,"[8] providing early warning of the dangers biofouling has imposed, and will continue to impose without further intervention, on these ecosystems. Due to the complexity of biofouling, we argue that existing mechanisms are inadequate for comprehensively regulating the problem, thereby leaving Florida manatees and other species susceptible to numerous negative effects from biofouling. A significant gap remains between the existing mechanisms in the management of biofouling associated with barges and associated support vessels, fishing vessels, and recreational craft. In addition, the existing mechanisms fail to 1) recognize the optimal factors for biofouling development and adhesion, 2) make recommendations to manage biofouling through design standards for marinas and harbors, 3) provide standards for biofouling removal, or 4) detail measures to treat high-risk vessels.

To address these inadequacies, we argue in this Article that biofouling should also be mitigated under the ESA, a statute which requires the government to protect listed endangered and threatened plant and animal species, as well as the habitats upon which they depend as necessary to prevent the taking of or harm to listed species.[9] First, considering the Florida manatee as a case study species, we

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where water used as a coolant is released at a higher temperature. *Id.* Because Florida manatees are rarely attacked by natural predators—like sharks, alligators, or crocodiles—their predominant causes of death are hypothermia during the winter months, collisions with the propellers of recreational watercrafts, habitat destruction and degradation, becoming trapped in flood gates and navigation locks, and becoming tangled in fishing lines or crab traps. *E.g.*, *id.* at 7, 145; Sea World et al., *Manatees: Longevity & Causes of Death*, http://www.seaworld.org/animal-info/info-books/manatee/longevity.htm (last visited Apr. 7, 2012). Although the Florida manatee is currently classified as "endangered" at the federal level, the Florida Fish and Wildlife Conservation Commission downgraded the manatee's status to "threatened" in Florida in June 2006, much to the disappointment of many conservation advocates. U.S. Fish & Wildlife Serv., *supra*; FLA. FISH & WILDLIFE CONSERVATION COMM'N, *supra*, at iii–iv. However, none of the state laws protecting Florida manatees have been changed to reflect the Florida manatee's downgraded status at the state level and they still remain listed at the federal level. *See id.*

7 *See, e.g.*, PETERSEN, *supra* note 5, at 123 (contending that the level to which biodiversity is maintained is an indication of the extent to which an ecosystem can remain stable and natural resources can be sustained).

8 Historically, "[m]iners used to carry canaries into mines as an early warning indicator of dangers to humans from methane gas. If the canary died, the miners were alerted that their own lives were in danger." Zygmunt J.B. Plater, *In the Wake of the Snail Darter: An Environmental Law Paradigm and Its Consequences*, 19 U. MICH. J.L. REFORM 805, 812 n.24 (1986). The precarious existence of the endangered snail darter in the Little Tennessee River Valley, the subject of the landmark ESA case of *Tennessee Valley Authority v. Hill*, 437 U.S. 153 (1978), likewise was referred to as "a canary in a coal mine." *Id.* at 812. In and of itself, the snail darter might have little importance except to those few who appreciate its natural beauty. However, the snail darter was a sensitive species that, by its endangerment in the Little Tennessee River Valley, acted as a "barometer" for the health of the ecosystem. *Id.* Ecologically, these types of species are commonly referred to as "indicator species." U.S. Envtl. Prot. Agency, *Biological Indicators of Watershed Health: Indicator Species*, http://www.epa.gov/bioiweb1/html/indicator.html (last visited Apr. 7, 2012) ("Biological indicator species are unique environmental indicators as they offer a signal of the biological condition in a watershed.").

9 U.S. Envtl. Prot. Agency, *Pesticides: Endangered Species Protection Program*, http://www.epa.gov/espp/ (last visited Apr. 7, 2012). The definition of "take" under the ESA includes "significant habitat modification or degradation that actually kills or injures wildlife." *Babbitt v. Sweet Home Chapter of Comtys. for a Great Or.*, 515 U.S. 687, 708 (1995) (quoting the Secretary's

suggest that Florida's Resource Conservation and Development (RC&D) areas[10] develop a Safe Harbor umbrella agreement under section 10 of the ESA to create a new generation of ecological harbors that are *actually* safe from the dangers of biofouling.[11] The agreement would include a Habitat Conservation Plan (HCP)[12] that incorporates a combination of behavioral and infrastructural biofouling mitigation techniques to be applied regionally across estuary, freshwater, and saltwater ecosystems.

Second, we suggest that both public and private owners—for example, state governments, municipalities, and private marina developers—of existing, proposed, and expanding marina developments be encouraged to voluntarily sign Safe Harbor Agreements (SHAs)[13] under the RC&D areas' umbrella agreement to avoid owners

construction of "take"); *see* Endangered Species Act of 1973, 16 U.S.C. § 1532(19) (2006) (including "harm" in the definition of "take"); 50 C.F.R. § 17.3(c) (2010) (expanding on the definition of "harm" within the definition of "take"). 50 C.F.R. § 17.3 is also known as the U.S. Fish and Wildlife Service's Harm Rule. *See, e.g.*, Eric S. Laschever, *The Endangered Species Act and Its Role in Land Use Planning: Lessons Learned from the Pacific Northwest*, 1 SEATTLE J. ENVTL. L. 103, 105 n.6 (2011).

[10] RC&D program's purpose is "to accelerate the conservation, development and utilization of natural resources, improve the general level of economic activity, and to enhance the environment and standard of living in designated RC&D areas." Natural Res. Conservation Serv., U.S. Dep't of Agric., *Resource Conservation & Development Program*, http://www.fl.nrcs.usda.gov/programs/flrcd.html (last visited Apr. 7, 2012). The RC&D program, originally implemented pursuant to section 102 of the Food and Agricultural Act of 1962, Pub. L. No. 87-703, § 102, 76 Stat. 605, 607–08, and currently utilized under the Farm Security and Rural Investment Act of 2002, Pub. L. No. 107-171, 116 Stat. 134, was developed to promote and enhance joint natural resource conservation efforts between state and local governments and nonprofit organizations in rural locales. NATURAL RES. CONSERVATION SERV., U.S. DEP'T OF AGRIC., FARM BILL 2002: RESOURCE CONSERVATION AND DEVELOPMENT PROGRAM 1 (2004), *available at* http://www.coralreef.gov/grants/nrcs/Res_Conserv_Dev_ProgDesc.pdf; *see also* Univ. of the Big Bend, *Program Description: General Information*, http://www.sulross.edu/pages/3566.asp (last visited Apr. 7, 2012). Florida's RC&D program includes the following areas: Florida Three Rivers, West Florida, Suwannee River, Central Florida, Florida West Coast, South Florida, and Treasure Coast. Res. Conservation & Dev. & Rural Land Div., *RC&D Councils Map: Resource Conservation and Development Areas*, http://www.rcdnet.org/storage/maps/map.html (last visited Apr. 7, 2012); FLA. ASS'N OF RESOURCE CONSERVATION & DEV. COUNCILS, FLORIDA ASSOCIATION OF RESOURCE CONSERVATION AND DEVELOPMENT COUNCILS 2, *available at* https://docs.google.com/viewer?a=v&q=cache:FHLNVmIbTbIJ:farcdc.org/State_Association_Overview%2520of%2520accomplishments%255B1%255D.pdf+&hl=en&gl=us&pid=bl&srcid=ADGEESj0ASfw-m358qIzgQwuj6TlCKY_S5g9_TgQ1F6_9oZN0Y73sphneHb-pFV6RJXWOxaFAs40Giz6qalJC8BgwfOIWezGaeiPBxFkr5wvRdY1f7IkaI91kFDka6d7O9w0Vm8Bm3VF&sig=AHIEtbRztaUpbhSS4CDgsLr1uKBzHABSJQ (listing all 11 RC&D areas in Florida).

[11] *See* 16 U.S.C. § 1539 (2006); Final Rule for Safe Harbor Agreements and Candidate Conservation Agreements with Assurances, 64 Fed. Reg. 32,706, 32,707 (June 17, 1999) (to be codified at 50 C.F.R. pts. 13, 17); Announcement of Final Safe Harbor Policy, 64 Fed. Reg. 32,717, 32,717 (June 17, 1999); Final Policy for Candidate Conservation Agreements with Assurances, 64 Fed. Reg. 32,726, 32,735 (June 17, 1999).

[12] *See* Notice of Final Handbook Availability, 61 Fed. Reg. 63,854, 63,855 (Dec. 2, 1996); *see also* Notice of Draft Addendum to the Final Handbook, 64 Fed. Reg. 11,485, 11,485 (Mar. 9, 1999) (providing additional clarifying guidance to agencies conducting the incidental take program).

[13] Final Rule for Safe Harbor Agreements and Candidate Conservation Agreements with Assurances, 64 Fed. Reg. at 32,706; Announcement of Final Safe Harbor Policy, 64 Fed. Reg. at 32,717; Final Policy for Candidate Conservation Agreements with Assurances, 64 Fed. Reg. at 32,726.

having to navigate the long and strenuous process of obtaining individual HCPs.[14] This strategy would require RC&D areas to carry out a range of biofouling best management practices that would protect Florida manatees and their habitat from the adverse effects of biofouling. It would also encourage public and private landowners to follow suit, while maintaining efficiency and rewarding participating landowners for voluntarily implementing additional Florida manatee conservation practices.[15]

This Article is organized in the following manner. First, Part II addresses the causes, conditions, and global consequences of biofouling. Part III then examines the local direct and tangential implications of biofouling on Florida manatees as a case study species, specifically how fouling organisms, pollutants from antifouling coatings, and nonindigenous aquatic species (NIAS) can affect Florida manatee health and habitat. Next, Part IV presents the international legal mechanisms[16] that currently aim to address the biofouling problem and explains why they are inadequate. Part V explains the obligations to protect Florida manatees and their habitat under the ESA. Part VI goes on to detail how Florida's RC&D areas, as well as public and private marina owners, can and should mitigate the effects of biofouling on Florida manatee health and habitat through improving marina design, marina site selection and marina infrastructure, as well as incorporating the use of vessel management techniques and educational and outreach programs under section 10 of the ESA. The strategy recommended here can also serve as a model for other states to better protect their own ecosystems, along with endangered mollusk and marine mammal populations, from the negative effects of biofouling.

Part VII discusses mitigation techniques and implementation strategies that have been executed or proposed under section 10 of the ESA that are analogous to those proposed in this Article. Specifically, this Part discusses HCPs and SHAs that are proposed or enacted that likewise combine public–private efforts; employ behavioral and infrastructural mitigation techniques; are implemented regionally; or protect estuary, freshwater, and saltwater ecosystems. Finally, the Article concludes by discussing the substantial need, given the gaps in existing international regulations, for marina owners to implement a combination of behavioral and infrastructural changes under section 10 of the ESA. We argue that these changes will effectively address the impacts of biofouling on Florida manatees, as well as other endangered species, and the ecosystems on which they depend.

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14 *See* Colleen Schreiber, *Gulf Coast Rancher Signs on to Safe Harbor Agreement*, LIVESTOCK WKLY., May 27, 1999, http://www.livestockweekly.com/papers/99/05/27/whlmccan.asp (last visited Apr. 7, 2012).

15 *See id.*

16 *E.g.*, International Conference on Ballast Water Management for Ships, Feb. 9–13, 2004, *Adoption of the Final Act and Any Instruments, Recommendations and Resolutions Resulting from the Work of the Conference*, Annex, *International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004*, IMO Doc. BWM/CONF/36, at 1 (Feb. 16, 2004), *available at* http://www.bsh.de/de/Meeresdaten/Umweltschutz/Ballastwasser/Konvention_en.pdf [hereinafter Ballast Water Convention]; International Convention on Control of Harmful Anti-Fouling Systems on Ships, 2001, Oct. 5, 2001, S. TREATY DOC. NO. 110-13 (2008), *available at* http://www.gc.noaa.gov/documents/afs_senate_treaty_110-13_1.22.08.pdf [hereinafter AFS Convention].

II. CAUSES, CONDITIONS, AND GLOBAL CONSEQUENCES OF BIOFOULING

Biofouling is the undesirable accumulation of microorganisms, plants, algae, arthropods, or mollusks to a surface, like a ship's hull, when it is in contact with water for a period of time.[17] Organisms do not stick directly to a substrate;[18] biofouling must begin with the production of biofilm to which the biofouling organisms then adhere.[19] Biofilm can consist of bacteria, such as *Thiobacilli* ; diatoms;[20] seaweed; or phytoplankton productivity.[21] Biofilm formation depends on favorable conditions for growth and attachment, which may vary regionally.[22] Both biofilm growth and attachment are greatly impacted by relative productivity,[23] biofilm organism concentration, water temperature, pH, and water velocity past the substrate.[24]

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17 *See* THOMPSON LENFESTEY, THE SAILOR'S ILLUSTRATED DICTIONARY 177 (2004).

18 A "substrate" is a "surface on which plants or animal grows or is attached." WEBSTER'S NEW COLLEGE DICTIONARY 1126 (3d ed. 2008). Therefore, a ship hull is a common substrate for a fouling organism such as a barnacle.

19 John D. Zardus et al., *Microbial Biofilms Facilitate Adhesion in Biofouling Invertebrates*, 214 BIOLOGICAL BULL. 91, 91 (2008), *available at* http://www.biolbull.org/cgi/reprint/214/1/91.pdf.

20 Diatoms, or *Bacillariophyta*, are microscopic, single-celled or colonial plant-like organisms. Their cell walls are made of silicon dioxide. Microscopy–UK, *Diatoms*, http://www.microscopy-uk.org.uk/mag/wimsmall/diadr.html (last visited Apr. 7, 2012); Univ. of Cal. Museum of Paleontology, Univ. of Cal., Berkeley, *Introduction to Bacillariophyta (The Diatoms)*, http://www.ucmp.berkeley.edu/chromista/bacillariophyta.html (last visited Apr. 7, 2012).

21 Kathleen D. Oppenheimer, Indicators of Biofilm Development and Adhesion in Subtropical and Tropical Oligotrophic Waters 2 (Mar. 15, 2005) (unpublished undergraduate research project, Sea Education Association) (on file with *Environmental Law*). Organisms that constitute biofilm include diatoms and phytoplankton productivity in this context. *Id.* at 1–2.

22 *Id.* at 2.

23 Relative productivity can be deduced by measuring in-vivo fluorescence, chlorophyll-a levels, and the total diatom counts in a sample. The higher the amount of in-vivo fluorescence, quantity of chlorophyll-a, and diatom count in a sample, the more productive the water body from which the sample was taken. *See id.* at 4 (measuring in-vivo fluorescence and chlorophyll-a levels and taking phytoplankton 100 counts as indicators of the relative productivity at each surface station); Amy Leventer et al., *Holocene Marine Diatom Records of Environmental Change*, *in* THE DIATOMS: APPLICATIONS FOR THE ENVIRONMENTAL AND EARTH SCIENCES 401, 402, 403 tbl.21.1 (John P. Smol & Eugene F. Stoermer eds., 2d ed. 2010) (indicating that total diatom counts are reflective of productivity levels).

24 Bacterial and diatom components of biofilm are most viscous and adhesive within warmer waters having a pH between seven and nine. *See, e.g.*, Jayaraman Muralidharan & Seetharaman Jayachandran, *Physicochemical Analyses of the Exopolysaccharides Produced by a Marine Biofouling Bacterium,* Vibrio Alginolyticus, 38 PROCESS BIOCHEMISTRY 841, 846 fig.8 (2003) (demonstrating that the bacterial components of biofilm are most adhesive within water having a pH between seven and nine); William G. Characklis, *Microbial Fouling*, *in* BIOFILMS 523, 551, 560, 563 (William G. Characklis & Kevin C. Marshall eds., 1990) (demonstrating in Figures 14.9, 14.14, 14.17, and 14.26 and the accompanying captions that 1) the accumulation and thickness of biofilm increases as temperature increases, 2) water flowing at a magnitude greater than 0.1 meters per second lessens the thickness and adhesion of biofilm while a magnitude of flow less than 0.1 meters per second sacrifices the production levels, and 3) biofilm thickness occurs in water with a pH of approximately seven). The accumulation of biofilm on a substrate increases as temperature increases. *See, e.g.*, *id.* In addition, research suggests that fouling bacterium achieve maximum thickness and adhesion in water flowing with a mean of 0.1 meters per second. *See, e.g.*, *id.*; T.R. Bott & P.C. Miller, *Mechanisms of Biofilm Formation on Aluminum Tubes*, 33 J. CHEMICAL TECH. & BIOTECHNOLOGY 177, 182 (1983) (stating that fouling bacterium achieve maximum thickness and adhesion in water flowing a mean of 0.1 meters per second).

Biofilm and the subsequent adhesion of biofouling organisms most commonly occur on ship hulls and propellers,[25] negatively impacting ship maneuverability and lifespan with dramatic economic and environmental consequences. First, if biofouling is left untreated on a substrate like a hull or propeller, it will eventually corrode.[26] For this reason, the unrestricted accumulation of fouling organisms can cause a significant fiscal loss due to the mounting costs of replacing damaged parts.[27] Second, any accumulation of fouling organisms creates a rough surface area that significantly increases drag and deteriorates maneuverability.[28] This resulting drag from biofouling is noteworthy as it can reduce vessel speed by up to 10%, which can require up to a 40% increase in fuel consumption.[29]

In the international context of commercial shipping, for example, fleets around the world have been estimated to consume approximately 300 million additional tons of fuel annually due to biofouling.[30] Even at a more conservative estimate of 120 million additional tons of fuel annually,[31] costs were estimated at $7.5 billion in 2000,[32] and, more recently, $30 billion.[33] Even just in the United States, colonized barnacles and biofilm settled on the hulls of Navy ships translates into roughly $500 million annually in extra fuel and maintenance costs.[34] The increased consumption of fuel not only is costly and wasteful, but also increases greenhouse gas emissions.[35] If the world's fleet was totally fouled, an extra 70.6 million tons of

25 Jason C. Yarbrough et al., *Contact Angle Analysis, Surface Dynamics, and Biofouling Characteristics of Cross-Linkable, Random Perfluoropolyether-Based Graft Terpolymers*, 39 MACROMOLECULES 2521, 2522, 2524 (2006), *available at* http://biosciences-labs.bham.ac.uk/callowj/ent/Yarborough%20et%20al_Macromolecules_2006.pdf.

26 *See* OLADIS T. DE RINCÓN ET AL., PAPER NO. 01479, THE EFFECT OF "PELO DE OSO" (*GARVEIA FRANCISCANA*) ON DIFFERENT MATERIALS IN LAKE MARACAIBO, *in* CORROSION 2001, at 8 (NACE Int'l 2001).

27 *See* Gabriela Voskerician et al., *Biocompatibility and Biofouling of MEMS Drug Delivery Devices*, 24 BIOMATERIALS 1959, 1960, 1965 (2003), *available at* http://www.ruf.rice.edu/~rau/phys600/1959.pdf.

28 Marianne Walch & Mary Zoccola, *New Approaches to Controlling Biofouling*, WAVELENGTHS, Apr. 1999, *reproduced at* http://writingbymaryzoccola.blogspot.com/2011/02/april-1999-excerpt-new-approaches-to.html (last visited Apr. 7, 2012).

29 Dag G., *Hull Bio-Mimetic Underwater Grooming (Hull BUG)*, ROB AID, Sept. 3, 2009, http://www.robaid.com/bionics/hull-bio-mimetic-underwater-grooming-hull-bug.htm (last visited Apr. 7, 2012).

30 Axel Rosenhahn et al., *Advanced Nanostructures for the Control of Biofouling: The FP6 EU Integrated Project AMBIO*, 3 BIOINTERPHASES IR1, IR1 (2008), *available at* http://www.springerlink.com/content/77715x6824ww835h/fulltext.pdf.

31 LYNN JACKSON, MARINE BIOFOULING AND INVASIVE SPECIES: GUIDELINES FOR PREVENTION AND MANAGEMENT 8 (2008), *available at* http://www.issg.org/pdf/publications/GISP/Guidelines_Toolkits_BestPractice/Jackson_2008.pdf.

32 *Id.*

33 *Id.*

34 Charles Q. Choi, *Powerful Ideas: Navy Plans Robotic Barnacle Buster*, LIVESCIENCE, Oct. 13, 2009, http://www.livescience.com/5765-powerful-ideas-navy-plans-robotic-barnacle-buster.html (last visited Apr. 7, 2012).

35 JAMES A. CALLOW, AMBIO: ADVANCED NANOSTRUCTURED SURFACES FOR THE CONTROL OF BIOFOULING: THE PUBLISHABLE FINAL ACTIVITY REPORT OF THE AMBIO INTEGRATED PROJECT 6 (2010), *available at* http://cordis.europa.eu/documents/documentlibrary/120142251EN6.pdf.

fuel would be burned per year, releasing more than 210 million additional tons of carbon dioxide and more than 5.6 million additional tons of sulfur dioxide.[36]

Antifouling paint products are the most widely accepted method of controlling and preventing biofouling.[37] Many antifouling paint products are tin-[38] or copper-based, which are toxic not only to biofouling organisms but also to other nontarget organisms.[39] The chemicals slowly leach into the water, where they can affect living organisms.[40] As a result, concentrations of these toxins build up in places with heavy boat traffic and limited water circulation.[41] The concentrations could become so great in these regions that they can potentially harm or destroy mollusk populations, such as the endangered Gulf moccasinshell (*Medionidus penicillatus*)[42] and Ochlockonee moccasinshell (*Medionidus simpsonianus*),[43] by weakening their physiological growth, reproductive and immunological systems.[44] In addition, fish like the endangered shortnose sturgeon (*Acipenser brevirostrum*)[45] can also be harmed by either absorbing or bioaccumulating[46] these environmental pollutants from feeding on infected mollusks or by swimming in waters with high concentrations, which in turn can affect human health when the contaminated fish

36 *Id.* at 40.

37 Julian Roberts & Martin Tsamenyi, *International Legal Options for the Control of Biofouling on International Vessels*, 32 MARINE POL'Y 559, 561 (2008).

38 Tin-based antifouling paints primarily consist of the organotin compound tributyltin (TBT). ALAN H. TAYLOR & GEOFF RIGBY, THE IDENTIFICATION AND MANAGEMENT OF VESSEL BIOFOULING AREAS AS PATHWAYS FOR THE INTRODUCTION OF UNWANTED AQUATIC ORGANISMS 4 (2002), http://www.usaf-nedmarine.com/Download-document/4-the-Identification-and-Management-of-Vessel-Biofouling-Areas-as-Pathways-for-the-Introduction-of-Un.html.

39 *See* Roberts & Tsamenyi, *supra* note 37, at 561; UK Marine Special Areas of Concern Project, *The Potential Effects of Antifouling Paints*, http://www.ukmarinesac.org.uk/activities/recreation/r03_03.htm (last visited Apr. 7, 2012) (noting that copper compounds tend to be less effective than tin compounds).

40 *See* TAYLOR & RIGBY, *supra* note 38, at 5.

41 *See id.*

42 U.S. Fish & Wildlife Serv., *Gulf Moccasinshell:* Medionidus Penicillatus, http://ecos.fws.gov/docs/life_histories/F03M.html (last visited Apr. 7, 2012).

43 *See* U.S. Fish & Wildlife Serv., *Ochlockonee Moccasinshell:* Medionidus Simpsonianus, http://ecos.fws.gov/docs/life_histories/F03N.html (last visited Apr. 7, 2012).

44 *See, e.g.*, Jamie Anne Gonzalez & Leigh Taylor Johnson, University of California Sea Grant Extension Program, Presentation at the Coastal Society Conference in St. Petersburg Beach, Florida: Agency Coordination: Resolving Water Quality and Invasive Species Policy Conflicts 140 (May 14–17, 2006), *available at* http://nsgl.gso.uri.edu/tcs/tcsc06001/pdffiles/papers/74056.pdf; J.M. Ruiz et al., *Effects of Tributyltin (TBT) Exposure on the Reproduction and Embryonic Development of the Bivalve* Scrobicularia Plana, 40 MARINE ENVTL. RES. 363, 376 (1995); Wesley J. Birge et al., *The Effects of Mercury on Reproduction of Fish and Amphibians*, 3 TOPICS IN ENVIRONMENTAL HEALTH: THE BIOGEOCHEMISTRY OF MERCURY IN THE ENVIRONMENT 629, 646–48 (J. O. Nriagu ed., 1979).

45 Office of Protected Res., Nat'l Oceanic & Atmospheric Admin., *Shortnose Sturgeon (*Acipenser Brevirostrum*)*, http://www.nmfs.noaa.gov/pr/species/fish/shortnosesturgeon.htm (last visited Apr. 7, 2012).

46 Bioaccumulation is the collection of "contaminants in the tissue of organisms through any route, including respiration, ingestion, or direct contact with contaminated water, [or] sediment." U.S. ENVTL. PROT. AGENCY, BIOACCUMULATION TESTING AND INTERPRETATION FOR THE PURPOSE OF SEDIMENT QUALITY ASSESSMENT: STATUS AND NEEDS, at xvii (2000), *available at* http://water.epa.gov/polwaste/sediments/cs/upload/bioaccum.pdf.

are consumed.[47] Increased concentrations of the toxins used in antifouling coatings also may result in marine mammals developing anemia, as well as suffering from degradation of the liver, kidneys, brain, and muscles,[48] beyond the consequences posed to marine mammals by the fouling organisms themselves.[49]

To address this global environmental concern, the International Maritime Organization (IMO) drafted the International Convention on the Control of Harmful Anti-Fouling Systems[50] on Ships (AFS Convention).[51] The AFS Convention banned the application of paint containing tin on all ships, excluding fixed and floating offshore oil installations, by January 1, 2003 and completely prohibited the presence of tin-based antifouling coatings on all ships by January 1, 2008.[52] Since the ban, some mariners have turned to coatings with high concentrations of copper or zinc.[53] Although no laws currently restrict their use, some also suspect that copper- and zinc-based coatings may cause cellular damage to nontarget organisms.[54]

47 *See, e.g.*, Conn. Dep't of Pub. Health, *Glossary*, http://www.ct.gov/dph/cwp/view.asp?a=3140&Q=386936&dphNav_GID=1826&dphNav=| (click on "C" hyperlink, then scroll down to "Consumption advisory" definition) (last visited Apr. 7, 2012).

48 RONALD EISLER, U.S. GEOLOGICAL SURVEY, COPPER HAZARDS TO FISH, WILDLIFE, AND INVERTEBRATES: A SYNOPTIC REVIEW 45, 85–86 (1998), *available at* https://www.pwrc.usgs.gov/infobase/eisler/CHR_33_Copper.pdf; AGENCY FOR TOXIC SUBSTANCES & DISEASE REGISTRY, U.S. PUB. HEALTH SERV., TOXICOLOGICAL PROFILE FOR COPPER 4 (1990), *available at* http://www.seagrant.umn.edu/water/report/chemicalsofconcern/copper/copper.pdf.

49 *See* discussion *infra* Part III (noting that the Florida manatee, for example, can collect fouling organisms—which, among other things, results in increased weight, decreased flexibility, decreased maneuverability, topical damage from anchoring organisms, and damage due to grazers preying on fouling organisms); *see, e.g.*, Martin Wahl, *Marine Epibiosis. I. Fouling and Antifouling: Some Basic Aspects*, MARINE ECOLOGY PROGRESS SERIES, Dec. 15, 1989, at 175, 181, *available at* http://www.int-res.com/articles/meps/58/m058p175.pdf. Those fouling organisms that attach to a living surface, like the skin of a Florida manatee, are known as "epibionts." Luciane Ayres-Peres & Fernando L. Mantelatto, *Epibiont Occurrence on Gastropod Shells Used by the Hermit Crab* Loxopagurus Loxochelis *(Anomura: Diogenidae) on the Northern Coast of São Paulo, Brazil*, 27 ZOOLOGIA, Apr. 2010, http://www.scielo.br/scielo.php?pid=S1984-46702010000200010&script=sci_arttext&tlng=es (last visited Apr. 7, 2012).

50 The term "antifouling system" refers to "a coating, paint, surface treatment, surface or device that is used on a ship to control or prevent attachment of unwanted organisms." TAYLOR & RIGBY, *supra* note 38, at IV.

51 AFS Convention, *supra* note 16, at VI.

52 *Id.* art. 4. Because the AFS Convention came into force at a date later than the required compliance dates (January 1, 2003, and January 1, 2008), the legal effect is that the requirements were moved forward to the entry into force date of September 17, 2008. *Id.* at V (letter of submittal).

53 *See* Mridula Srinivasan & Geoffrey W. Swain, *Managing the Use of Copper-Based Antifouling Paints*, 39 ENVTL. MGMT. 423, 423–24 (2007) (stating that in recent times the most commonly used antifouling coating has a copper base); *see also* Diego Meseguer Yebra et al., *Antifouling Technology—Past, Present and Future Steps Towards Efficient and Environmentally Friendly Antifouling Coatings*, 50 PROGRESS IN ORGANIC COATINGS 75, 81 (2004) (describing when copper-based antifouling paints were most popular through history); Andrew Turner, *Marine Pollution from Antifouling Paint Particles*, 60 MARINE POLLUTION BULL. 159, 159 (2010) (analyzing the leaching behavior of both copper and zinc in marine environments).

54 *See* sources cited *supra* note 44.

The significant environmental impacts of a number of co-biocides,[55] such as the triazine herbicide "Irgarol 1051," have begun to raise the eyebrows of environmentalists and legislators. As such, they will likely be heavily restricted in the years to come.[56] For example, in 2011, the European Union's Sixth Environmental Action Plan established a framework to prevent further degradation and conserve the biodiversity of these freshwater, estuary, coastal, and groundwater ecosystems.[57]

Another method to treat biofouling is scraping the affected surface to release the offending organisms. This approach addresses the problem only temporarily and, if not conducted responsibly, contributes to the global problem of transporting NIAS because the NIAS that are dislodged from the hull can potentially survive and establish within the local area with terrible ecological effects.[58] Mature NIAS that are injured from the scraping process may also be induced to release larvae into the surrounding environment.[59] In addition, the areas from which fouling organisms are scraped may be more likely to re-acquire certain types of NIAS and other fouling organisms, according to some studies.[60] As a result, the risk of NIAS re-colonization from an affected vessel may escalate.[61]

The effects of NIAS can be significant, as they can outcompete with native species for space and resources, thereby reducing biodiversity, threatening the viability of fisheries or aquaculture, introducing diseases or algae that can be harmful to aquatic life and humans,[62] and generally disturbing resting and mating behavior of native species.[63] NIAS can also result in significant financial hardships

55 A biocide is a chemical substance capable of killing living organisms. WEBSTER'S NEW COLLEGE DICTIONARY 113 (3d ed. 2008).

56 Advanced Nanostructured Surfaces for the Control of Biofouling (AMBIO), What Is Biofouling and How Will the AMBIO Project Help to Solve It Through Nanotechnology (unpublished manuscript) (on file with *Environmental Law*).

57 On May 3, 2011, the European Commission adopted a new strategy to halt the loss of biodiversity and ecosystem services in the European Union (EU) by 2020. *Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions: Our Life Insurance, Our Natural Capital: An EU Biodiversity Strategy to 2020*, at 1, COM (2011) 244 final (Mar. 5, 2011), *available at* http://ec.europa.eu/environment/nature/biodiversity/comm2006/pdf/2020/1_EN_ACT_part1_v7%5b1%5d.pdf.

58 Nancy C. Balcom, *Hull Fouling's a Drag on Boats and Local Ecosystems*, WRACK LINES, Fall/Winter 2005, at 14, 15, *available at* http://web2.uconn.edu/seagrant/publications/magazines/wracklines/fallwinter05/hullfoul.pdf.

59 *See id.* at 15–16; Roberts & Tsamenyi, *supra* note 37, at 561.

60 Roberts & Tsamenyi, *supra* note 37, at 561.

61 *Id.*

62 Balcom, *supra* note 58, at 15.

63 For example, the suckermouth armored catfish (*Hypostomus plecostomus*) has invaded streams, canals, and lakes throughout much of peninsular Florida. Leo G. Nico et al., *Non-Native Suckermouth Armored Catfishes in Florida: Description of Nest Burrows and Burrow Colonies with Assessment of Shoreline Conditions*, ANSRP BULL., Mar. 2009, at 1, 1, *available at* http://fl.biology.usgs.gov/pdf/ansrp-v09-1%28LR%29.pdf [hereinafter Nico et al., *Non-Native Suckermouth*]. The catfish's behavior of clustering around and attaching to Florida manatees is considered to be menacing, as Florida manatees cannot adequately rest and must exert additional energy to move to another location away from the catfish. Leo G. Nico et al., *Interactions Between Non-Native Armored Suckermouth Catfish (Loricariidae:* Pterygoplichthys*) and Native Florida Manatee (*Trichechus Manatus Latirostris*) in Artesian Springs*, 4 AQUATIC INVASIONS 511, 513–14 (2009), *available at* http://www.

for marina and harbor owners and the marine services and amenities they provide by destroying infrastructure and imposing significant costs for mitigation measures.[64] Between 40% and 60% of NIAS transport is estimated to be attributable to ship fouling.[65] The remaining 40% to 60% of NIAS transport is likely to be attributable to the discharge of ballast water from large, transoceanic cargo ships, aquaculture, the aquarium trade, the nursery trade, seafood processing, or the fishing bait industry.[66]

Many authors have noted that the majority of established NIAS, and the attachment of biofouling generally, occur in and around ports, marinas, and harbors.[67] This is clearly linked to the fact these locations are the first stop for international and domestic vessels arriving in a new region and where hull scraping and ballast water discharge occurs.[68] As such, marinas are one of the main locations for the introduction, establishment, and spread of NIAS.[69] In addition to hosting hull scraping and ballast water discharge activities, the design of marina facilities actually exacerbate the proliferation of NIAS and other fouling organisms.[70] Specifically, marinas designed to hold a high density of compactly spaced vessels, with a great number of artificial surfaces, and slow water velocity,[71] are generally

aquaticinvasions.net/2009/AI_2009_4_3_Nico_etal.pdf [hereinafter Nico et al., *Interactions*]; Audio tape: Interview with Kathleen Tripp, Director of Science & Conservation, Save the Manatee Club, in Maitland, Fla. (Nov. 3, 2010, at 11:45–12:15) (on file with author).

64 Roberts & Tsamenyi, *supra* note 37, at 559.

65 *See* Balcom, *supra* note 58, at 16.

66 *See id.*; Aquatic Nuisance Species Task Force et al., *Protect Your Waters: Frequently Asked Questions About Aquatic Hitchhikers*, http://www.protectyourwaters.net/faq.php (last visited Apr. 7, 2012).

67 *E.g.*, James T. Carlton, *Patterns of Transoceanic Marine Biological Invasions in the Pacific Ocean*, 41 BULL. MARINE SCI. 452, 453 (1987) [hereinafter Carlton, *Transoceanic Marine Biological Invasions*]; James T. Carlton, *Biological Invasions and Cryptogenic Species*, 77 ECOLOGY 1653, 1653 (1996); James T. Carlton, *Pattern, Process, and Prediction in Marine Invasion Ecology*, 78 BIOLOGICAL CONSERVATION 97, 99 (1996); A. N. Cohen et al., *Introduction, Dispersal and Potential Impacts of the Green Crab* Carcinus Maenas *in San Francisco Bay, California*, 122 MARINE BIOLOGY 225, 228–29 (1995); M. L. Campbell & C. L. Hewitt, *Vectors, Shipping and Trade*, *in* MARINE BIOLOGICAL INVASIONS OF PORT PHILLIP BAY, VICTORIA 45, 45 (Chad L. Hewitt et al. eds., 1999); Dan Minchin & Stephan Gollasch, *Fouling and Ships' Hulls: How Changing Circumstances and Spawning Events May Result in the Spread of Exotic Species*, 19 BIOFOULING 111, 111 (Supp. 2003); Anna Occhipinti Ambrogi, *Biotic Invasions in a Mediterranean Lagoon*, 2 BIOLOGICAL INVASIONS 165, 169 (2000).

68 *See* Balcom, *supra* note 58, at 15–16; Carlton, *Transoceanic Marine Biological Invasions*, *supra* note 67, at 453.

69 *See* O. Floerl et al., *The Importance of Transport Hubs in Stepping-Stone Invasions*, 46 J. APPLIED ECOLOGY 37, 43 (2009).

70 *E.g.*, Beth L. McGee et al., *Sediment Contamination and Biological Effects in a Chesapeake Bay Marina*, 4 ECOTOXICOLOGY 39, 55–56 (1995); Oliver Floerl & Graeme J. Inglis, *Boat Harbor Design Can Exacerbate Hull Fouling*, 28 AUSTRAL ECOLOGY 116, 124 (2003).

71 Optimal sites for biofilm development and adhesion are expected to occur at locations with a large relative abundance of biofilm organisms—like diatoms—and with features including local phytoplankton productivity, temperatures of at least 30°C, a pH between seven and nine, and water flowing with a mean of 0.1 meters per second. *See* discussion *supra* note 24; T. GREENBERG & D. ITZHAK, PAPER NO. 02184, MARINE BIOFOULING OF TITANIUM ALLOYS IN THE CORAL REEF ENVIRONMENT, *in* CORROSION 2002, at 3 (NACE Int'l 2002) (discussing early stage biofouling phenomena on titanium alloys).

considered to be preferred by NIAS and other fouling organisms for colonization.[72] The combination of these factors increases the risk of NIAS establishing within such an environment.[73] Once NIAS have been introduced, their proliferation within or adjacent to a marina environment creates a constant source of seaweed spores or invertebrate larvae for facilitating the continued infection of vessels.[74] Consequently, marinas and berths[75] are significant contributors to the biosecurity[76] risks associated with NIAS and other foulers on vessels. The international shipping regulations under the International Convention for the Control and Management of Ships' Ballast Water and Sediments (Ballast Water Convention)[77] aim to address the transfer of NIAS;[78] however, the Ballast Water Convention fails to comprehensively regulate all aspects of the biofouling problem, including marina design.[79]

III. Biofouling Impacts on the Florida Manatee

Barnacles, epiphytes,[80] and other biota often grow on Florida manatees since they are slow moving and unable to ward off attaching organisms.[81] When fouling organisms attach to Florida manatees, a variety of potential harms may arise. Possible dangers include increased weight, decreased flexibility, increased drag resulting from the additional friction imposed on the Florida manatee's skin, damage from anchoring, and damage due to grazers preying on the fouling organisms, among other things.[82]

In addition to the direct effects of fouling organisms, the toxic chemicals used to prevent the accumulation of fouling organisms on vessels have the potential to harm Florida manatees and their habitat. For example, excessive copper intakes[83] may have serious after effects in Florida manatees. Although mammals and birds are 100 to 1000 times more resistant to copper than more primitive animals—like

72 Tim M. Glasby et al., *Nonindigenous Biota on Artificial Structures: Could Habitat Creation Facilitate Biological Invasions?*, 151 Marine Biology 887, 888, 892–94 (2007).

73 Richard Piola & Barrie Forrest, Options for Managing Biosecurity Risks from Recreational Vessel Hubs 5 (2009).

74 *Id.*

75 The term "berth" is a location in a port or harbor to moor vessels while not at sea. Lenfestey, *supra* note 17, at 44.

76 Biosecurity is protection of all natural resources from biological invasion and threats and can include the protection of a geographical area from invasion by unwanted organisms like NIAS. *See, e.g.*, Jeffrey R. Ryan & Jan F. Glarum, Biosecurity and Bioterrorism: Containing and Preventing Biological Threats 19 (2008).

77 Ballast Water Convention, *supra* note 16, at 2–3.

78 *Id.* at 3 ("Parties undertake . . . to prevent, minimize and ultimately eliminate the transfer of Harmful Aquatic Organisms and Pathogens . . . .").

79 *See infra* Part IV.C.

80 Plants and organisms that grow upon some other object nonparasitically, including bacteria, algae, and many mosses. *See* Oxford Dictionary of Biology 225 (5th ed. 2004).

81 *See* Roger L. Reep & Robert K. Bonde, The Florida Manatee: Biology and Conservation, at xvi, 21–22 (2006). On average Florida manatees only swim about 3.1 to 5.0 miles per hour; however, they have been known to swim up to 16 miles per hour in short bursts. *See id.*

82 Wahl, *supra* note 49, at 181.

83 Copper intakes may result from pooling concentrations of copper from copper-based antifouling coatings. *See supra* notes 53–54.

mollusks, coelenterates,[84] echinoderms,[85] and worms[86]—mammals may, depending on the species, have limited growth and food consumption; develop a deficiency of red blood cells or hemoglobin in the blood; and have deteriorating muscle, brain, kidney, or liver functions.[87] Such severe alterations to the feeding behavior and musculoskeletal, nephrological, hepatological, and neurological make-up of mammalian species often result in death.[88]

Considerable intake of zinc[89] causes significant adverse effects on growth, reproduction, and survival in sensitive marine and freshwater species of aquatic plants on which Florida manatees graze.[90] Furthermore, excessive zinc intake can adversely affect the survival of marine mammals, like the Florida manatee, by producing an array of neurological, hematological, immunological, hepatological, cardiovascular, developmental, and genotoxic[91] effects.[92] Effects may include diminished growth rate and reproductive function, hypodermic hematomas, acute gastrointestinal disorders including inflammation of the stomach lining and diarrhea, lesions on major limb joints or kidneys, raised zinc levels in the blood and tissue, copper deficiency, and decreased protein activity of the heart and liver.[93] In severe cases, resulting tissue damage in the liver and pancreas and degenerative changes in the kidneys and gastrointestinal tract can lead to fatal hemolytic anemia.[94]

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84 Typical characteristics of coelenterates may include having stinging tentacles, a jelly-like appearance, and the ability to alternate generational reproductive modes—meaning that sometimes these species may reproduce asexually one generation, and then switch to sexual reproduction the next. Biology Online, *Primitive Animals: The Origins of Life*, http://www.biology-online.org/10/5_primitive_animals.htm (last visited Apr. 7, 2012).

85 A "starfish" is an example of this classification of organisms, exhibiting five-part symmetry. *Id.*

86 *See id.*; EISLER, *supra* note 48, at 85.

87 *See* EISLER, *supra* note 48, at 85–86.

88 *See id.*

89 Zinc intakes may result from pooling concentrations of zinc from zinc-based antifouling coatings. *See supra* notes 53–54.

90 *See* RONALD EISLER, U.S. FISH & WILDLIFE SERV., ZINC HAZARDS TO FISH, WILDLIFE, AND INVERTEBRATES: A SYNOPTIC REVIEW 54 (1993), *available at* http://www.pwrc.usgs.gov/infobase/eisler/CHR_26_Zinc.pdf.

91 *See* Cedre, *Glossary*, http://www.cedre.fr/en/glossary.php (last visited Apr. 7, 2012) (click on the "G" hyperlink to view "genotoxic," defined as an "agent which increases the appearance of genetic mutations"); OFFICE OF THE ADM'R, U.S. ENVTL. PROT. AGENCY, TERMS OF ENVIRONMENT: GLOSSARY, ABBREVIATIONS, AND ACRONYMS: TERMINOLOGY SERVICES – RLOSSARY KEYWORD LIST DETAIL REPORT (rev. 2009), *available at* http://iaspub.epa.gov/sor_internet/registry/termreg/searchandretrieve/termsandacronyms/search.do (defining "genotoxic" as "[d]amaging to DNA; pertaining to agents known to damage DNA").

92 EISLER, *supra* note 90, at 85.

93 *Id.*

94 *Id.*; J. G. Allen et al., *Zinc Toxicity in Ruminants*, 93 J. COMP. PATHOLOGY 363, 374 (1983). "Hemolytic anemia is a condition in which there are not enough red blood cells in the blood, due to the premature destruction of red blood cells." Nat'l Ctr. for Biotechnology Info. et al., *PubMed Health: Hemolytic Anemia*, http://www.ncbi.nlm.nih.gov/pubmedhealth/PMH0001597/ (last visited Apr. 7, 2012).

A. Effects of Nonindigenous Aquatic Species

The South American suckermouth armored catfishes (*Pterygoplichthys loricariidae*) now inhabit parts of Central and North America—including the streams, canals, and lakes of Florida—Asia, the Caribbean, and Hawaii after being widely introduced as a result of the ornamental fish trade.[95] As a largely tropical species of fish, the vermiculated sailfin catfish (*Pterygoplichthys disjunctivus*), for example, has become increasingly common in several warm spring habitats within the St. Johns River drainage, relocating to stay warm during the winter months.[96] It is in warm spring habitats like those within the St. Johns River that large numbers of Florida manatees congregate, graze, rest, and nurse during the cold fall and winter months to maintain body temperature and avoid hypothermia.[97] While the catfish and Florida manatees seasonally cohabitate in the springs, the catfish form large crowds surrounding the Florida manatees to dine on the fouling organisms fastened to the Florida manatees' skin.[98] While scouring the Florida manatees' skin for food, the catfish sweep across nearly all parts of the Florida manatees, including their heads, snouts, fins, bellies, and tails.[99] This scouring behavior occurs even if the Florida manatees are resting along the bottom, nursing, swimming, or grazing on vegetation.[100]

Biologists believe the catfish are inadvertently harassing the Florida manatee by constantly touching the ultrasensitive hair follicles all over the Florida manatee's body that are used for tactile exploration and orientation.[101] The movement of each hair is coded by sensory receptors and the associated nerve fibers that stimulate each hair follicle.[102] As a result, the catfish's behavior actually torments Florida manatees so much so that they are unable to rest.[103] In addition, Florida manatees would die from the cold temperatures if they were to leave the warm springs and return to the cold saltwater, where the catfish could not follow them.[104] Therefore, Florida manatees must also exert additional energy to constantly move to new areas within the spring to get away from the catfish.[105]

Although the introduction of the invasive sailfin catfish population to Florida is thought to be a result of the ornamental fish trade, and not through biofouling on vessels or the improper dumping of ballast water,[106] the sailfin catfish issue demonstrates the substantial danger the release of NIAS through biofouling can pose to Florida manatees. If not properly addressed, NIAS may be released to Florida manatee habitat from the scraping of biofouling organisms off ship hulls or

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95 Nico et al., *Interactions*, *supra* note 63, at 511; Nico et al., *Non-Native Suckermouth*, *supra* note 63, at 2.

96 Nico et al., *Non-Native Suckermouth*, *supra* not 63, at 2.

97 *Id.*; *see also* U.S. Fish & Wildlife Serv., *supra* note 6, at 2.

98 Nico et al., *Interactions*, *supra* note 63, at 513.

99 *Id.*

100 *See id.*

101 Audio tape: Interview with Kathleen Tripp, *supra* note 63, at 10:05.

102 *Id.* at 12:35.

103 *Id.* at 12:00.

104 *Id.* at 14:25.

105 *Id.* at 12:00–14:30.

106 *See* Nico et al., *Non-Native Suckermouth*, *supra* note 63, at 2; Audio tape: Interview with Kathleen Tripp, *supra* note 63.

through the improper disposal of ballast water in the future, adversely affecting Florida manatee behavior, health, food supply, or habitat in ways similar to, or even worse than, the invasive catfish.

IV. EXISTING INTERNATIONAL LEGAL MECHANISMS

A. International Mechanisms Governing Shipping

The 1982 United Nations Convention on the Law of the Sea[107] recognizes IMO as the international organization responsible for setting rules and standards to manage impacts of vessel-sourced pollution and to maintain navigational safety.[108] Accordingly, IMO developed a series of regulations comprehensively addressing maritime transportation and is working toward developing universal criteria for shipping safety and marine environmental protection.[109] Despite IMO's achievements in shipping and marine water quality, IMO has not developed international standards to specifically address the many facets of the biofouling problem.[110] However, over the course of the last forty-five years IMO has developed a series of treaty and nontreaty instruments intended to minimize the threat of NIAS and prevent and mitigate water pollution from vessels.[111] These instruments include over sixty codes and recommendations as well as the AFS Convention[112] and the Ballast Water Convention,[113] which both have relevance in the area of biofouling.[114]

1. The AFS Convention

In November 1999 IMO adopted an Assembly resolution that called on the Marine Environment Protection Committee (MEPC)[115] to develop an international, legally binding instrument to address the harmful effects of antifouling systems used on ships.[116] The international mechanism the MEPC developed was the AFS Convention, which requires that ships 400 gross register tonnage (GRT)[117] and

107 United Nations Convention on the Law of the Sea, Dec. 10, 1982, 1833 U.N.T.S. 397.

108 Roberts & Tsamenyi, *supra* note 37, at 562; *see also* United Nations Convention on the Law of the Sea, *supra* note 107, at 575 (calling on IMO to draw up and maintain a list of experts "in the field of navigation, including pollution from vessels and by dumping").

109 Roberts & Tsamenyi, *supra* note 37, at 562.

110 *See id.* at 560, 562.

111 *Id.* at 560, 562.

112 *Id.* at 562–63; AFS Convention, *supra* note 16, at 2.

113 The Ballast Water Convention will enter into force 12 months after ratification by 30 states, representing 35% of the world's merchant shipping tonnage. Ballast Water Convention, *supra* note 16, art. 18. "As of 15 August 2007 only 10 States, representing 3.42% world merchant shipping tonnage had become contracting States to the convention." Roberts & Tsamenyi, *supra* note 37, at 563 n.9.

114 Roberts & Tsamenyi, *supra* note 37, at 560, 562–63.

115 The MEPC is a committee of IMO. The committee meets every nine months to develop international conventions relating to a variety of marine environmental concerns including the recycling of ships, controlling emissions and harmful aquatic organisms in ballast water, among others. *See* Int'l Mar. Org., *MEPC*, http://www.imo.org/newsroom/mainframe.asp?topic_id=109 (last visited Apr. 7, 2012) (indexing and providing links to MEPC meeting–briefing reports).

116 AFS Convention, *supra* note 16, at 2.

117 GRT represents the total internal volume of a vessel, with some exemptions for nonproductive spaces such as crew quarters; one GRT is equal to a volume of 100 cubic feet (2.83 m³). *See generally*

above—excluding fixed or floating platforms—engaged in international voyages undergo both a preliminary survey, either before the ship begins a voyage or the International Anti-Fouling System Certificate is first issued, and a subsequent survey should the anti-fouling system ever be changed or replaced.[118] Ships of twenty-four meters or more in length, but less than 400 GRT—excluding fixed or floating platforms—engaged in international voyages are also required to carry a Declaration on Anti-Fouling System (Declaration) signed by the owner or authorized agent on board.[119] Under the AFS Convention, the Declaration is to be accompanied by appropriate documentation such as a paint receipt or contractor invoice.[120]

The AFS Convention also called for a global prohibition on the application or re-application of organotin-based antifouling systems on all ships by January 1, 2003, and a complete prohibition on all ships, excluding certain fixed and floating offshore oil installations, by January 1, 2008.[121] It is worth noting that the AFS Convention came into force at a date later than the dates of requirements were effective, resulting in the requirements being moved forward to the entry into force date.[122] In other words, the legal effect of the January 1, 2003, and January 1, 2008, dates were suspended until September 17, 2008, when the AFS Convention was entered into force.[123] During the time before the AFS Convention was entered into force, "Port States"[124] could not apply any requirements of the AFS Convention to foreign ships entering their ports.[125] However, "Flag States"[126] could apply the requirements of the AFS Convention to their national fleet, depending on their national legal system and decisions of that country, but their International Anti-Fouling Certificates were not recognized until the date of entry into force.[127]

The AFS Convention also includes four technical annexes which address, respectively, controls on those substances defined under the AFS Convention as

International Convention on Tonnage Measurement of Ships, 1969, Annex 1, June 23, 1969, 1291 U.N.T.S. 4, 13–17 (explaining the method for calculating tonnage and volume for vessels).

118 AFS Convention, *supra* note 16, at 20.

119 *Id.* at 22.

120 *Id.*

121 *Id.* at 16.

122 *Compare id.*, *with* Int'l Mar. Org., *Harmful Ships' Paint Systems to Be Outlawed as International Convention Meets Entry into Force Criteria*, IMO NEWS, no. 4, 2007, at 6, 6, *available at* http://www.imo.org/mediacentre/newsmagazine/documents/2007/imonewsno407lr.pdf (announcing the entry into force of the AFS convention and explaining its significance).

123 *See* Int'l Mar. Org., *supra* note 122, at 6.

124 A "Port State" is the "governmental authority under which a country exercises regulatory control over the [commercial] vessels which are registered under another countries' [f]lags." MANTA MAR. LTD., A GUIDE TO THE MANDATORY CHARTER YACHT RULES AND REGULATIONS 1 (n.d.), *available at* http://mantamaritime.com/downloads/regulations.pdf. This authority only exists while those vessels are operating within that country's territorial waters. *Id.*

125 Int'l Mar. Org., *Anti-Fouling Systems*, http://www.imo.org/blast/mainframe.asp?topic_id=223 (last visited Apr. 7, 2012).

126 "Flag State" refers to the "governmental authority under which a country exercises regulatory control over the [commercial] vessels which [are] registered under its flag. This involves the inspection, certification and issuance of safety and pollution prevention documents." MANTA MAR. LTD., *supra* note 124, at 1.

127 Int'l Mar. Org., *supra* note 125.

harmful antifouling systems,[128] proposal requirements to define a substance as a harmful antifouling system under the AFS Convention,[129] requirements for a comprehensive proposal to define a substance as a harmful antifouling system,[130] and surveys and certificate requirements for antifouling substances.[131] The regulations of the technical annexes address: surveys; issuing, endorsing, and assessing validity of International Anti-Fouling Certificates; and antifouling systems declarations.[132] IMO has also developed a number of technical guidelines to ensure the AFS Convention is applied uniformly.[133]

2. The Ballast Water Convention

In addition to adopting the AFS Convention, IMO adopted the Ballast Water Convention.[134] The Ballast Water Convention requires that all vessels with ballast tanks—new or existing—implement ballast water management[135] procedures and meet specific standards when traveling into a nation's waters from beyond its Exclusive Economic Zone.[136] These requirements were enacted to prevent, minimize, and ultimately eliminate the transfer of harmful NIAS and pathogens.[137] Under the Ballast Water Convention, ships are required to implement a custom Ballast Water Management Plan approved by the Administration and a Ballast Water Record Book and keep both on board.[138] In particular, the Ballast Water Record Book must document when ballast water is received, distributed, or treated for management purposes; any purposeful discharges into the ocean or a reception facility; and any accidental[139] discharges.[140]

The Ballast Water Convention also touches on the issues of research and monitoring, certification and inspection, and technical assistance to limit the transfer of NIAS and pathogens. First, the Ballast Water Convention calls for parties to individually or jointly promote and facilitate scientific and technical

128 AFS Convention, *supra* note 16, at 16 (Annex 1).

129 *Id.* at 17 (Annex 2).

130 *Id.* at 18 (Annex 3).

131 *Id.* at 20 (Annex 4).

132 *Id.* at 20–27; *see also* Roberts & Tsamenyi, *supra* note 37, at 563.

133 Current regulations include survey, certification, brief sampling, and inspection of antifouling systems on ships. *See* Roberts & Tsamenyi, *supra* note 37, at 563 n.13.

134 Ballast Water Convention, *supra* note 16; *see* Roberts & Tsamenyi, *supra* note 37, at 562–63.

135 The specific requirements for ballast water management are contained in regulation B-3, Ballast Water Management for Ships. AFS Convention, *supra* note 16, at 18 (Annex 3).

136 *See* Roberts & Tsamenyi, *supra* note 37, at 562–63. Under the Law of the Sea, an Exclusive Economic Zone is a seazone over which a state has special rights regarding the exploration and use of marine resources. It stretches from the seaward edge of the state's territorial sea out to 200 nautical miles from its coast. *See* WILLIAM R. SLOMANSON, FUNDAMENTAL PERSPECTIVES ON INTERNATIONAL LAW 184 (1990).

137 *See* Roberts & Tsamenyi, *supra* note 37, at 559, 563 (discussing Ballast Water Convention, *supra* note 16, at 17 (Annex 2)).

138 *Id.* at 563 (discussing Ballast Water Convention, *supra* note 16, at 17 (Annex 2)).

139 In the context of this discussion, this refers to an "accidental, unwitting and often unknowing introduction [of NIAS], directly or indirectly caused by human activity." JACKSON, *supra* note 31, at 59.

140 Roberts & Tsamenyi, *supra* note 37, at 563 (discussing Ballast Water Convention, *supra* note 16, at 17 (Annex 2)).

research on ballast water management and monitor the effects of ballast water management in waters under their jurisdiction.[141] Second, ships are required to be surveyed and certified[142] and may be inspected by Port State control officers who can verify that the ship has a valid certificate, inspect the Ballast Water Record Book, and sample the ballast water.[143] If a particular vessel is perceived to be high risk then a detailed inspection may be carried out and, depending on the results of such an inspection, the inspector is permitted to take steps to ensure that the vessel will not discharge ballast water until it can do so without endangering the environment or human health.[144] Control officers are to take all possible efforts to avoid a ship being unduly delayed or detained, however.[145]

As with the AFS Convention, IMO developed a series of fourteen technical guidelines to assist in the unified implementation of the Ballast Water Convention.[146] These technical guidelines have been developed to provide Flag Administrations and Port State Authorities with guidance on procedures and principles to minimize the risk of transferring NIAS in ships' ballast water and sediments and to be in compliance with the Ballast Water Convention.[147] The Ballast Water Convention also allows parties to request technical assistance through IMO and other international bodies in respect to the control and management of ships' ballast water and sediments.[148] Specifically, parties can request technical assistance for personnel training, technology, equipment, and facilities, joint research and development programs, and other elements that are necessary for effective implementation of the Ballast Water Convention.[149]

B. International Mechanism Governing Nonindigenous Aquatic Species

Similar to IMO's adoption of the AFS Convention and Ballast Water Convention, the United Nations Environment Programme (UNEP) has not presented an international agreement dealing directly with biofouling as a pathway for introduction of NIAS. However, UNEP has implemented a Convention relating to NIAS generally. The Convention on Biological Diversity (Biodiversity Convention) is an international, legally binding treaty administered by UNEP that

141 Ballast Water Convention, *supra* note 16, at 5.
142 *Id.* at 6.
143 *Id.* at 6–7.
144 *Id.* at 7.
145 *Id.* at 8.
146 Roberts & Tsamenyi, *supra* note 37, at 563.
147

> Guidelines have been written for: sediment reception facilities; ballast water sampling; ballast water management equivalent compliance; ballast water management and development of ballast water management plans; ballast water reception facilities; ballast water exchange; risk assessment; approval of ballast water management systems; procedure for approval of ballast water management systems that make use of active substances; approval and oversight of prototype ballast water treatment technology programmes; ballast water exchange design and construction standards; sediment control on ships; additional measures including emergency situations; and, designation of areas for ballast water exchange.

Id. at 563 n.10.
148 Ballast Water Convention, *supra* note 16, at 8.
149 *Id.*

was adopted in Rio de Janeiro in June 1992 and entered into force on December 29, 1993.[150] It provides some measures to protect components of biodiversity against NIAS.[151]

The Biodiversity Convention requires parties "as far as possible and as appropriate . . . [to p]revent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species."[152] The second ordinary meeting of the Conference of the Parties to the Biodiversity Convention in 1995 also adopted a program of action for implementing the Convention in marine and coastal environments.[153] At the seventh meeting of the Conference of the Parties to the Biodiversity Convention, the parties identified five thematic issues, one of which related to NIAS.[154] The goal was to "prevent the introduction of invasive alien species into the marine and coastal environment, and to eradicate to the extent possible those invasive alien species that have already been introduced."[155]

C. Inadequacy of Existing Mechanisms

Due to the complexity of biofouling, we argue that existing mechanisms are inadequate for comprehensively regulating the problem, thereby leaving Florida manatees and other species susceptible to numerous negative effects from biofouling.[156] Specifically, a significant gap remains between the existing mechanisms in the management of biofouling associated with barges and associated support vessels, fishing vessels, and recreational craft.[157] In addition, the existing mechanisms fail to recognize the optimal factors for biofouling development and adhesion,[158] make recommendations to manage biofouling through design standards for marinas and harbors,[159] provide standards for biofouling removal, or detail

150 Convention on Biological Diversity, June 5, 1992, 1760 U.N.T.S. 79.

151 *See, e.g.*, *id.* at 146, 149.

152 *Id.* at 148–49.

153 Conference of the Parties to the Convention on Biological Diversity, Jakarta, Indon., Nov. 6–17, 1995, *Rep. of the Second Meeting of the Conference of the Parties to the Convention on Biological Diversity*, Appendix, *Jakarta Ministerial Statement on the Implementation of the Convention on Biological Diversity*, UNEP/CBD/COP/2/19, at 40–41 (Nov. 30, 1995), *available at* http://www.cbd.int/doc/meetings/cop/cop-02/official/cop-02-19-en.pdf.

154 Conference of the Parties to the Convention on Biological Diversity, Kuala Lumpur, Malay., Feb. 9–20, 27, 2004, *Decision Adopted by the Conference of the Parties to the Convention on Biological Diversity at Its Seventh Meeting*, UNEP/CBD/COP/DEC/VII/5, at 11–19 (Apr. 13, 2004), *available at* http://www.cbd.int/doc/decisions/cop-07/cop-07-dec-05-en.pdf.

155 *Id.* at 19.

156 *See* discussion *supra* Part III.

157 *See, e.g.*, AFS Convention, *supra* note 16, at 4 (applying the Convention to all ships, with the exception of government owned or operated ships used for noncommercial purposes); Ballast Water Convention, *supra* note 16, at 3–5 (defining "ship" as "a vessel of any type whatsoever operating in the aquatic environment" and detailing the entities to which the convention applies); Convention on Biological Diversity, *supra* note 150, at 148–49 (stating the parties' commitments to the prevention and control of invasive species, but making no reference to the management of biofouling).

158 *See supra* text accompanying notes 17–29 (explaining the optimal factors for biofilm development and adhesion, thereby facilitating biofouling).

159 *See* discussion *infra* Part VI.A.1 (explaining how marina design can greatly exacerbate the effects of biofouling from both the NIAS and toxic antifouling coating perspectives); *see, e.g.*, McGee et al., *supra* note 70, at 56 (theorizing that marina sediment has higher concentrations of contaminants

measures to treat high-risk vessels.[160] While IMO has expressed a clear commitment to addressing the issue of biofouling on international vessels,[161] additional measures under the ESA must be taken to protect the endangered Florida manatee and its habitat in the meantime.

V. THE FLORIDA MANATEE AND THE ENDANGERED SPECIES ACT

Under the ESA, the government protects listed endangered and threatened plants and animal species, as well as the habitats upon which they depend.[162] The ESA issues two independent legal mandates for federal agencies. Specifically, the ESA requires federal agencies to ensure that any action it authorizes, funds, or carries out does not 1) "take"[163] a listed species except in compliance with an

because marina design limits flushing, therefore limiting the export of contaminants); Floerl & Inglis, *supra* note 70, at 117 (explaining that enclosing a marina through permanent breakwalls may limit flushing of both planktonic larvae and toxic antifouling residues).

160 *See, e.g.*, AFS Convention, *supra* note 16, at 4–5 (requiring that parties take "appropriate measures" in the removal of antifouling systems, but providing no standards for removal of biofouling or measures to treat high-risk vessels); Ballast Water Convention, *supra* note 16, at 5 (requiring each party to develop national policies and programs for Ballast Water Management). *See generally* Convention on Biological Diversity, *supra* note 150 (making no reference to biofouling or vessels of any kind).

161 The *2011 Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species* was reviewed and approved by IMO in July 2011. Marine Environment Protection Committee Sixty-Second Session, July 11–15, 2011, *Adoption of the 2011 Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species*, IMO Res. MEPC.207(62), IMO Doc. MEPC 62/24/Add.1, at Annex 26, (July 15, 2011), *available at* http://www.imo.org/blast/blastDataHelper.asp?data_id=30766 &filename=207%2862%29.pdf [hereinafter Guidelines]. The Guidelines touch on biofouling management plans and recordkeeping; fouling control system installation and maintenance; in-water inspection, cleaning, and maintenance; training and education; and ship design and construction. *Id.* at 5–14. However, they still do not comprehensively address the multifaceted biofouling problem. Namely, the Guidelines are only directed to marine shipping vessels, without consideration of other marine and freshwater vessels that can carry fouling organisms; are only voluntary and not legally enforceable internationally; do not incorporate marina and harbor designs that will mitigate the effects of biofouling; and governmental agencies still have not determined the best means of implementation. *See generally id.* at Annex 26 (outlining the approved guidelines and indicating that they pertain to international, marine shipping under the Ballast Water Convention); AKZONOBEL, Q&A DOCUMENT: IMO ADDRESS TRANSLOCATION OF INVASIVE SPECIES CAUSED BY BIOFOULING ON SHIPS' HULLS 1, 1–2 (2011), *available at* http://www.international-marine.com/InvasiveSpecies/Documents/BiofoulingQADocument.pdf (explaining that Guidelines are voluntary and "are not legally-enforceable at a global level"); Australian Mar. Safety Auth., *AMSA's Role in Maritime Environmental Issues*, http://www.amsa.gov.au/Marine_Environment_Protection/AMSAs_Role_in_Maritime_Environmental_Issues/ (last visited Apr. 7, 2012) (providing an example of a participating nation that has yet to implement the Guidelines: "The Department of Agriculture Fisheries and Forestry [of Australia] will consult with Commonwealth government agencies, State/NT governments and industry on the best way to undertake implementation of the new Guidelines."). The Guidelines was recently published and is available for purchase. INT'L MAR. ORG., GUIDELINES FOR THE CONTROL AND MANAGEMENT OF SHIPS' BIOFOULING TO MINIMIZE THE TRANSFER OF INVASIVE AQUATIC SPECIES (2012).

162 Endangered Species Act of 1973, 16 U.S.C. §§ 1531(b), 1532(3) (2006).

163 The definition of "take" under the ESA means to "harm," which, according to federal regulation, includes "significant habitat modification or degradation that actually kills or injures

incidental take statement,[164] 2) "jeopardize" the continued existence of any listed species,[165] or 3) "result in the destruction or adverse modification of" any critical habitat for that species.[166] Florida manatees are listed as an endangered species and, therefore, are themselves protected under the ESA, as well as their habitat as necessary to prevent the taking of, or harm to, Florida manatees.[167]

When nonfederal entities such as states, counties, local governments, tribal governments, and private landowners wish to conduct an otherwise lawful activity that might incidentally, but not intentionally, "take" a listed marine species,[168] an incidental take permit (ITP)[169] must first be obtained from the National Oceanic Atmospheric Administration (NOAA) National Marine Fisheries Service or, in the case of the Florida manatee, the U.S. Fish and Wildlife Service (USFWS).[170] In order to receive an ITP, all applicants must submit a Conservation Plan (CP)—or specifically, a Habitat Conservation Plan (HCP) if the CP is habitat-based—that meets the requirements outlined in section 10 of the ESA as well as federal agency implementing regulations and guiding documents developed pursuant to section 10.[171] CPs and HCPs are designed to mitigate the potential harm that a proposed development or land use may pose to listed species and provide opportunities for strong public–private partnerships, while still allowing participating landowners

wildlife." *Id.* § 1532(19); 50 C.F.R. § 17.3(c)(3) (2010); *Babbitt v. Sweet Home Chapter of Cmtys. for a Great Or.*, 515 U.S. 687, 708 (1995).

164 16 U.S.C. § 1539(a)(1)(A)–(B) (2006).

165 *Id.* § 1536(a)(2); *see also* 50 C.F.R. § 402.14(a) (2010) (requiring each agency to "review its actions at the earliest possible time to determine whether any action may affect listed species or critical habitat").

166 16 U.S.C. § 1536(a)(2) (2006); *see also* 50 C.F.R. § 402.02 (2010) (defining the required biological opinion as the determination as to whether the "[f]ederal action is likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of critical habitat").

167 U.S. Fish & Wildlife Serv., *supra* note 6.

168 "Take" means to "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." 16 U.S.C. § 1532(19) (2006). "Harm" is further defined to include "significant habitat modification or degradation which actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including, breeding, spawning, rearing, migrating, feeding or sheltering." 50 C.F.R. § 222.102 (2010) (NOAA Fisheries' Harm Rule); *see also* 50 C.F.R. § 17.3(c) (2010) (defining harm as "significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding or sheltering"). Under this "Harm Rule," see, e.g., Laschever, *supra* note 9, at 105 n.6, significant habitat modification that results in the impairment of species' essential behavioral patterns may constitute a violation of the section 9 take prohibition. The ESA provides for civil penalties of up to $25,000 per violation, and criminal penalties of up to $50,000 with an additional penalty of a one-year imprisonment per violation. 16 U.S.C. § 1540(a)(1), (b)(1) (2006).

169 16 U.S.C. § 1539(a)(1)(B) (2006).

170 *See, e.g.*, U.S. FISH & WILDLIFE SERV. & NAT'L OCEANIC & ATMOSPHERIC ADMIN., HABITAT CONSERVATION PLANNING AND INCIDENTAL TAKE PERMIT PROCESSING HANDBOOK 3-1 (1996), *available at* http://www.nmfs.noaa.gov/pr/pdfs/laws/hcp_handbook.pdf [hereinafter HCP & ITP HANDBOOK] (describing the roles of the Services in the ITP process).

171 Office of Protected Res., Nat'l Oceanic & Atmospheric Admin., *Conservation Plans (CPs)*, http://www.nmfs.noaa.gov/pr/permits/cp.htm (last visited Apr. 7, 2012); *see also* Habitat Conservation Plan Assurances ("No Surprises") Rule, 63 Fed. Reg. 8859, 8859–60 (Feb. 23, 1998) (codified at 50 C.F.R. pts. 17, 222); Announcement of Final Safe Harbor Policy, 64 Fed. Reg. 32,717, 32,717 (June 17, 1999); Notice of Final Handbook Availability, 61 Fed. Reg. 63,854, 63,855 (Dec. 2, 1996).

flexibility.[172] Such a proactive approach can reduce future conflicts and may even preclude the listing of species at the outset, furthering the purposes of the ESA.[173]

Private landowners or other nonfederal property owners[174] may undertake voluntary conservation actions on their lands through a direct SHA between the landowner and the USFWS or NOAA.[175] Additionally, entities such as counties or groups of counties may implement an "umbrella SHA,"[176] whereby a state or local government, or several resource conservation nonprofit organizations act as the intermediary[177] to develop a Safe Harbor Program for a specific area.[178] Once USFWS or the NOAA National Marine Fisheries Service approves the umbrella SHA developed by the intermediary, the intermediary then collaborates with individual landowners to create written agreements that will function under the intermediary's umbrella agreement.[179] The result for the landowners is exactly the same as with an individual SHA; however, much of the red tape is eliminated.[180] Landowners can restore habitats for endangered species without being required to utilize the long and strenuous process of obtaining their own voluntary conservation incentive plans,[181] as in an individual SHA, because the voluntary conservation incentive plan of an umbrella SHA is conducted as part of the intermediary's permit.[182]

When a landowner signs either type of SHA, a baseline survey[183] and voluntary conservation incentive plan[184] have to be developed. Because USFWS must enforce the ESA, that agency is entrusted with conducting the baseline

172 Office of Protected Res., *supra* note 171.

173 *Id.* Congress intended for the HCP processes to provide a framework that would encourage such "creative partnerships" between the public and private sectors and state, municipal, and federal agencies in the interests of endangered and threatened species and habitat conservation. HCP & ITP HANDBOOK, *supra* note 170, at 3-1. Congress also intended for the HCP processes to reduce conflicts between listed species and economic development activities. *Id.*

174 A Safe Harbor Agreement is a voluntary agreement involving private or other nonfederal property owners—including state governments and municipalities—whose actions contribute to the recovery of threatened or endangered species under the ESA. U.S. Fish & Wildlife Serv., *For Landowners: Safe Harbor Agreements*, http://www.fws.gov/endangered/landowners/safe-harbor-agreements.html (last visited on Apr. 7, 2012).

175 *See* HCP & ITP HANDBOOK, *supra* note 170, at 3-41; Safe Harbor Agreements and Candidate Conservation Agreements with Assurances, 64 Fed. Reg. 32,706, 32,706 (June 17, 1999) (to be codified at 50 C.F.R. pts. 13, 17); Final Safe Harbor Policy, 64 Fed. Reg. 32,717, 32,717 (June 17, 1999); Final Policy for Candidate Conservation Agreements with Assurances, 64 Fed. Reg. 32,726, 32,726 (June 17, 1999).

176 HCP & ITP HANDBOOK, *supra* note 170, at 3-11.

177 ENVTL. DEF., SAFE HARBOR: HELPING LANDOWNERS HELP ENDANGERED SPECIES 4 (1999), *available at* http://apps.edf.org/documents/8420_SafeHarborHandbook.pdf.

178 *Id.*

179 *Id.*

180 *Id.*

181 *See* Fla. Fish & Wildlife Conservation Comm'n, *Safe Harbor*, http://myfwc.com/conservation/terrestrial/safe-harbor/ (last visited Apr. 7, 2012).

182 *See* ENVTL. DEF., *supra* note 177, at 4.

183 The "baseline condition" of the property to be covered by the SHA reflects the "known biological and habitat characteristics that support existing levels of use of the property by species covered in the Agreement." Announcement of Final Safe Harbor Policy, 64 Fed. Reg. 32,717, 32,723 (June 17, 1999).

184 *See* Fla. Fish & Wildlife Conservation Comm'n, *supra* note 181.

survey.[185] The survey determines the presence or lack of any protected plant or animal.[186] Protected species and habitat present at the time of the survey are all the landowner is responsible for at the end of the SHA's term.[187] For example, if a landowner has ten birds on his land at the time the survey is conducted, then a count of ten birds becomes his "baseline population." He is only responsible for the baseline number, not any additional birds that come onto his land due to habitat restoration performed on the property.[188] Additionally, the landowner receives regulatory assurances that he can alter or modify property enrolled in the SHA and return it to the originally agreed-upon baseline conditions once the agreement terminates, even if this means incidentally "taking" the listed species.[189] Essentially, participating landowners that voluntarily and proactively mitigate adverse impacts to endangered species and habitat are rewarded with regulatory assurances regarding their obligations during and after the term of the SHA.[190]

If the property owner's satisfaction in knowing that he voluntarily restored habitat on his property is not enough, he also 1) is absolved of responsibility for any species that come to the property because of the mitigation measures implemented under the SHA, 2) obtains regulatory assurances that the property can be returned to the originally agreed-upon baseline conditions at the end of the SHA, and 3) may even be able to earn money by participating in a Safe Harbor Program.[191] For example, once Landowner A signs an SHA and completes required mitigation measures specified within the agreement, he has essentially received permission from the USFWS to restore the habitat of an endangered species.[192] Of course, it is habitat that Landowner A created and that would not exist without his efforts.[193]

To expand on this example, consider a second landowner in the community, Landowner B, who has the same type of endangered species on her property yet still wishes to turn habitat on her land into urban development.[194] So long as Landowner B's property is not covered by a SHA, she can either abandon the plan to develop or ask USFWS for permission to develop since the proposed

185 Schreiber, *supra* note 14. However, the National Resources Conservation Service, a state biologist, or even a private environmental consultant may also conduct the survey. *Id.*

186 *See id.*; Fla. Fish & Wildlife Conservation Comm'n, *supra* note 181; *see also* Announcement of Final Safe Harbor Policy, 64 Fed. Reg. at 32,723 ("To the extent determinable, the parties to the Agreement must identify and agree on the degree to which the enrolled property is inhabited . . . [and the Services] must review and concur with the determination . . . .").

187 ENVTL. DEF., *supra* note 177, at 9.

188 *See id.*

189 U.S. FISH & WILDLIFE SERV., WORKING TOGETHER: TOOLS FOR HELPING IMPERILED WILDLIFE ON PRIVATE LANDS 6 (2005), *available at* http://www.fws.gov/endangered/esa-library/pdf/ImperiledWildlifeFinalDec2005.pdf.

190 *Id.*

191 *See, e.g.*, *id.*; ENVTL. DEF., *supra* note 177, at 9–10, 16.

192 *See* ENVTL. DEF., *supra* note 177, at 6.

193 *See id.* Land ownership is commonly described as consisting of a "bundle" of several different rights. *See* DANIEL R. MANDELKER, LAND USE LAW § 2.03 (5th ed. 2003). The bundle of rights includes timber rights, the right to build a structure—or development rights—mineral rights, access rights, and the right to sell. *See, e.g.*, Gerald R. Barber, *Bundle of Rights Approach to Value*, PRIVATE LANDOWNER NETWORK, http://www.privatelandownernetwork.org/plnlo/bundleofrights.asp (last visited Apr. 7, 2012).

194 *See* ENVTL. DEF., *supra* note 177, at 16.

development does harm the habitat of the endangered species.[195] Under section 10 of the ESA, USFWS can grant her permission to develop her land, but only if she agrees to some type of mitigation for the loss of habitat.[196] This agreement can take the form of Landowner B paying Landowner A not to exercise her right to commercially or residentially develop the land that she enrolled in the SHA.[197] In other words, Landowner B financially compensates Landowner A to increase her baseline[198] and permanently protect a larger amount of habitat for endangered species.[199]

Such a transaction has several benefits. For one, there is equity; those who gain from the added development opportunity compensate those who agree to have less development opportunity in order to benefit the public. Secondly, the consolidation of what would otherwise be small, fragmented habitat conservation projects into large, contiguous sites creates higher quality habitats for endangered species.[200]

This scenario, known as "species banking," "biodiversity banking," or "habitat conservation banking," is gaining popularity.[201] In exchange for permanently protecting land, a private or public bank operator is permitted to sell credits, established for the specific listed species that occur on the site, to landowners who voluntarily participate.[202] Currently, there are an estimated 717 wetland and stream banks and 102 species banks in the United States, protecting or

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195 *Id.*

196 *See* Endangered Species Act of 1973, 16 U.S.C. § 1539(a)(2) (2006).

197 *See* ENVTL. DEF., *supra* note 177, at 16.

198 *Id.*

199 *Id.*; Cal. Dep't of Fish & Game, *Conservation and Mitigation Banking*, http://www.dfg.ca.gov/habcon/conplan/mitbank/ (last visited Apr. 7, 2012).

200 Cal. Dep't of Fish & Game, *supra* note 199. Habitat fragmentation is a major threat to biodiversity because it 1) decreases population abundance and distribution, genetic diversity, population growth rate, and breeding success; and 2) alters species interactions and aspects of animal behavior that affect foraging success. *E.g.*, Lenore Fahrig, *Effects of Habitat Fragmentation on Biodiversity*, 34 ANN. REV. ECOLOGY, EVOLUTION, & SYSTEMATICS 487, 499 (2003); Todd BenDor et al., *Simulating Population Variation and Movement Within Fragmented Landscapes: An Application to the Gopher Tortoise (*Gopherus Polyphemus*)*, 220 ECOLOGICAL MODELLING 867, 867 (2009); *see also* PHILIP R. BERKE ET AL., URBAN LAND USE PLANNING 168–71 (5th ed. 2006) (detailing the effects of landscape fragmentation on biodiversity and providing a list of landscape characteristics that support the migration, breeding, nesting, and foraging needs of wildlife, which, in turn support biodiversity).

201 *See, e.g.*, U.S. FISH & WILDLIFE SERV., *supra* note 189, at 10 (citing the Dove Ridge Conservation Bank as an example of this scenario); Ecosystem Marketplace, *Speciesbanking.com: About Us*, http://www.speciesbanking.com/pages/about_us (last visited Apr. 7, 2012) (providing facts and figures with regard to the prevalence of species banks in the United States). Habitat conservation banking is similar to mitigation banking; however, mitigation banking is specifically for wetland restoration, creation, and enhancement. *See* Martin W. Doyle & Todd BenDor, *Evolving Law and Policy for Freshwater Ecosystem Service Markets*, 36 WM. & MARY ENVTL. L. & POL'Y REV. 153, 165–66 (2011). "Use of mitigation bank credits must occur in advance of development, when the compensation cannot be achieved at the development site or would not be as environmentally beneficial. . . . Mitigation banks are generally approved by the wildlife agencies, the U.S. Army Corps of Engineers, and the U.S. Environmental Protection Agency." Cal. Dep't of Fish & Game, *supra* note 199. For more information regarding mitigation banking, see Doyle & BenDor, *supra*, at 159–61 (describing the origins of mitigation banks in the early 1990s, the regulatory processes to mitigation bank designation, and the restoration-in-advance characteristic of this method).

202 Cal. Dep't of Fish & Game, *supra* note 199.

restoring a total of 481,629 acres, with credit prices ranging from $1500 to $650,000 per acre.[203] Although not a guaranteed income source, landowners willing to forgo development can notify USFWS and NOAA National Marine Fisheries Service—agencies responsible for the regulation and approval of habitat conservation banks—and either of these agencies may facilitate a sale of these safe harbor rights.[204]

VI. STRATEGIES: MITIGATION TECHNIQUES AND IMPLEMENTATION

There are two broad ways to reduce or eliminate biofouling risks: source population[205] and direct vector[206] management control.[207] The first control method restricts the source population of the biofouling organisms. Control approaches that reduce the density of fouling organisms will theoretically reduce the likelihood that the vector—or water vessels—will become infected in the first place. Work completed for the New Zealand Ministry of Agriculture and Forestry (Division of Biosecurity) suggests that source population control that achieves near-zero density can be highly effective in reducing the risk of vector infection.[208] The second approach, direct management of vectors, reduces the risk that biofouling organisms will be transported with vector movements, for example, by removing infestation from affected vectors.[209] For coastal states, direct management of vectors is the only way they can hope to prevent the introduction of NIAS at the outset, as they have no authority with regard to the environmental conditions and management techniques used in ports outside their jurisdiction.[210]

These two broad management approaches are not mutually exclusive. Data analysis indicates that a reduction in specific NIAS populations to very low densities, in combination with direct vessel management, greatly reduces the incidence of infection by specific NIAS on vessels.[211] However, in the absence of a consistent and sustained long-term commitment, specific NIAS will quickly

203 Ecosystem Marketplace, *Speciesbanking.com: Home*, http://www.speciesbanking.com/index.php (last visited Apr. 7, 2012).

204 ENVTL. DEF., *supra* note 177, at 16; Cal. Dep't of Fish & Game, *supra* note 199.

205 The term "source population control" refers to approaches that reduce pest density, which will theoretically reduce the likelihood that a water vessel, or other vector, will be infected with biofouling organisms in the first place. PIOLA & FORREST, *supra* note 73, at 9; *see also infra* note 206 and accompanying text (defining the term "vector").

206 The term "vector" refers to the "physical means, agent or mechanism" that facilitates transference of organisms or their propagules—which include spores, seeds, larvae, or regenerative tissue fragments—from one location to another. JACKSON, *supra* note 31, at 58–59. A water vessel is one example of a vector in this context.

207 PIOLA & FORREST, *supra* note 73, at 9.

208 *See id.*

209 *Id.*

210 Roberts & Tsamenyi, *supra* note 37, at 564.

211 PIOLA & FORREST, *supra* note 73, at 9 (describing a study by the Cawthron Institute, which analyzed "data generated during a management programme for *Undaria* in southern New Zealand over 1997–2004 . . . [which] indicates that a reduction in the *Undaria* population to very low densities (*e.g.* 1% of infestation densities) in Bluff Harbour and Big Glory Bay (Stewart Island) in combination with direct vessel management, reduced the incidence of infection by *Undaria* to [approximately] 1% of vessels in those two locations").

reestablish substantial and widespread populations on port structures and in adjacent natural habitats.[212]

Therefore, given the considerable effects biofouling may pose to Florida manatee health and habitat and the significant regulatory gaps of the existing international mechanisms, this Article proposes implementing both direct vector management and source population control measures simultaneously and consistently under section 10 of the ESA. While IMO makes strides toward developing a comprehensive solution to the biofouling problem,[213] the strategy proposed here will aid in the immediate prevention and mitigation of those adverse effects impacting Florida manatee health and habitat.

A. Proposed Source Population Control Mitigation Techniques

1. Marina and Harbor Design and the Use of Antifouling Materials

Research has shown that marina and boat harbor designs may actually exacerbate the proliferation of NIAS and other fouling organisms,[214] with certain designs creating high concentrations of biofilm organisms and slow water velocity necessary for optimal biofilm development and adhesion.[215] Many marinas are designed to be "enclosed" or locked with solid breakwalls or gates to protect vessels from high currents and strong winds (see Figure 1(A)). However, water circulation within enclosed marinas is limited, creating retention areas—for example, eddies—that suspend propagules[216] of fouling organisms for longer periods of time than unenclosed[217] marinas (see Figure 1(B)).[218] Enclosed marinas with more than 200 boats have also been found to have limited tide and current activity, and be more likely to contain fouling organisms than unenclosed marinas with fewer than 200 boats.[219]

212 *Id.*

213 *See supra* note 161 and accompanying text (discussing Australia and IMO's recent efforts to develop best practice measures to minimize the transfer of NIAS through biofouling and research on how to best undertake the proposed measures).

214 *E.g.*, McGee et al., *supra* note 70, at 55–56 (discussing the "benthic community" plight where "poor flushing of the marina basin could result in stagnation and accumulation of oxygen-demanding substances, ultimately causing water quality degradation"); Floerl & Inglis, *supra* note 70, at 124.

215 For a discussion of the optimal factors for biofilm development and adhesion, which thereby allow successful biofouling, see *supra* note 22–25 and accompanying text.

216 The term "propagules" refers to the dispersal agents of an organism, including spores, seeds, larvae, or regenerative tissue fragments. JACKSON, *supra* note 31, at 58.

217 Unenclosed marinas are also referred to as "open" or "tidal" marinas. *See* Floerl & Inglis, *supra* note 70, at 117–18. See *infra* Figure 1(B) for an example of an unenclosed marina.

218 Floerl & Inglis, *supra* note 70, at 124.

219 *See id.* at 117–18, 124. Together, Floerl and Inglis studied both enclosed marinas accommodating between 200 and 240 vessels, and unenclosed marinas accommodating between 140 and 200 vessels. *Id.* at 117–18. They found that these two harbor designs greatly influence the rate at which fouling organisms attach to available surfaces within marinas. *Id.* at 124. The way in which water moves within enclosed marinas with more than 200 vessels results in limited water circulation and effective transportation of planktonic propagules, while also increasing propagule pressure to facilitate attachment to available surfaces including ship hulls. *Id.* Floerl and Inglis's findings indicate that enclosed marinas with berths for 200 to 240 vessels are likely to accelerate the development of

Figure 1: (A) Aerial view of the enclosed Brighton Marina.[220] Arrows illustrate limited water circulation and velocity resulting from the marina's enclosed design. Brighton Marina is the largest marina in the United Kingdom with 1600 yacht berths, accommodating vessels between five and twenty-five meters in length for short or long stays.[221] (B) Aerial view of the open Longshore Club Park and Country Club marina in Westport, Connecticut. Arrows illustrate the enhanced water circulation and velocity resulting from the marina's unenclosed design.[222] (C) Rhu Marina on the west coast of Scotland is made from prefabricated parts and is further sheltered by its own integral floating concrete breakwater system.[223]

hull-fouling accumulations, and increase the chances of transporting NIAS that establish populations as compared to unenclosed marinas with berths for 140 to 200 vessels. *Id.*

220 The authors of this Article altered the original image by applying small arrow icons to demonstrate limited water circulation and flushing. "Brighton Marina." 50º48'38.61" N and 0º06'04.27" W. GOOGLE EARTH. Apr. 15, 2007. June 19, 2011.

221 *See* Premier Marinas, *Brighton Marina and Boatyard*, http://www.premiermarinas.com/pages/brighton_marina_east_sussex (last visited Apr. 7, 2012); Brighton Marina, *Premier Marinas*, http://www.brightonmarina.co.uk/water/premier-marinas.aspx (last visited Apr. 7, 2012).

222 The authors of this Article altered the original image by applying large arrow icons to demonstrate enhanced water circulation and flushing. "Longshore Club Park and Country Club Marina." 41º06'32.76" N and 73º22'04.00" W. GOOGLE EARTH. Apr. 15, 2007. June 19, 2011.

223 "Rhu Marina." 56º00'41.36" N and 40º46'27.27" W. GOOGLE EARTH. Apr. 15, 2007. Aug. 20, 2011. *See* CharterWorld, *SF Marina Breakwater Calms Rhu Marina Scotland*, LUXURY YACHT &

Limited water circulation and heavy boat traffic in enclosed marinas, especially those that house more than 200 vessels, also allow a heavy concentration of metal pollutants to develop and intensify in the marina over time.[224] These metal pollutants typically come from sources such as zinc- and copper-based antifouling paints, industrial waste, urban runoff, sewage discharge, and treated timber pilings.[225] Metal contamination may interfere with the physiological growth, reproductive, and immunological systems of fouling populations, as well as other nontarget communities, at a cellular level.[226]

One prime example of how harbor design influences the development and adhesion of biofilm and the accumulation of metal pollutants is the Dominican Republic's Samaná Harbor. The tropical climate in Samaná Harbor[227] affords the ideal temperature and pH to accumulate a considerable amount of the organisms that can constitute a thick layer of biofilm[228] on a substrate. Furthermore, it is naturally enclosed by the land to the north, south, and west,[229] allowing for the ideal water velocity necessary for biofilm organisms to become suspended in retention areas and adhere to a substrate.[230] In addition, a major development plan for Samaná Harbor, consisting of a yacht marina with several hundred slips and a pier for ocean liners to anchor, was proposed several years ago.[231]

SUPERYACHT NEWS, Mar. 7, 2011, http://www.charterworld.com/news/sf-marina-breakwater-calms-rhu-marina-scotland (last visited Apr. 7, 2012).

224 *See, e.g.*, McGee et al., *supra* note 70, at 39, 56 (discussing marine sediment contamination by metal pollutants); Floerl & Inglis, *supra* note 70, at 116–17 (analyzing water circulation patterns in harbors); PIOLA & FORREST, *supra* note 73, at 5–6 (discussing water circulation in marinas and metal pollutants).

225 PIOLA & FORREST, *supra* note 73, at 6. Pressure treatment of timber pilings forces chemical preservatives into the cellular structure of the wood, enabling the preserved wood to maintain a chemical barrier against decay and marine biofouling organisms. Timber Piling Council, *General Information*, http://www.timberpilingcouncil.org/general.html (last visited Apr. 7, 2012).

226 *See* PIOLA & FORREST, *supra* note 73, at 6. *See also supra* note 44.

227 Samaná Harbor is nestled along the northeast coastline of the Dominican Republic. *See, e.g.*, Hispaniola.com, *Hispaniola Topographic*, http://www.hispaniola.com/dominican_republic/xmaps/hispaniola-topographic.jpg (last visited Apr. 7, 2012).

228 *See* Oppenheimer, *supra* note 21, at 10–11. Organisms that constitute biofilm include diatoms and phytoplankton productivity in this context. *Id.* at 1–2.

229 Samaná Harbor is bordered by the island of Hispaniola's main land—which includes Haiti and the Dominican Republic to the south and west of the harbor—and the harbor's northern border is the Samaná Peninsula. Hispaniola.com, *supra* note 227.

230 *See* Oppenheimer, *supra* note 21, at 9–11. The primary author of this Article studied productivity, diatom abundance, temperature, pH, and water velocity as indicators of biofilm development and adhesion in the tropical and subtropical waters of the Florida Current, the Sargasso Sea, and the Caribbean Sea. *Id.* at 2–3, 9. Data for this paper was collected aboard the SSV *Corwith Cramer* during Cruise C-197 in February and March of 2005, as an extension of courses conducted at the Sea Education Association for six weeks on shore in Woods Hole, Massachusetts. GARY E. JAROSLOW, SEA EDUC. ASS'N, CRUISE REPORT C-197: SCIENTIFIC ACTIVITIES UNDERTAKEN ABOARD THE SSV *CORWITH CRAMER* 5 (2005), *available at* http://www.sea.edu/documents/cruisereports/C-197cruisereport.pdf. During the cruise, data was collected at 153 oceanographic stations in addition to continuous sampling. *Id.*

231 Press Release, Banyan Tree Hotels & Resorts, Banyan Tree to Operate the Most Upscale Marina Resort in the Dominican Republic (Dec. 14, 2007), *available at* http://www.angsanasamanabay.com/en/assets/pdf/Angsana_article_06.zip; Samana.net, *What's New*, http://web.archive.org/web/20080827160618/http://www.samana.net/M/16-old.html (last visited Apr. 7, 2012). However, the project has been delayed by political transitions and financial considerations. *Id.*

Samaná Harbor is an ideal environment for biofilm development and adhesion.[232] Additionally, the accumulation of metal contaminants occurs naturally as a result of its geography and can be expected to be a natural source for the proliferation of NIAS on foreign vessels and the destruction of mollusk populations as a result.[233] If the proposed marina development is constructed to accommodate several hundred boats, these problems will likely be exacerbated.[234]

Therefore, to effectively decrease a resident vessel's risk of infection by unwanted fouling species, a marina should be designed to accommodate fewer than 200 vessels and be either unenclosed or semi-enclosed utilizing floating breakwaters.[235] Although most enclosed marinas utilize permanent breakwaters, floating breakwaters have several advantages over fixed varieties.[236] First, because they are floating they are always well positioned to protect vessels from high currents and strong wind while still allowing for natural water circulation and flushing.[237] In addition, they allow for more flexibility as they are moveable, have low capital costs,[238] and are prefabricated.[239] The floating breakwater design that would be most effective in a marina environment is the RESA design, which consists of floating piers moored to piles[240] (see Figure 1(C)), and a design that utilizes two pontoons separated by a perforated base with a vertical barrier below the lee side.[241] Implementing these design techniques will help to decrease the direct and tangential effects of befouling within marinas at a low capital cost, while still protecting resident vessels from strong waves and wind.[242]

Beyond marina design, the materials used on marina structures can also control the population source. One proven method to control NIAS populations in a marina environment involves covering vessels and marine structures such as pontoons, pilings, and moorings with impermeable plastic or geotextile fabric (see

232 Oppenheimer, *supra* note 21, at 11.

233 *See, e.g.*, Birge et al., *supra* note 44, at 646–48 (describing the differential effects of mercury and other metals on four species of fish); Floerl & Inglis, *supra* note 70, at 125 (positing that nonindigenous species more readily cling to hulls of vessels in enclosed marinas due to enhanced fouling in such locations); McGee et al., *supra* note 70, at 39–40, 48–49, 53, 55–56 (revealing pronounced differences in the concentration of metal contaminants and the biological make-up between an enclosed marina and open water); Oppenheimer, *supra* note 21, at 1–2 (noting the negative effects of metal contaminants on mollusks).

234 *See* Birge et al., *supra* note 44, at 637, 648; Floerl & Inglis, *supra* note 70, at 124–25; McGee et al., *supra* note 70, at 40, 53–54.

235 *See* Floerl & Inglis, *supra* note 70, at 117–18, 124–25; McGee et al., *supra* note 70, at 40, 53–56. A "breakwater" is a fixed—either permanent or temporary—embankment that is usually man-made and constructed to protect harbors and marinas from rough water. LENFESTEY, *supra* note 17, at 65.

236 DONALD W. ADIE, MARINAS: A WORKING GUIDE TO THEIR DEVELOPMENT AND DESIGN 190 (3d ed. 1984) (1975).

237 *Id.*

238 Capital costs are the total cost needed to bring a floating breakwater to an operable status and do not include labor costs except for the labor used for construction. *See* Ctr. for Int'l Envtl. Law, *Climate Change Glossary*, *available at* http://www.ciel.org/Publications/climatechangeglossary.pdf (defining the term "capital costs").

239 ADIE, *supra* note 236, at 190.

240 Breakwater, U.S. Patent No. 3,595,026 (filed Apr. 4, 1969).

241 ADIE, *supra* note 236, at 181, 192.

242 *Id.* at 190.

Figure 2).[243] This technique is referred to as "wrapping" and involves encapsulating a small amount of water between the wrapping material and the infected substrate.[244] Over the course of several days or weeks, the encapsulated water becomes completely depleted of dissolved oxygen or reaches a very low concentration of dissolved oxygen, thereby smothering NIAS and other fouling organisms.[245] When wrapping, the integrity of the wrap must be protected and monitored for the duration of its application period to ensure that external water does not mix with the anoxic water[246] inside the wrap through tears or gaps in the wrapping material.[247] If the wrapping material is correctly applied and maintained to prevent exchange of the encapsulated water, wrapping has been proven to be 100% effective in eliminating fouling.[248]

243 *E.g.*, Piola & Forrest, *supra* note 73, at 10, 12; Aaron Pannell & Ashley D. M. Coutts, Treatment Methods Used to Manage *Didemnum Vexillum* in New Zealand 8–11, 20–21 (2007) (detailing how plastic sheeting and geotextile fabric has also been used to smother *Didemnum vexillum* on both artificial and natural substrates, respectively).

244 Piola & Forrest, *supra* note 73, at 10.

245 *Id.* Whether the depletion of oxygen inside the wrapping occurs within a matter of days or weeks depends on 1) the extent to which the infected substrate is fouled, and 2) the species of fouling organism(s) that are attached to the infected substrate. *Id.*

246 Anoxic water is sea or freshwater that is absent any dissolved oxygen or has a very low concentration of dissolved oxygen of less than 0.5 milligrams per liter. *See* U.S. Geological Survey, *Volatile Organic Compounds in the Nation's Ground Water and Drinking-Water Supply Wells: Supporting Information: Glossary*, http://water.usgs.gov/nawqa/vocs/national_assessment/report/glossary.html (last visited Apr. 7, 2012) (defining the term "anoxic").

247 Piola & Forrest, *supra* note 73, at 11–12.

248 *Id.* (citing to Pannell & Coutts, *supra* note 243, at 25).

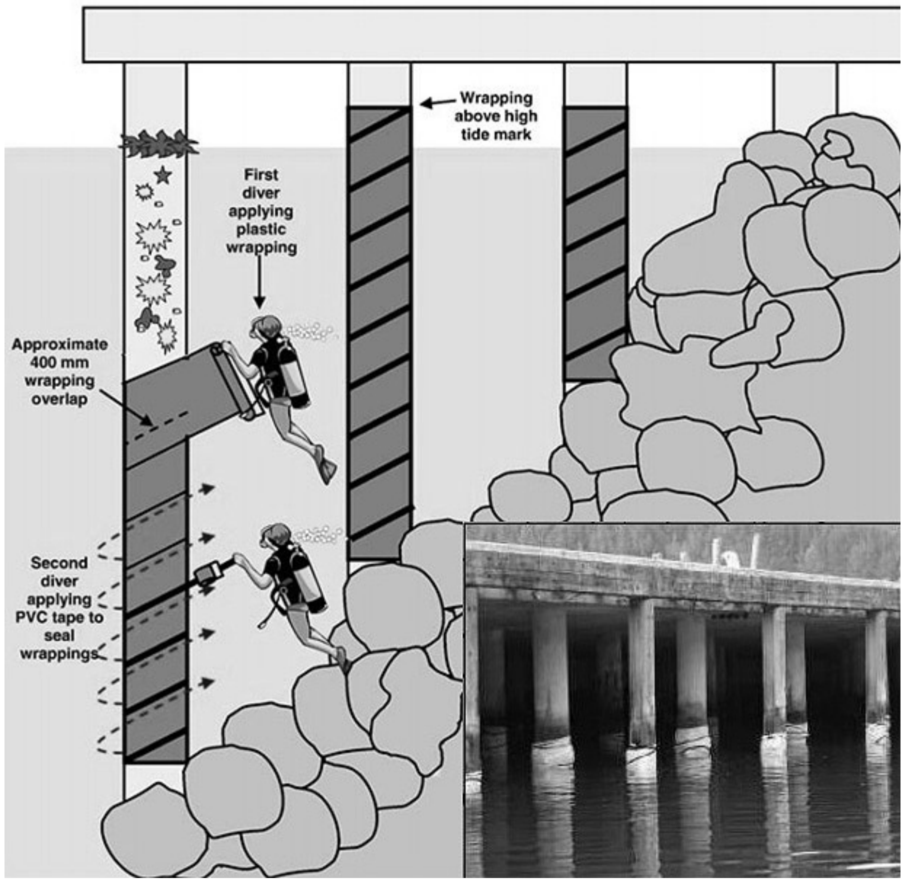

Figure 2: Schematic of the plastic wrapping method used to treat infected wharf piles in Marlborough Sounds, Bluff Harbour, and Waimahara Wharf in New Zealand.[249]

While wrapping is not an inexpensive strategy,[250] it is still considered to be "the best cost-effective method available"[251] with regard to treating wharf pilings when implemented to eliminate the NIAS sea squirt (*Didemnum vexillum*) near

249 The authors of this Article adapted original images from two sources: PIOLA & FORREST, *supra* note 73, at 11 fig.3, and PANNELL & COUTTS, *supra* note 243, at 6 fig.3.

250 Wrapping pilings, as demonstrated in Figure 2, requires the use of plastic balage wrap material at approximately $145.00 per roll and PVC tape at approximately $3.55 per roll plus the cost of labor and equipment. PANNELL & COUTTS, *supra* note 243, at 5. In Waimahara Wharf, New Zealand, for example, it took six days to wrap 178 pilings—costing approximately $16,000 for labor and equipment use, and approximately $1650 for materials to apply the wraps—and is estimated to take three days to remove the wraps—costing $7500 for labor and $1000 for removal materials. *Id.* at 5–6. Wrapping jetties and pontoons with the "set-n-forget" plastic silage technique costs approximately $10,000 for labor and equipment, and $611 in materials per jetty or pontoon. *Id.* at 11. As for the wrapping of vessels, it costs $560 to treat each vessel on average. *Id.* at 16.

251 PANNELL & COUTTS, *supra* note 243, at 5.

Picton, New Zealand, in 2003.[252] Wrapping a vessel is certainly less expensive than providing the additional space and infrastructure to haul out[253] and clean infected vessels.[254] Nonetheless, if management authorities were to find the cost of wrapping for long-term management of biofouling to be too high, they should still consider wrapping to reduce biofouling during crucial seasons.[255] Wrapping just during the spring and summer months, for example, would still be beneficial given that the abundance of many fouling organisms increases with the rise in water or substrate temperature.[256] Alternatively, management authorities should, at a minimum, wrap substrates that are infected with specific, high-threat NIAS or individual, high-risk moorings to still address the dangers of NIAS and other fouling organisms while reducing costs.[257]

Given that antifouling marina designs and wraps can be implemented to significantly address the biofouling problem—or in the case of wraps, be 100% effective[258]—while still being relatively cost-effective, it is feasible for marina management authorities to employ these methods and crucial that they do so. The specific management measures of port, harbor, and marina design should be developed with input from planners, environmental engineers, and scientists to effectively separate berths for domestic and foreign vessels, maximize water circulation, and encapsulate infected marine structures and high-risk vessels with antifouling materials. Employing these measures is the surest way to effectively decrease biofouling and the high concentrations of metal pollution associated with antifouling paint and treated timber pilings. The marina design and wrapping specifications that develop should then be incorporated into the HCPs and SHAs recommended in Part VI.C.[259]

252 PIOLA & FORREST, *supra* note 73, at 12 (detailing the history of the *Didemnum* management program).

253 See *supra* Part VI.B.1 for an in-depth discussion of haul out as a proposed direct vector mitigation technique.

254 Although Piola & Forrest found the cost of wrapping a vessel to be comparable to the cost of hauling out and cleaning a single vessel, the prices of both methods are not comparable given that the costs related to the harbor infrastructure, refuse collection, hauling services, and hull cleaning services necessary to haul out and treat infected vessels can be quite considerable. PIOLA & FORREST, *supra* note 73, at 21 (stating that the cost of wrapping the average 12-meter vessel or hauling out and cleaning the same size vessel is approximately $500). *But see* COASTAL, ESTUARIAL AND HARBOUR ENGINEER'S REFERENCE BOOK 444 (Michael B. Abbott & W. Alan Price eds., 1994) (stating that the planning process as well as the provision of necessary infrastructure services at a marina "can be large and can affect the initial cash flow of new developments").

255 PIOLA & FORREST, *supra* note 73, at 12.

256 *See, e.g.*, *id.* (recommending seasonal wrapping to address the increased quantity and density of fouling organisms, like the *Didemnum*, throughout the spring and summer); Characklis, *supra* note 24, at 563, 574 (stating that the thickness of biofilm, necessary for biofouling organisms to attach to a substrate, increases as water temperature increases and that extent of biofilm accumulation can depend on the substrate's temperature, with the greatest amounts of accumulation generally occurring between spring and fall); JOHN R. DEPALMA, U.S. NAVAL OCEANOGRAPHIC OFFICE, REP. NO. NO0 RP 12, FINAL REPORT ON MARINA BIOFOULING STUDIES AT ADMIRALTY INLET, WASHINGTON 1, 4 (1976), *available at* http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA028786 ("Animal foulers in Admiralty Inlet settle and grow mostly in spring and summer.").

257 *See, e.g.*, PIOLA & FORREST, *supra* note 73, at 12.

258 *Id.*

259 *See, e.g.*, Floerl & Inglis, *supra* note 70, at 124 (recognizing the demonstrable influence of marina design on larval flux and recruitment rates of fouling organisms).

2. Urban Planning and Site Selection for New Marinas

The urban planning aspects of new marina development cover a broad spectrum of considerations from the broad issues of national and regional policies and the evaluation of potential in terms of the boating market, the effect on real estate prices, employment, transportation, and future expansion, to the more narrow and immediate questions of land use planning—including the possibility of mixing uses or several functions within the same marina development[260]—obtaining the necessary approvals, and the preparation of overall feasibility studies.[261] Urban planners and land use attorneys also play vital roles in site selection, for they coordinate, control, and compile the relevant information upon which an objective and logical decision may be found.[262] Planners and land use attorneys will lead teams of several skills and professions at the site selection state, uniting and correlating their expertise to the client's benefit.[263] If, for example, the tidal range at a site is thirty-five feet, and the site is situated along a coast with rough water, then an enclosed marina may be required, and the subsequent planning carried out in light of this constraint.[264]

However, given the marina design techniques recommended in Part VI.A.1, planners, land use attorneys, engineers, and the developer should collaborate during the site selection phase to determine a site where either an unenclosed marina or semi-enclosed marina utilizing floating breakwaters and accommodating no more than 200 vessels is realistic from a land use perspective and economically and structurally feasible. In addition, the planner should consult with a biologist to narrow down the list of potential sites to those that have unfavorable conditions for biofilm growth and attachment.[265] Although the formation of biofilm is dependent upon factors that vary regionally,[266] both biofilm growth and attachment are constrained where there is a short supply of biofilm organisms, like diatoms; limited phytoplankton productivity; water temperatures below 30°C; a pH less than seven or greater than nine; and water flows at a mean speed greater than 0.1 meters per second.[267] These interdisciplinary consultations during the preliminary planning and site selection phase will proactively minimize the likelihood of a future resident vessel becoming infected with fouling species[268] and dangerous concentrations of

260 When mixed-use marina development is properly handled, it stimulates interest and contributes to the architectural character of the development. ADIE, *supra* note 236, at 61. An example of this is St. Katharine's Docks in London, where historic waterfront warehouses were converted to high-density residential structures; all the water was retained as a marina and associated uses. *Id.* at 61.

261 *Id.* at 24. The planning process should also consider, among other things, the general boating market, the number of patrons expected to utilize a proposed marina development, and the increase in real estate prices for lots in the vicinity of proposed marina development. *See id.* at 59, 321.

262 *Id.* at 24.

263 *Id.*

264 *Id.*

265 *See supra* Part II (discussing the relationship between biofilm and biofouling, and the favorable conditions for biofilm growth and attachment).

266 Phillip R. Cowie, *Biofouling Patterns with Depth*, *in* BIOFOULING 87, 94–95 (Simone Dürr & Jeremy C. Thomason eds., 2010).

267 *See* discussion *supra* note 24.

268 *See* Floerl & Inglis, *supra* note 70, at 124–25.

zinc- and copper-based antifouling paints, industrial waste, urban runoff, and sewage discharge.[269]

3. Vessel Design

Vessel design and the fineness[270] of the bow and stern areas compared to the midsection must allow for the best possible flow of water over the hull and water into the propeller, as well as the most streamlined water flow across the entire vessel.[271] This design reduces the frictional resistance from the hull and enhances propeller efficiency.[272] Good laminar flow will effectively safeguard a coating of an antifouling paint system, which will allow for continuous and controlled release of the biocide, thereby reducing the risk of biofouling and the possible introduction of NIAS.[273]

Likewise, if the hull has a large block coefficient,[274] then there is a greater potential for turbulent flow at the bow and stern causing whirlpool currents on the hull, resulting in increased frictional resistance and faster wearing away of the antifouling paint.[275] This condition allows for areas of the hull to suffer more rapid biofouling, as the biocide release is exhausted.[276] Damage, excessive welding reinforcements, and poorly designed mechanical elements of a vessel are all roughened surfaces that can cause eddy currents in the water flow over the hull with the subsequent premature wearing away of the antifouling paint.[277]

The specific design of the bow and stern also impacts biofouling. Bulbous bows[278] are designed to decrease the frictional resistance of the hull, thereby improving laminar flow[279] around the bow compared to the laminar flow around an angular bow.[280] Similarly, bulbous sterns[281] are designed to improve the laminar flow across the hull, around the stern, and into the propeller.[282] Both the bulbous

269 PIOLA & FORREST, *supra* note 73, at 6.

270 A narrow, thin A-line-ended vessel with a sharp V-shaped hull and sharp or narrow front is considered to be "fine." LENFESTEY, *supra* note 17, at 164.

271 Also known as "laminar flow." Laminar flow is "[n]onturbulent flow . . . in layers near a boundary." WEBSTER'S NEW COLLEGE DICTIONARY, *supra* note 18, at 631.

272 TAYLOR & RIGBY, *supra* note 38, at 55.

273 *Id.*

274 If you draw a box around the submerged part of the ship, the block coefficient (C_B) is the ratio of the box volume occupied by the ship. Full forms such as oil tankers will have a high C_B where fine shapes such as sailboats will have a low C_B. *See* 1 K. J. RAWSON & E. C. TUPPER, BASIC SHIP THEORY 12–13 & fig.2.11 (2d ed. 1976).

275 TAYLOR & RIGBY, *supra* note 38, at 55.

276 *Id.*

277 *Id.* at 55–56.

278 A "bulbous bow" is a protruding bulb at the bow of a vessel just below the waterline. LENFESTEY, *supra* note 17, at 68. The bulbous bow is used to reduce the size of the crest of the waves that form at the bow when the vessel moves forward through the water, also known as the "bow wave." *Id.*; Dictionary.com, *Bow Wave*, http://dictionary.reference.com/browse/bow+wave (last visited Apr. 7, 2012).

279 *See supra* note 271 and accompanying text (defining laminar flow).

280 TAYLOR & RIGBY, *supra* note 38, at 59.

281 Similar to a bulbous bow, a bulbous stern works to decrease a ship's stern wave for greater efficiency. Neely-Chaulk & Assocs., *Bulbous Stern*, http://www.neely-chaulk.com/narciki/Bulbous_stern (last visited Apr. 7, 2012).

282 TAYLOR & RIGBY, *supra* note 38, at 60.

bow and stern designs are necessary to enhance the life of the antifouling coating in these areas, thus reducing biofouling.[283]

For these reasons, all areas of the underwater hull, bow, and stern should be designed to minimize the turbulent flow of water across the vessel in order to minimize the risk of biofouling occurring in turbulent areas due to the premature wearing away the antifouling paint. Anodes[284] should also be designed to minimize drag and installed across the hull in areas where turbulence can be reduced in order to maintain the integrity of antifouling coatings.[285] The federal government should consider how to incentivize these preferred vessel designs under the ESA to better address biofouling.

4. Border Control Measures and Inspection

The most effective method to control for NIAS and other foulers is to have border officials inspect every single international vessel for fouling organisms at its first port of call and quickly mandate the cleaning of those that are found to be high risk.[286] However, this process would be extremely time consuming and the costs of administration, equipment, materials, and infrastructure would be significant.[287] As an alternative, it is recommended that a risk assessment system be incorporated into the HCPs and SHAs proposed in Part VI.C and implemented by border officials to identify and subsequently treat high-risk vessels.[288]

As part of an effective risk assessment program, Lynn Jackson of the Global Invasive Species Project suggests that border officials examine a vessel's maintenance, compliance, and travel records, as well as a complete a "risk assessment matrix."[289] A risk assessment matrix provides a series of questions pertaining to the type of vessel and the vessel's maintenance, compliance, and travel history in order to direct border officials to the appropriate response or action (see Figure 3).[290] The first step under the risk assessment matrix is to determine whether the vessel is a "high priority vessel" (see Figure 3).[291] Jackson classifies all vessels that are slow moving and have been in port for a long period of time—including barges, drilling platforms, pontoons, floating dry-docks,[292] and those that

283 *Id.* at 59–60.

284 An "anode" is a cylindrical piece of metal installed into the hull of a vessel to conduct electrical currents away from the vessel into the water, thereby reducing corrosion of metal parts on the vessel. *See* LENFESTEY, *supra* note 17, at 82, 384.

285 TAYLOR & RIGBY, *supra* note 38, at 58.

286 JACKSON, *supra* note 31, at 39.

287 *See id.*

288 *Id.*

289 *See id.* at 39–40.

290 *See id.* at 40.

291 *Id.*; L.S. GODWIN ET AL., THE ASSESSMENT OF HULL FOULING AS A MECHANISM FOR THE INTRODUCTION AND DISPERSAL OF MARINE ALIEN SPECIES IN THE MAIN HAWAIIAN ISLANDS 1, 44 fig.24 (2004), *available at* http://hbs.bishopmuseum.org/pdf/bmtechrep28.pdf.

292 JACKSON, *supra* note 31, at 40. A floating dry-dock is a type of air-filled structure, or pontoon, that allows a vessel to be floated in, then drained to allow the vessel to come to rest on a dry platform. *See* LENFESTEY, *supra* note 17, at 171. Dry-docks are used for the construction, maintenance, and repair of ships, boats, and other watercraft. *See id.* "Floating drydocks are also subject to frequent change of ownership, and are moved around the world, thus making them an even greater [biosecurity] risk." JACKSON, *supra* note 31, at 40.

extemporaneously enter a port to address medical, mechanical, or other emergencies—as high priority vessels.[293]

Beyond utilizing a risk assessment matrix, inspection techniques could begin with the initial step of a visual inspection.[294] The visual inspection can be performed from the pier, a boat alongside the suspect vessel, or an underwater camera operated from the pier to rank the level of fouling according to an agreed upon system.[295] Like the risk assessment matrix, this initial ranking can be used to determine whether a more rigorous, manual inspection by divers is necessary or whether heavy fouling is readily apparent such that the infected vessel must be cleaned or leave port.[296]

Few countries have implemented risk management procedures to limit the introduction of NIAS by international vessels; however, management authorities in Darwin, Australia, the capital city of the Northern Territory, have done so with success.[297] It is estimated that their inspection of more than 700 international vessels between 1999 and 2009 may have prevented approximately thirty introductions of NIAS.[298]

293 JACKSON, *supra* note 31, at 40.

294 *Id.*

295 *Id.* An example of a visual inspection system has been developed. *See generally* Oliver Floerl et al., *A Risk-Based Predictive Tool to Prevent Accidental Introductions of Nonindigenous Marine Species*, 35 ENVTL. MGMT. 765 (2005) (describing the development of a predictive system to analyze risks presented by individual vessels).

296 JACKSON, *supra* note 31, at 40.

297 Floerl et al., *supra* note 295, at 775.

298 *Id.*

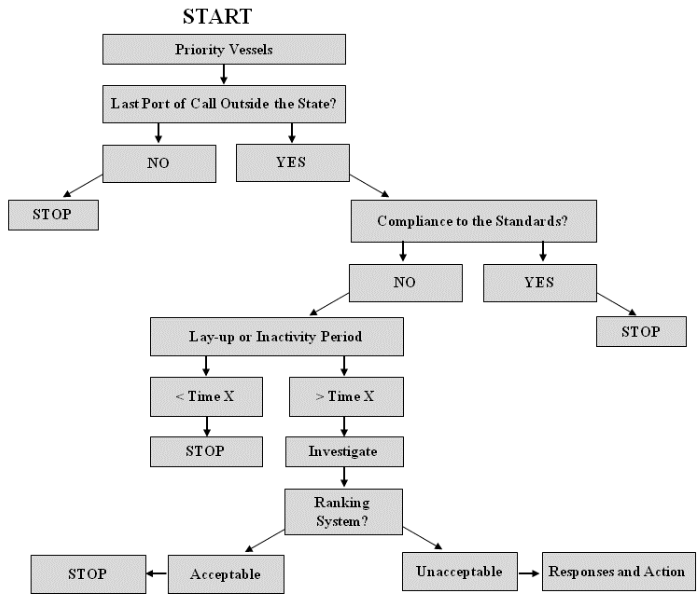

Figure 3: Hypothetical risk assessment matrix.[299]

Predictive modeling[300] proved to be an effective border-based observational technique to identify clean and fouled yachts after their arrival in this instance.[301] In addition, preventing the introduction and establishment of NIAS at the outset is the safest and most efficient way to protect all vectors that transport NIAS and avoid the hefty costs of and environmental dangers that develop as a result of delaying mitigation,[302] especially in combination with other tools suggested in this Article. The predictive tools developed for risk assessment purposes should be included in the HCPs and SHAs recommended in Part VI.C to more comprehensively address the global biofouling problem.

The HCPs and SHAs should also require vessels to keep accurate documentation of antifouling coating applications and maintenance for verification purposes. Specifically, it is recommended that all vessels carry an Anti-Fouling System Record Book (AFSRB) to retain a record of certificates, including an Anti-Fouling Certificate,[303] as well as documentation verifying antifouling coating

299 This hypothetical risk assessment matrix is closely modeled after the one presented by L.S. Godwin. *See* GODWIN ET AL., *supra* note 291, at 44 fig.24. To maintain administrative efficiency, not every vessel entering a port can be investigated. To make the best use of administrative resources it is necessary to prioritize the vessels based on simple binary choices. *Id.* at 50.

300 "Predictive modeling has had several applications in invasion science, including attempts to predict [] successful invaders or their impacts, future invaders, and locations or habitats that are likely to be invaded." *Id.* (citation omitted).

301 *Id.*

302 *Id.* at 776.

303 A certification scheme should be developed to allow for approval of individual antifouling systems, as well as endorsement of warranty provisions for individual antifouling substances and

applications and maintenance.[304] Moreover, all vessels should also carry a Hull Maintenance Record Book (HMRB) to maintain a record of all maintenance performed to the vessel.[305] Both the AFSRB and HMRB should be kept on board and should be made readily available for inspection by the appropriate authority. Prescribed forms for Anti-Fouling Certificates should be drafted and included in the HCPs and SHAs recommended in Part VI.C.[306] The HCPs and SHAs should also detail the requirements of surveys and certification periods for antifouling system integrity and biofouling, including any need for additional surveys and the penalties for failing to meet these requirements.[307]

5. Marina Management Guidelines and Education

Most commercial vessels, if they are not just passing through, are likely to stop over in ports or in their vicinity.[308] However, smaller vessels, and yachts in particular, may just anchor off the coast, especially around small islands and in more remote areas.[309] Although there would be difficulty in enforcing regulations in such situations, the HCPs and SHAs recommended in Part VI.C should include marina management guidelines for visiting vessels. The guidelines should clearly present the biofouling mitigation techniques[310] employed at the facility and express that patron cooperation is expected and required.[311] In addition, the guidelines can outline a biofouling levy and fee systems to cover the costs associated with a biofouling risk management program and penalize the owners of high-risk vessels who are unwilling to treat them.[312]

The management of biofouling involves a wide range of stakeholders and, as is true when new requirements and responsibilities are introduced in any field, they need to be educated to have an understanding of the issue and be trained in management techniques as part of the HCPs and SHAs proposed in Part VI.C.[313] Target groups should include owners and operators of recreational boats,

standards for application and certification of antifouling coatings. The certificate would confirm that the antifouling system was of a type approved under the HCPs and SHAs proposed in Part V.C, and would verify the integrity of the hull coating. *See* Roberts & Tsamenyi, *supra* note 37, at 563–64.

304 Taylor & Rigby, *supra* note 38, at 7.

305 Roberts & Tsamenyi, *supra* note 37, at 566.

306 *See id.*

307 *See id.*

308 *See* Marjorie J. Wonham et al., *Going to the Source: Role of the Invasion Pathway in Determining Potential Invaders*, Marine Ecology Progress Series, May 2001, at 1, 2 (discussing the actions of typical bulk cargo vessels).

309 *See* Piola & Forrest, *supra* note 73, at 1, 4.

310 For example, use of antifouling materials, *see supra* Part VI.A.1, border control measures and inspection systems, *see supra* Part VI.A.4, and standards for biofouling removal, *see infra* Part VI.B.1, should be present in the guidelines.

311 Marina management guidelines, when employed individually by a marina, often address compliance, pollution control, payment of fees—how much, when, and to whom—and control of repairs to vessels within the marina—including vessel hull cleanings and antifouling coat applications. *See, e.g.*, Or. State Marine Bd., Oregon Clean Marina Guidebook 3, 19, 22, 24, 159 (2005) (seeking to educate boaters and marinas on clean operations by providing checklists, forms, and other information).

312 See *infra* Part VI.C for a more detailed discussion of this cost-recovery strategy.

313 *See, e.g.*, Piola & Forrest, *supra* note 73, at 1, 32; Jackson, *supra* note 31, at 29.

commercial ships, ports, marinas, dockyards, and ship scrapyards.[314] In the face of the enormous numbers of recreational boats and boaters, many countries have already put considerable emphasis on outreach programs. The Department of Fisheries and Oceans in Canada, for example, partners with the Ministry of Natural Resources to produce stickers and brochures to distribute at marinas and trade shows.[315] Similar campaigns have also been conducted in the United States and New Zealand.[316]

The Connecticut Sea Grant Extension Program[317] is also collaborating with other Sea Grant programs in the northeastern United States to develop educational and outreach materials for recreational boaters and marina management officials.[318] These materials will not only explain the dangers of NIAS transfers and chemical antifouling coatings, but also detail best practices for hull cleaning and maintenance to reduce the likelihood of accidental introductions of NIAS.[319] These materials will be made available through participating marinas, boating websites and chat rooms, listservs, and boating magazines.[320] Once the marina management guidelines are adopted under the HCPs and SHAs proposed in Part VI.C, more formal education training may be necessary for effective implementation and the outreach materials developed by the Sea Grant Extension Program will be valuable in meeting that need.[321]

B. Proposed Direct Vector Mitigation Techniques—Standards for Biofouling Removal

The HCPs and SHAs proposed below should also consider requiring that marina developers, planners, and engineers allocate additional space, infrastructure, and labor to haul out, clean, and manage high-risk vessels. Ideally, vessel owners would promptly haul out and clean their own vessels; however, some vessel owners may be unavailable or unwilling to cooperate with a haul-out request made pursuant to a biofouling management program.[322] In the case of absentee or nonconforming vessel owners, marina management officials should implement policies and gather the resources to forcibly haul out and clean vessels infected with NIAS or other fouling organisms.[323] Currently, some marina berth rental agreements include language requiring mandatory hauling out and cleaning of

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314 JACKSON, *supra* note 31, at 29.

315 *Id.* at 31.

316 *Id.* at 30.

317 Univ. of Conn., *Connecticut Sea Grant: CTSG Extension*, http://seagrant.uconn.edu/about/extension.php (last visited Apr. 7, 2012) (explaining that the Connecticut Sea Grant Extension Program operates as a part of the University of Connecticut to provide programs in research, outreach, education, and administration for coastal and marine issues).

318 Balcom, *supra* note 58, at 17.

319 *See id.*

320 *Id.*

321 *See* JACKSON, *supra* note 31, at 29.

322 PIOLA & FORREST, *supra* note 73, at 20. See *infra* notes 365–67 for an explanation of how owners may purposely ignore requirements of the biofouling management program in order to have their vessels forcibly hauled out and cleaned for the same cost as doing it themselves and without the hassle of having to organize their own haul out and cleaning.

323 PIOLA & FORREST, *supra* note 73, at 20.

infected vessels.[324] The availability of space and infrastructure to forcibly manage high-risk vessels in this way needs to be considered during the design phase of marina development or expansion, and in advance of incorporating this language into lease agreements.[325]

In situations where there are insufficient resources or infrastructure for the forcible haul-out cleaning of infected vessels and haul-out cleaning cannot be performed promptly to avoid the introduction of NIAS, in-water vessel cleaning is a practicable alternative.[326] Hand removal of problematic NIAS is one way of cleaning vessels without hauling it out of the water; however, hand removal may still result in the dispersal of NIAS's spores, seeds, larvae, or regenerative tissue fragments and subsequent establishment and attachment of NIAS.[327] Other in-water treatments are available that account for removing these propagules[328] of NIAS. One such alternative is the plastic in-water wrapping method,[329] which depletes the water immediately surrounding the vessel of oxygen over the course of several days or weeks, smothering NIAS at any life stage, while the vessel is still in the water.[330] If the wrapping material is applied and maintained so as to maintain its integrity, wrapping can be 100% effective in quarantining high-risk vessels while concurrently eliminating NIAS and other fouling species at a manageable cost.[331] In-water vessel wrapping is also a viable alternative if prompt action is required to prevent the reproduction and attachment of NIAS and timely access to haul-out facilities is delayed or impossible.[332]

Wrapping or enclosure systems are also becoming commercially available.[333] The Sea Pen,[334] for example, is a type of dry-docking enclosure system that

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324 *Id.*

325 *Id.*

326 *Id.*

327 *See id.*

328 *See supra* note 216 (defining the term "propagules").

329 PIOLA & FORREST, *supra* note 73, at 20; *see supra* Figures 1, 2.

330 PIOLA & FORREST, *supra* note 73, at 10, 20; *see supra* notes 242–47 (detailing the wrapping process).

331 PIOLA & FORREST, *supra* note 73, at 11–12; *see supra* note 250 (detailing the cost of vessel wrapping); *see also supra* note 254 (explaining that the cost of wrapping an infected vessel is less expensive than providing the additional space and infrastructure necessary to haul out and clean vessels).

332 PIOLA & FORREST, *supra* note 73, at 21.

333 *Id.*

334 *Id.* A Sea Pen can accommodate vessels between 20 and 100 feet in length. Sea Pen, *Homepage*, http://www.seapen.com.au/seapen.php (last visited Apr. 7, 2012) (follow "ENTER" hyperlink; then follow "faq" hyperlink under the "our products" heading; then click on "9. What size does the Sea Pen come in" hyperlink to access relevant information). The cost of a Sea Pen can vary depending on the size, type, and location of the pen. For example, a model for a 6.5 meter-long vessel is AUD $10,900 and a model for a 30 meter-long vessel is AUD $99,000. E-mail from Mark Barber, Managing Director, Sea Pen, to Kathleen D. Oppenheimer (Apr. 5, 2011, 01:18 EST) (on file with *Environmental Law*). However, the most commonly purchased model is for an 8.5 meter-long vessel at AUD $14,900. *Id.* Please contact Sea Pen for an accurate quote. *See* Sea Pen, *Contact Seapen*, http://www.seapen.com.au/contact.php (last visited Apr. 7, 2012). However, the Sea Pen is cost effective in that it helps maintain the value of one's vessel. *See, e.g.*, E-mail from Mark Barber, *supra*; Sea Pen, *Homepage*, http://www.seapen.com.au (last visited Apr. 7, 2012) (follow "ENTER" hyperlink; then follow "faq" hyperlink under the "our products" heading; then click on "6. How much

encapsulates infected vessels with a waterproof membrane without removing them from their berth.[335] Unlike wrapping, the Sea Pen does not require leaving a small amount of water within the wrap to deplete it of oxygen to smother foulers.[336] Instead, the Sea Pen removes all residual water from within the membrane, exposing the vessel's hull to air, thereby preventing the establishment of fouling organisms.[337] Marina management officials should consider incorporating a dry enclosure system like the Sea Pen during the design phase of marina development or expansion, where space and infrastructure for haul-out cleaning are not available or financially feasible.

C. Implementing Recommended Mitigation Techniques

The ESA requires landowners seeking to develop land or perform certain activities on properties with listed species or critical habitat to obtain an ITP.[338] ITPs require landowners to develop an HCP that clearly defines which activities the landowner intends to perform on the subject property, and how he will abate habitat incidentally taken.[339] This requirement has the potential to be unnecessarily time consuming and redundant in the event adjacent landowners must obtain their own individual HCPs, even though the properties have similar habitat and the same species residing there.

To circumvent this inefficiency while still protecting our case study species—the Florida manatee—and by extension its habitat, we first recommend that Florida's RC&D areas[340] develop umbrella SHAs under section 10 of the ESA[341] to cover a collection of neighboring counties. Under this process, it is encouraged that the voluntary conservation incentive plan incorporate a combination of behavioral and infrastructural biofouling mitigation techniques recommended above in estuary, saltwater, and freshwater ecosystems where Florida manatees rest, graze, and mate.[342] After obtaining approval, we also recommend that both public and private owners[343] of existing, proposed, and expanding marina developments be encouraged to voluntarily sign SHAs under section 10 of the ESA that are covered by the

does it cost?" hyperlink to access relevant information). The Sea Pen can also be retrofitted to fit existing berths. PIOLA & FORREST, *supra* note 73, at 21.

335 PIOLA & FORREST, *supra* note 73, at 21.

336 *Id.* at 21; *see also supra* notes 243–48 and accompanying text (detailing how the wrapping technique operates to remove fouling organisms).

337 PIOLA & FORREST, *supra* note 73, at 21.

338 *See* Schreiber, *supra* note 14.

339 *See id.*; Office of Protected Res., *supra* note 171; *see supra* notes 9, 163 (discussing the definition of take).

340 Florida's RC&D program areas include Central Florida, Florida Three Rivers, Florida West Coast, South Florida, Suwanee River, Treasure Coast, and West Florida. Nat'l Ass'n of Res. Conservation & Dev. Councils, *RC&D Council List*, http://www.rcdnet.org/all-councils-list-by-locatio/ (last visited Apr. 7, 2012).

341 *See* discussion and sources cited *supra* note 11.

342 Manatees can be found in shallow, slow-moving rivers, estuaries, saltwater bays, canals, and coastal areas. U.S. Fish & Wildlife Serv., *supra* note 6.

343 For example, these include state governments, municipalities, and private marina developers.

RC&D areas' umbrella SHA, rather than having to go through the long and strenuous process of obtaining their own individual HCPs.[344]

This umbrella strategy was successfully implemented in 1995 to restore habitat and protect the Attwater prairie chicken (*Tympanuchus cupido attwateri*)[345] of the Texas coastal prairie from extinction.[346] Ranchers voluntarily signed written SHAs under the Sam Houston RC&D's[347] umbrella SHA.[348] As long as the ranchers implement the mitigation practices outlined in the SHA and comply with their baseline requirements, they may lawfully use their property, even if such use incidentally affects a threatened or endangered species or its habitat.[349] Further, should any of the management practices implemented by participating ranchers attract threatened or endangered species, neither the participating landowner nor adjacent landowners will be responsible for any additional regulatory obligations.[350]

As with the Attwater prairie chicken umbrella SHA, the implementation strategy suggested in this Article would require RC&D areas to carry out a range of the recommended biofouling management practices needed to adequately protect Florida manatees and the estuary, saltwater, and freshwater ecosystems on which they depend, as well as maintain efficiency by allowing public and private landowners to follow suit under the umbrella SHA. There are many incentives to encourage landowners to participate voluntarily:[351] 1) the scope of the participating landowners' obligations is limited to the baseline population and does not include any additional species that arrive after they restore habitat;[352] 2) participating landowners are only required to return the property enrolled in the SHA to the baseline conditions after the term of the SHA expires without incurring penalty for a "take";[353] and 3) landowners are not required to go through the long and strenuous process of obtaining individual HCPs.[354] In addition, voluntary participation in the

344 *See* Schreiber, *supra* note 14.

345 U.S. Fish & Wildlife Serv., *Meet the Attwater's Prairie-Chicken*, http://www.fws.gov/southwest/refuges/texas/attwater/meetapc.html (last visited Apr. 7, 2012).

346 *See* U.S. Fish & Wildlife Serv., *Safe Harbor Agreement: Gulf Coast Prairies*, http://ecos.fws.gov/conserv_plans/servlet/gov.doi.hcp.servlets.PlanReport?plan_id=268&region=2&type=SHA&rtype=1 (last visited Apr. 7, 2012) [hereinafter FWS, *SHA: Gulf Coast Prairies*]; *see also* U.S. Fish & Wildlife Serv., *A Story of Loss and Hope*, http://www.fws.gov/southwest/refuges/texas/attwater/story.html (last visited Apr. 7, 2012).

347 The Sam Houston RC&D is an "independent, non-profit organization dedicated to helping communities develop and conserve the environment." Div. of Endangered Species, U.S. Fish & Wildlife Serv., Safe Harbor/Habitat Conservation Plan for the Gulf Coast Prairies of Texas: Questions and Answers (1999), *available at* http://library.fws.gov/Pubs9/Texas_prairies_HCP.pdf.; Natural Res. Conservation Serv., U.S. Dep't of Agric., *Sam Houston RC&D Area*, http://www.tx.nrcs.usda.gov/programs/rcd/Sam_Houston.html (last visited Apr. 7, 2012).

348 *See* Schreiber, *supra* note 14.

349 *Id.*

350 *Id.*

351 *See id.*

352 Envtl. Def., *supra* note 177, at 9 ("[The landowner] won't incur any added obligations as a result of helping those endangered populations increase in number [beyond the determined baseline].").

353 U.S. Fish & Wildlife Serv., *supra* note 189, at 6.

354 *See* Schreiber, *supra* note 14; Envtl. Def., *supra* note 177, at 2, 4 ("The result for the landowners is exactly the same [under an individual agreement and an umbrella agreement]—they

Safe Harbor Program may be financially incentivized through "species banking," "biodiversity banking," or "habitat conservation banking."[355] Currently, mitigation credit prices range from $1500 to $650,000 in the United States.[356]

Unfortunately, banking may be the only financial incentive to encourage voluntary participation in the Safe Harbor Program, as many core endangered species programs, including recovery planning, consultation, and candidate conservation, have been historically underfunded.[357] However, a proposed option for offsetting the cost to implement a biofouling management system within a marina under an umbrella SHA is to introduce a biofouling levy and cost-recovery system as follows:

> 1. A relatively small levy imposed on all vessels using or visiting the marina to cover costs associated with . . . [the biofouling risk management techniques implemented under the SHA], including costs of a regular vessel inspection regime . . . and associated administration.
> 2. A larger fee imposed on owners of vessels identified as high risk to cover costs associated with vessel haul-out, cleaning, and storage, where owners are unable or unwilling to do this. In the case of unwillingness, an infringement notice (*i.e.* fine) system, or even eviction from the marina are possible additional options.[358]

Patrons to a marina implementing such a system may object to it, believing that a marina-wide levy penalizes the majority of vessel owners who already practice good "hull hygiene"[359] and, after all, a marina development cannot succeed unless it appeals to the boating public.[360] Therefore, it is important to keep the levy relatively small[361] so that it may be more widely accepted, but slightly higher for transient and visiting vessels, thereby reflecting the greater likelihood of NIAS being introduced by visiting vessels.[362] Revenue generated from the levy can be used in a number of ways, including 1) financing the administration of a biofouling management program and the vessel inspection system it necessitates;[363] and 2) forcibly hauling out, cleaning, and storing high-risk vessels when the owners are unavailable or unwilling to conform to the requirements of the management program and collecting repayment from the owners for all fees incurred.[364] The

can now restore habitats for endangered species without fear of new regulations—but much of the red tape is handled by the intermediary that holds the permit.").

355 *See, e.g.*, ENVTL. DEF., *supra* note 177, at 16; U.S. FISH & WILDLIFE SERV., *supra* note 189, at 10–11; Ecosystem Marketplace, *supra* note 203 (providing information and resources for those parties that are new to these types of conservation markets).

356 Ecosystem Marketplace, *supra* note 203.

357 SARAH MATSUMOTO ET AL., CITIZENS' GUIDE TO THE ENDANGERED SPECIES ACT 50–51 (2003), *available at* http://earthjustice.org/sites/default/files/library/reports/Citizens_Guide_ESA.pdf.

358 PIOLA & FORREST, *supra* note 73, at 23.

359 *Id.*

360 ADIE, *supra* note 236, at 40.

361 Piola and Forrest recommend approximately $25 per resident vessel a year. PIOLA & FORREST, *supra* note 73, at 24.

362 *Id.* at 24.

363 *Id.*

364 *Id.* This is also referred to as "direct cost recovery."

manner in which the levy revenue will be used should be made clear to the boating public so it may better appreciate the need for the additional expense.[365]

In addition to direct cost recovery from boat owners, a fine system may be implemented.[366] This would be effective for addressing repeat offenders or owners who see direct cost recovery as a convenient way of having a haul-out cleaning done for them.[367] Marina management officials and their legal counsel should consider incorporating a fee notice system into standard berth rental agreements to provide clear notice of the policy to boat owners and increase the likelihood that they will comply with the biofouling management program.[368]

The comprehensive biofouling management and cost-recovery strategy recommended here can safeguard not only the endangered Florida manatee under the ESA. Implementation of this strategy will also protect entire estuary, saltwater, and freshwater ecosystems on which the endangered Florida manatee,[369] Gulf moccasinshell,[370] Ochlocknee moccasinshell,[371] and Shortnose sturgeon[372] depend, from the negative direct and tangential effects of biofouling. Furthermore, this strategy can also serve as a model for other states to better protect their local ecosystems and the corresponding endangered aquatic species from the dangers of biofouling.

VII. ANALOGOUS IMPLEMENTATION AND MITIGATION TECHNIQUES UNDER SECTION 10 OF THE ENDANGERED SPECIES ACT

To adequately protect Florida manatee health and habitat from the adverse effects of biofouling, this Article recommends that both behavioral and infrastructural mitigation techniques be jointly and regionally employed by public and private landowners across estuary, saltwater, and freshwater ecosystems where Florida manatees rest, graze, and mate under section 10 of the ESA. Although these recommendations may seem idealistic or unworkable in real world practice, Congress intended for the HCP processes to provide a framework that would encourage such "creative partnerships" between the public and private sectors, and state, municipal, and federal agencies in the interests of endangered and threatened species and habitat conservation.[373] Not only are the partnerships recommended in this Article consistent with legislative intent, but also there is precedent for employing analogous mitigation and implementation techniques in proposed and approved HCPs and SHAs under section 10. The Gulf Coast Prairies SHA discussed in Part VI.C, for example, was jointly signed by private individuals, a

365 *See* JACKSON, *supra* note 31, at 29.
366 PIOLA & FORREST, *supra* note 73, at 24.
367 *Id.* at 24–25.
368 *Id.* at 25.
369 U.S. Fish & Wildlife Serv., *supra* note 6.
370 U.S. Fish & Wildlife Serv., *supra* note 42.
371 U.S. Fish & Wildlife Serv., *supra* note 43.
372 Office of Protected Res., *supra* note 45.
373 Congress also intended for the HCP and SHA processes to reduce conflicts between listed species and economic development activities. HCP & ITP HANDBOOK, *supra* note 170, at 1-2 (citing H.R. REP. NO. 97-835, at 31, *reprinted in* 1982 U.S.C.C.A.N. 2860, 2872).

nongovernmental organization,[374] and local jurisdictions.[375] Furthermore, like the implementation strategy proposed in this Article, the Gulf Coast Prairies SHA is regional, covering more than 10 million acres of coastal prairie habitat across nineteen counties.[376]

Aside from the Gulf Coast Prairies SHA, there are other section 10 preservation initiatives that are mostly analogous to the umbrella SHA proposed in this Article. Washington's proposed Aquatic Lands HCP,[377] for example, incorporates behavioral and infrastructural biofouling mitigation techniques in estuary, saltwater, and freshwater ecosystems across the state.[378] Specifically, the Aquatic Lands HCP identifies the following behavioral biofouling mitigation measures:

- Prohibition on painting, cleaning, or fouling organism removal over water;[379]
- Reduction of accumulated biofouling solids and aquatic growth releases;[380]
- Establishment of practices that minimize accumulation of biofouling organisms into aquatic environments;[381]
- Incorporation of best management practices to eliminate or reduce contamination from ballast waters, antifouling paints, and other related contaminants from vessel operations and navigation;[382]
- Incorporation of maintenance techniques such as replacement of damaged components and removal of fouling organisms from floats and rafts;[383]
- Prohibition of the use or discharge of toxic chemicals to control fouling of aquaculture nets;[384] and
- Broaden and strengthen invasive species management with the Washington Department of Ecology, Fish and Wildlife, Health, and Agriculture.[385]

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374 *See* U.S. FISH & WILDLIFE SERV., THE COASTAL PRAIRIE CONSERVATION INITIATIVE (CLCI), *available at* http://library.fws.gov/Pubs4/prairie_bookmark.pdf; FWS, *SHA: Gulf Coast Prairies*, *supra* note 356.

375 FWS, *SHA: Gulf Coast Prairies*, *supra* note 346.

376 *Id.*

377 Washington State anticipates signing the implementation agreement with NOAA and USFWS in 2012 for a term of 50 years. Wash. State Dep't of Natural Res., *Aquatic Lands Habitat Conservation Plan*, http://www.dnr.wa.gov/researchscience/topics/aquatichcp/pages/aqr_aquatics_hcp.aspx (last visited Apr. 7, 2012).

378 WASH. STATE DEP'T OF NATURAL RES., AQUATIC RESOURCES PROGRAM ENDANGERED SPECIES COMPLIANCE PROJECT: COVERED HABITAT TECHNICAL PAPER 1-2, 1-10 tbl.1.2 (2005), *available at* http://www.dnr.wa.gov/Publications/aqr_esa_habitat2007.pdf (explaining the scope of the proposed HCP applies to over 2.4 million acres of state-owned tidelands, bedlands, and shorelands in estuarine, saltwater, and freshwater systems and analyzing various activities requiring authorization).

379 WASH. STATE DEP'T OF NATURAL RES., AQUATIC RESOURCES PROGRAM ENDANGERED SPECIES ACT COMPLIANCE PROJECT: POTENTIAL EFFECTS AND EXPECTED OUTCOMES TECHNICAL PAPER 4-32, 6-3 (2007), *available at* http://www.dnr.wa.gov/Publications/aqr_esa_potentail_effects_chapters_1of2.pdf. Best management practices are expected when cleaning, painting, or scraping, including use of off-season haul outs, in order to minimize discharges into the surrounding aquatic environment. *See id.* at 6-3, 6-17.

380 *Id.* at 6-3.

381 *Id.*

382 *Id.* at 6-17.

383 *Id.* at 4-32.

384 *Id.* at 6-2.

385 *Id.*

Beyond behavioral biofouling mitigation measures, the Aquatic Lands HCP goes on to identify in-water and out-of-water infrastructural biofouling mitigation measures to be incorporated and goals to achieve, including the:

- Implementation of dry boat storage, to the maximum extent possible, to reduce the need for overwater structures such as marinas, boat ramps, ship yards, and floating docks ;[386] and
- Reducing the risk of spills and cross-contamination from in-water and hauled-out vessels and equipment through effective design.[387]

The Washington State Department of Natural Resources further recognized how marina design can augment or limit the adverse effects of biofouling in its development of the Aquatic Lands HCP.[388] Specifically, the Department conducted an initial site reconnaissance study to find potential marina monitoring sites to help determine whether widespread implementation of the proposed mitigation measures in a real-world marina environment would be effective for the species and habitat protected under the proposed HCP.[389] In its search for potential monitoring sites, the Department conducted fieldwork to find those marinas that already have the proposed mitigation measures in place or have reasonable opportunities to employ the proposed mitigation measures and are representative of complex marina designs.[390] The field work determined that the Elliott Bay Marina (see Figure 4(A)), Sea Crest Pier, Boat World, and Seattle Leschi Pier in Seattle, Washington, met these criteria; whereas the City of Seattle Pier 55/56, for example, was too large and complex for the Department to efficiently and accurately take the habitat observations and measurements necessary to evaluate the effectiveness of the proposed mitigation measures (see Figure 4(B)).[391]

Although Washington's proposed Aquatic HCP only applies to state-owned aquatic lands,[392] public and private lands can both be protected under a HCP in the Gulf Coast Prairies SHA. For example, Washington's Forest Practices HCP[393]

386 *See id.* at 6-17; *see also id.* at 4-33 to 4-36 (describing the potential water quality, noise, and other impacts associated with the operation and maintenance of these overwater structures).

387 *Id.* at 6-3.

388 *See, e.g.*, Wash. State Dep't of Natural Res., Aquatic Resources Program Endangered Species Compliance Project: Effectiveness Monitoring Design: Suggested Approaches and Considerations 1-1 to 1-3 (2007), *available at* http://www.dnr.wa.gov/Publications/aqr_esa_effective_monitoring_rpt.pdf (stating the report's goals of identifying areas where changes can be implemented, to help develop the HCP, and to monitor the changes effect on the protected areas).

389 *Id.* at B-2.

390 *See id.* at B-5 to B-13 (describing why particular sites were chosen for the study).

391 *Id.* at B-6 to B-9, B-11 to B-13.

392 Wash. State Dep't of Natural Res., *supra* note 377.

393 Noticed in the Federal Register on February 11, 2005, and ESA section 10 permit issued on May 26, 2006. U.S. Fish &Wildlife Serv., *Conservation Plans & Agreements Database*, *Washington Dept. Natural Resources Forest Practices HCP*, http://ecos.fws.gov/conserv_plans/servlet/gov.doi.hcp.servlets.PlanSelect (follow "Region 1: Pacific" hyperlink under the "Habitat Conservation Plans" heading; then scroll to "Washington Dept. Natural Resources Forest Practice"; then follow "Individual Report" hyperlink) (last visited Apr. 7, 2012); Notice of Availability

covers aquatic and riparian habitat along all fish bearing and nonfish bearing systems associated with approximately 9.3 million acres of nonfederal and private forestland in Washington State.[394] Ownership patterns range from individuals and families who own small forest parcels, to large holdings owned or managed by private corporations and public agencies.[395]

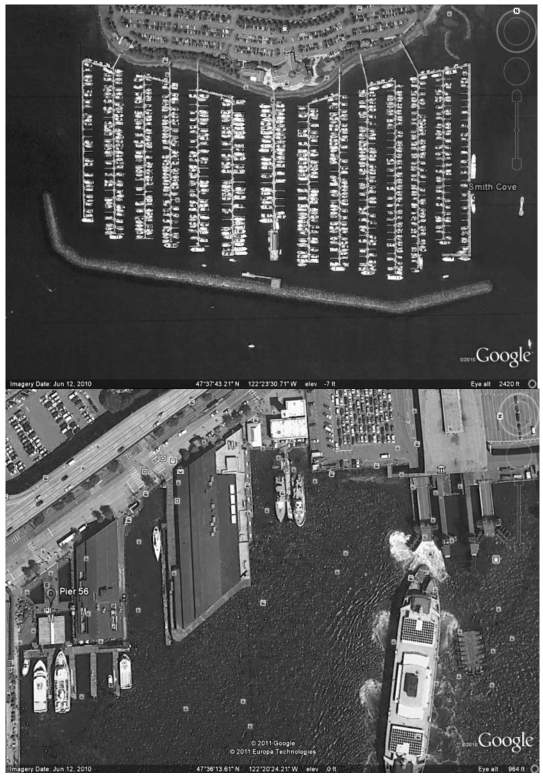

Figure 4: (A) Aerial view of Elliott Bay Marina and the surrounding area.[396] (B) Aerial view of Pier 55/56.[397]

Having strong precedent for employing behavioral and infrastructural mitigation techniques regionally across estuary, saltwater, and freshwater habitats on both public and private lands through the HCP and SHA processes, in addition to consistency with legislative intent, the mitigation techniques, and implementation strategies suggested in this Article are not impracticable. They are, in fact, politically and administratively feasible.

of Draft Environmental Impact Statement and Conservation Plan, 70 Fed. Reg. 7245, 7245–47 (February 11, 2005).

394 U.S. Fish & Wildlife Serv., *supra* note 393; WASH. STATE DEP'T. OF NATURAL RES., FINAL FPHCP – NXECUTIVE SUMMARY, at iii, *available at* http://www.dnr.wa.gov/Publications/fp_hcp_06exsum.pdf.

395 U.S. Fish &Wildlife Serv., *supra* note 393; WASH. STATE DEP'T OF NATURAL RES., *supra* note 394, at iii.

396 "Elliot Bay Marina." 47°37'43.21" N and 122°23'30.71" W. GOOGLE EARTH. June 12, 2010. June 19, 2011.

397 "Pier 55/56." 47°36'13.61" N and 122°20'24.21" W. GOOGLE EARTH. June 12, 2010. June 19, 2011.

Given the considerable effects biofouling may pose to Florida manatee health and habitat and the significant regulatory gaps of the existing international mechanisms, the proposed direct vector management and source population control measures discussed in Part VI can, and should, be incorporated into a regional Safe Harbor umbrella agreement by Florida's RC&D areas. Furthermore, public and private landowners should be encouraged to voluntarily sign SHAs enfolded in the RC&D areas' umbrella agreement. Doing so would be a significant step toward comprehensively and effectively protecting Florida manatees and their habitat from the effects of biofouling.

VIII. CONCLUSIONS

Biofouling is a complex global problem that has serious economic implications for a number of industries, including shipping, aquaculture, and recreation. At the same time, biofouling has substantial global consequences including increased greenhouse gas emissions[398] and established NIAS populations.[399] Moreover, antifouling paints have largely been based on the use of biocides, which is believed to have implications for the broader aquatic environment.[400] Even cleaning measures for fouling can additionally damage the environment if the fouling organisms are not properly disposed of once removed from a vessel.[401]

Biofouling also has specific, serious consequences for marine mammals such as the endangered Florida manatee. Its skin can accumulate fouling organisms resulting in increased weight, decreased flexibility, increased friction, topical damage from anchoring fouling organisms, and damage due to grazers preying on fouling organisms.[402] Toxic levels of zinc and copper from antifouling paint products can also accumulate in harbors, bays, and marinas with heavy boat traffic and limited water circulation,[403] potentially stifling a Florida manatee's growth and food intake or causing anemia or degradation of liver, kidney, brain, and muscle.[404] Further, the potential transfer of NIAS from biofouling could greatly impact the very existence of the Florida manatee by introducing additional predators, reducing

398 Marianne Stanczak, *Biofouling: It's Not Just Barnacles Anymore*, http://www.csa.com/discoveryguides/biofoul/overview.php (last visited Apr. 7, 2012).

399 *E.g.*, Balcom, *supra* note 58, at 14–15; *Ballast Water Management: New International Standards and National Invasive Species Act Reauthorization: Hearing Before the Subcomms. on Coast Guard and Maritime Transportation and on Water Resources and Environment*, 108th Cong. 25–27 (2004) (statement of Catherine Hazlewood, Clean Oceans Program Manager, Ocean Conservancy).

400 *See, e.g.*, Birge et al., *supra* note 44, at 641–42 (explaining the effects of chronic mercury exposure on trout).

401 *See* Balcom, *supra* note 58, at 15 (explaining that cleaning a hull by scraping its surface to release fouling organisms is only a temporary solution and, if not conducted responsibly, contributes to the global problem of transporting NIAS).

402 Wahl, *supra* note 49, at 181.

403 *See* McGee et al., *supra* note 70, at 56.

404 EISLER, *supra* note 48, at 85–86; AGENCY FOR TOXIC SUBSTANCES & DISEASE REGISTRY, *supra* note 48, at 4.

food supply, spreading foreign disease, and generally disturbing resting and mating behavior.[405]

Therefore, the Florida manatee has become a "canary in a coal mine,"[406] indicating the degrading health of the entire ecosystem on which it depends, providing early warning of the dangers biofouling has, and will continue to impose, without further intervention, on the estuary, saltwater, and freshwater ecosystems on which it depends. While considerable attention has been given to regulatory options for the control of ballast water, an international legal instrument to specifically control biofouling does not yet exist. Existing international legal mechanisms only touch on some aspects of the biofouling problem, making them insufficient to comprehensively manage the entire issue to adequately protect Florida manatees and their habitat. While IMO has expressed a clear commitment to addressing the issue of biofouling on international shipping vessels,[407] additional measures under the ESA must be taken to protect the Florida manatee and its supporting ecosystems.

In our discussion of methods for effectively mitigating the risks of biofouling on Florida manatees and their habitat, this Article recommends that 1) direct vector management and source population control measures, recommended in Part VI, be employed regionally through an umbrella SHA signed by Florida's RC&D areas under section 10 of the ESA across estuary, saltwater, and freshwater ecosystems; and 2) both public and private landowners be encouraged to sign auxiliary SHAs to be covered by the RC&D areas' Safe Harbor umbrella agreement. This strategy would employ effective mitigation techniques to protect Florida manatee health and the ecosystems on which they depend, while maintaining efficiency, rewarding participating landowners for voluntarily engaging in conservation efforts, and making significant strides towards creating ecological harbors that are actually safe.[408]

The comprehensive biofouling management strategy proposed here also has several implications for the urban planning processes surrounding marina construction and expansion. If implemented, urban planners and land use attorneys will be expected to proactively lead interdisciplinary collaborations between developers, engineers, biologists, and municipal and state representatives during the marina site selection phase to an unprecedented degree. Planners and land use attorneys will then bring together information obtained from all parties to determine which site is the most economically, biologically, legally, and structurally feasible for the client and has the greatest potential to minimize the negative effects of biofouling on surrounding ecosystems. Planners may also be a key resource for increasing awareness and understanding about the harms of biofouling and the introduction of NIAS amongst their clients, as well as the various biofouling mitigation techniques proposed in Part VI that boaters, marina operators, and boat yards should implement under the proposed SHAs.

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405 *See* Balcom, *supra* note 58, at 15; Nico et al., *Interactions*, *supra* note 63, at 517; Audio tape: Interview with Kathleen Tripp, *supra* note 63.

406 Plater, *supra* note 8, at 812.

407 *See supra* note 161.

408 *See* Schreiber, *supra* note 14.

It is also important to note that the biofouling mitigation techniques proposed in Part VII will only be successful in addressing biofouling's adverse effects when implemented for both commercial and recreational vessels. Recreational vessels can pose a significant and often overlooked biosecurity risk generally, and to the Florida manatee specifically. In addition, these measures must also be drafted with consideration of how biofilm—the layer of bacteria, diatoms, and seaweed to which biofouling organisms—adheres, develops, and attaches to a surface. Specifically, successful measures must recognize how biofilm development and adhesion to a substrate is dependent upon favorable conditions including biofilm organism concentration, water temperature, pH, and water velocity past the substrate, as well as the relationship between biofilm and biofouling organisms.[409]

The recognition of optimal factors for biofilm development and adhesion and the relationship that exists between biofilm and biofouling organisms should logically permeate HCPs and SHAs to manage biofouling through design standards for marinas and harbors, maintenance and inspections, standards for biofouling removal, and measures to treat and monitor high-risk vessels, as detailed in Part VI. These methods of managing biofouling were not fully considered in the existing legal instruments at the international level in light of the biological considerations of biofilm or biofouling organisms. However, they are crucial to comprehensively addressing the global issue of biofouling and its local impacts on estuary, saltwater and freshwater ecosystems on which Florida manatee depend and, therefore, must be addressed using HCPs and Safe Harbor umbrella agreements under the ESA.

409 For a discussion of the optimal sites for biofilm development and adhesion, see discussion *supra* note 24.