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## Chumming on the Chesapeake Bay and Complexity Theory: Why the Precautionary Principle, Not Cost-Benefit Analysis, Makes More Sense as a Regulatory Approach

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# CHUMMING ON THE CHESAPEAKE BAY AND COMPLEXITY THEORY: WHY THE PRECAUTIONARY PRINCIPLE, NOT COST-BENEFIT ANALYSIS, MAKES MORE SENSE AS A REGULATORY APPROACH

Hope M. Babcock\*

*Abstract:* “[H]istory reveals not merely that change is real but also that change is various. All change is not the same, nor are all changes equal. Some changes are cyclical, some are not. Some changes are linear, others are not. Some changes take an afternoon to accomplish, some a millennium. We can no more take any particular kind of change as absolutely normative than we can take any particular state of equilibrium as normative . . . . The challenge is to determine which changes are in our enlightened self-interest and are consistent with our most rigorous ethical reasoning, always remembering our inescapable dependency on other forms of life.”<sup>1</sup>

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## INTRODUCTION

Estuaries like the Chesapeake Bay (“Bay”) and Puget Sound are in grave trouble. They each suffer from poor water quality, loss of habitat, and declining biodiversity, and efforts to restore their health are straining both public and private resources.<sup>2</sup> While accomplishments are often

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\* Professor of Law, Georgetown University Law Center. The contents of this article rely partially on a rulemaking petition students at the Institute for Public Representation (IPR), a public interest law clinic at Georgetown, submitted on behalf of Captain Norman W. Bartlett to the Maryland Department of the Environment in January 2007. The author is indebted to IPR students Bradford McLane and Jeremy Osborne and IPR graduate teaching fellow Erik Bluemel who wrote that petition.

1. DONALD WORSTER, NATURE’S ECONOMY: A HISTORY OF ECOLOGICAL IDEAS 432 (Cambridge Univ. Press 2d ed., 1994).

2. See PUGET SOUND ACTION TEAM, OFFICE OF THE GOVERNOR, STATE OF THE SOUND 2004 59 (2005) [hereinafter PUGET SOUND ACTION TEAM],

recorded in the fight against these ills, it is clear these accomplishments “are not yet equal to the scale of the problems.”<sup>3</sup> The focus of this article is on the nation’s largest estuary, the Bay. Despite the investment of billions of dollars to improve water quality,<sup>4</sup> the Bay continues to suffer from severe environmental degradation that impairs statutorily protected uses such as “[t]he growth and propagation of fish (other than trout), other aquatic life, and wildlife.”<sup>5</sup>

Among the most serious of the ills afflicting the Bay’s water quality is eutrophication.<sup>6</sup> Eutrophication, which lowers dissolved oxygen levels in the water, sets off positive feedback loops<sup>7</sup> further eroding the Bay’s health. This article brings to the fore a largely overlooked source of the Bay’s eutrophication problem: the practice of chumming. Chumming involves dumping a slurry of decomposed or decomposing baitfish, usually menhaden, over the side of a boat to attract highly-prized game species like striped bass. The practice is widely used by Maryland’s recreational fishing industry, which is an important part of Maryland’s economy.<sup>8</sup>

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<http://www.psat.wa.gov/Publications/StateSound2004/PSATSOS2004.pdf> (“The pace of change in the Puget Sound region is staggering. Population growth and the accompanying increases in impervious surfaces; alteration and loss of habitat; and a slew of toxic contaminants entering the water, are all challenging government and private sector efforts to keep even with, or get ahead of, the problems.”).

3. *Id.*

4. CHESAPEAKE BAY PROGRAM, CHESAPEAKE BAY 2005 HEALTH AND RESTORATION ASSESSMENT, PART TWO: RESTORATION EFFORTS 4 (Mar. 2006), [http://www.chesapeakebay.net/assess/restoration\\_report\\_final\\_033106\\_web.pdf](http://www.chesapeakebay.net/assess/restoration_report_final_033106_web.pdf) (noting that “[f]rom 1995–2004 state and federal government partners invested \$2.5 billion in their efforts to cut nutrient and sediment pollution into the Bay and its tributaries”) [hereinafter CHESAPEAKE BAY 2005 PART II]. Federal and state officials estimate that the work that remains to restore the health of the Bay will cost approximately \$28 billion—the equivalent of purchasing six aircraft carriers. See David A. Fahrenthold, *What Would It Take to Clean Up the Bay by 2010?*, WASH. POST, Jan. 29, 2007, at A1.

5. See MD. CODE REGS. § 26.08.02.02(B)(1)(d) (2007); CHESAPEAKE BAY PROGRAM, CHESAPEAKE BAY 2005 HEALTH AND RESTORATION ASSESSMENT, PART ONE: ECOSYSTEM HEALTH 4 (Mar. 2006), [http://www.chesapeakebay.net/assess/health\\_report\\_final\\_033106\\_web.pdf](http://www.chesapeakebay.net/assess/health_report_final_033106_web.pdf) (providing a “health assessment summary” of Chesapeake Bay in light of restoration efforts) [hereinafter CHESAPEAKE BAY 2005 PART I]; CHESAPEAKE BAY PART II, *supra* note 4 (providing summary of restoration efforts and amounts invested by state and federal government partners during the period from 1995–2004).

6. CHESAPEAKE BAY 2005 PART I, *supra* note 5, at 4.

7. In positive feedback, the original process whereby the consequences of an ongoing process become factors in modifying or changing that process is reinforced. PETER COVENEY & ROGER HIGHFIELD, *FRONTIERS OF COMPLEXITY: THE SEARCH FOR ORDER IN A CHAOTIC WORLD* 427 (Fawcett Columbine, 1995). Here that cycle is set in motion by low dissolved oxygen levels.

8. See Charlie Petrocci, *The Deep Lines of Fishing – Part I An Economic Engine*, SKIPJACK.NET

Chum contributes to the Bay's serious nutrient enrichment problem by increasing biological oxygen demand, resulting in lower dissolved oxygen levels in the water.<sup>9</sup> It also increases water turbidity and may be a source of bacterial disease in striped bass. The use of menhaden as baitfish is also contributing to the decline in populations of that critically important food and filter fish. Even though chumming adversely affects the Bay's water quality and threatens its biodiversity, neither the federal government nor Maryland currently regulates the practice. While Bay area regulators may believe that they have made an economically rational decision to attend to larger targets of opportunity such as nutrient discharges from sewage treatment plants and farm fields, the high cost and political flashpoints of addressing those large sources of nutrients have largely paralyzed legislators and regulators for nearly two decades.<sup>10</sup> The result is that the Bay's eutrophication problem is getting worse, and the bill for addressing the problem is getting bigger.

The reluctance of regulators to address small sources of environmental problems, or even small environmental problems, is not unusual and is what makes the chumming story relevant to those who live outside the Bay's watershed. The premise of this article is that the

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(Apr. 2004), <http://www.skipjack.net/article.asp?StoryID=33> (saying "Maryland has the second highest level of expenditures by saltwater anglers in the Northeast Region"). In 1991, these expenditures produced nearly \$14 million in state sales tax. See Susan-Marie Stedman & Jeanne Hanson, *Habitat Connections: Wetlands, Fisheries and Economics Part Five: Wetlands, Fisheries, & Economics in the Mid-Atlantic*, <http://www.nmfs.noaa.gov/habitat/habitatconservation/publications/habitatconnections/num5.htm>. Saltwater recreational fishing in 1991 also generated nearly 5,000 jobs and resulted in more than \$103 million in earnings for people in Maryland's coastal communities. See *id.* The U.S. Fish & Wildlife Service estimated that recreational fishers spent \$854 million dollars in 2001 in Washington. Wash. Dep't of Fish and Wildlife, *ADDING IT UP, WASHINGTON COMMUNITIES PROFIT FROM FISH, WILDLIFE RECREATION 1* (Dec. 2002), [http://wdfw.wa.gov/pubaffrs/adding\\_it\\_up\\_lg.pdf](http://wdfw.wa.gov/pubaffrs/adding_it_up_lg.pdf).

9. Biological oxygen demand (BOD) is the amount of oxygen consumed by microorganisms in decomposing organic matter in a body of water. See EPA, *MONITORING AND ASSESSING WATER QUALITY: DISSOLVED OXYGEN AND BIOCHEMICAL OXYGEN DEMAND*, <http://www.epa.gov/volunteer/stream/vms52.html> (last visited Dec. 8, 2006).

10. Professor William H. Rodgers, Jr., the Stimson Bullitt Professor of Environmental Law at the University of Washington Law School and author of numerous law journal articles and one of the most well-respected treatises on environmental law, asks whether an agency's failure to achieve a primary objective with respect to solving "tougher resource commons disputes," here the Bay's over-nutritification problems, can affect its resource allocation practices, and whether agencies are "inclined to preside over the extirpation of a resource caught up in the decline of the commons or do considerations of institutional self-interest dictate a fall-back strategy that at least slows down the decline?" William H. Rodgers, Jr., *Building Theories of Judicial Review in Natural Resources Law*, 53 U. COLO. L. REV. 213, 220 (1981-82).

failure of regulators to regulate chumming originates through a misapprehension about how complex natural systems like estuaries behave and also in an over-dependence on economic analytical methodologies, like bioeconomics and cost-benefit analysis. Economic approaches measure success based on the amount of pollutants taken out of the waste stream and undervalue broader, more difficult-to-quantify improvements to the receiving environment. Because economic approaches depend on factors remaining stable, they are also singularly ill-suited to constantly changing natural systems. Precautionary principles are better suited to the preservation of biodiversity in these systems, where so much is scientifically uncertain and where the goal is to avoid irreversible and catastrophic consequences regardless of the economic sense in taking the precautionary steps.<sup>11</sup> These same conclusions apply to other complex, evolving natural systems and other types of low volume, but ultimately highly detrimental environmental harms to them.

To assist in the development of this thesis, Part I of the article presents background information on the Bay and the serious problem of nutrient enrichment. Part II introduces the reader to the practice of chumming and its contribution to the Bay's over-enrichment problems. Part III explores how the misguided reliance of regulators on choosing an economically rational target, usually the largest sources of environmental problems, misapprehends the capacity of smaller sources in complex natural systems like estuaries to cause potentially irreversible and catastrophic positive feedback loops. This misguided approach, in turn, may lead to loss of biodiversity. Part III also describes the precautionary principle, and how its application would direct regulators to prohibit the practice of chumming in the Bay.

## I. THE BAY IS IN SERIOUS TROUBLE

The Bay, covering 2,500 square miles, is North America's largest estuary.<sup>12</sup> At 4,000 miles in length, it is also the longest estuary in the country—longer than the entire West Coast.<sup>13</sup> The Bay's 64,000-square-

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11. See generally Cass R. Sunstein, *Irreversible and Catastrophic*, 91 CORNELL L. REV. 841, 896–97 (2006) (arguing the relevance of precautionary principles regardless of the expected value from the averted risk).

12. CHESAPEAKE BAY 2005 PART I, *supra* note 5, at 2.

13. WHITE, CHESAPEAKE BAY FIELD GUIDE. In contrast, Puget Sound has 2,500 miles of shoreline and appears to be slightly larger, containing 2,800 square miles of inland marine waters.

mile drainage area encompasses all or parts of six states and the District of Columbia.<sup>14</sup> It is home to more than 3,600 species of plants and animals,<sup>15</sup> including 348 species of finfish and 173 species of shellfish,<sup>16</sup> and it offers unique commercial and recreational opportunities, prime among which is fishing.<sup>17</sup> Approximately seventy-eight percent of Maryland's commercial fisheries depend upon the Bay for some part of their life cycle, food, and shelter.<sup>18</sup> The Bay has been among the most productive of the country's estuaries—only the Atlantic and Pacific oceans rival the Chesapeake's annual seafood output.<sup>19</sup>

The Bay is different from the “glacier cut fjords” of the Pacific Northwest, like Puget Sound, or in the East, like Hudson Bay.<sup>20</sup> It is “more finely sloped” and shallower, giving wetlands traction along its shores and allowing sunlight to reach aquatic plants.<sup>21</sup> The Bay's wide mouth allows for vigorous tidal flushing as well as a net outflow of water to the ocean; its many tributaries contribute freshwater, nutrients, and other important material for plant growth.<sup>22</sup> The Bay's plant life

*See* Puget Sound Online, *The Physical Sound*, [http://www.psat.wa.gov/About\\_Sound/psindex.htm](http://www.psat.wa.gov/About_Sound/psindex.htm) (last visited Aug. 18, 2007). More than fifty percent of Washington's recreational salmon is caught in Puget Sound, and nearly two million pounds of oysters and clams are harvested annually by recreational harvesters. *See id.* Puget Sound's shore line is a mixture of “beaches, bluffs, deltas, mudflats, and wetlands.” Puget Sound Online, *About the Sound*, [http://www.psat.wa.gov/About\\_Sound/AboutPS.htm](http://www.psat.wa.gov/About_Sound/AboutPS.htm) (last visited Aug. 18, 2007). More than 10,000 streams and rivers drain into the Sound from Washington State and British Columbia. *Id.*

14. WHITE, *supra* note 13, Fig. 2, at 8. This creates “a watershed land to Bay water volume ratio seven times that of any other major estuary in the world.” CHESAPEAKE BAY 2005 PART I, *supra* note 5, at 2.

15. Chesapeake Bay Program, *Other Plants and Animals, Status and Trends*, <http://www.chesapeakebay.net/baybio.htm>.

16. Chesapeake Bay Program, *Did You Know*, <http://www.chesapeakebay.net/factoids.htm> (last visited Aug. 18, 2007).

17. Md. Dep't of the Env't, Chesapeake Bay Restoration, <http://www.mde.state.md.us/water/bayrestoration.asp> (last visited Oct. 31, 2006); MD. CODE REGS. § 26.08.02.02(B)(1)(a)–(c) (2007) (describing designated uses). Similarly rich in biological resources, the Puget Sound has 100 species of sea birds, 200 species of fish, twenty-six different types of marine mammals, and numerous invertebrates. *See* PUGET SOUND ACTION TEAM, *supra* note 2, at 2.

18. Stedman & Hanson, *supra* note 8.

19. WHITE, CHESAPEAKE BAY FIELD GUIDE, *supra* note 13, at 3.

20. *Id.* at 4.

21. *Id.* The Bay's average depth is twenty-one feet. *Id.*

22. *Id.* at 4. “On average, 70,000 cubic feet of water flow into the Bay each second from its tributary sources . . . barely one ninth the volume of sea water flowing into the Bay at any instant.” *Id.* at 13.

provides oxygen and critically important habitat and nursery areas<sup>23</sup> for aquatic species, as well as protective shelter for crabs and juvenile fish.<sup>24</sup>

However, the Bay, like all estuaries, also presents a naturally “stressful” environment for many species because of temperature fluctuations and salinity gradients, both of which create barriers that many species cannot cross.<sup>25</sup> In addition, the Bay’s “circulatory system,” which contains critically important organic and inorganic compounds, dissolved gases, and nutrients, is affected by the “dynamic interaction” of freshwater, salinity, and tidal flow, each of which “is highly variable.”<sup>26</sup> This volatility results in a highly unstable environment for estuarine organisms and migratory species.<sup>27</sup> Water turnover in the Bay is slow, taking on average approximately two to three weeks to move through the Bay’s entire length.<sup>28</sup>

One hundred and fifty tributary rivers and streams drain into the Bay.<sup>29</sup> The diversity in the geophysical regions supplying fresh water with a broad geochemical range creates a variety of ecological zones in the Bay, which Christopher P. White, formerly a staff biologist with the Chesapeake Bay Foundation, calls “ecological partitions.”<sup>30</sup> Only a few species can tolerate these stressful conditions.<sup>31</sup> These phenomena,

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23. Many anadromous species like striped bass spawn in the brackish waters of tributaries and the upper Bay, those areas where fresh and salt water mix, “where detritus, nutrients and phyton plankton are at a maximum.” *Id.* at 7. While marine species, like menhaden, spawn in the Atlantic, their larvae get carried into the Bay by deepwater currents where they mature into juveniles and adults. These juvenile species, in turn attract adult bluefish and other carnivorous fish into the Bay.

24. *Id.*; see also *id.* at 5 (saying the larger the plant base of the “food pyramid . . . the greater number of consumers . . . can be supported, or . . . cultured and harvested for market).

25. *Id.* White refers to the estuarine zone as a “no-man’s land,” accounting for the fact that estuaries have “comparatively few residents, mostly visitors, and these appear only at certain times of the year.” *Id.*

26. *Id.* at 13.

27. *Id.* The southern basin of Puget Sound is similarly “characterized by slow circulation and shallow bathymetry.” J.K. Box, R.A. Reynolds, J. Newton & S.A. Albertson, Wash. Dep’t of Ecology, *Assessing Sensitivity to Eutrophication of the Southern Basin: Spatial and Seasonal Perspectives*, Poster Group F: Marine Waters, available at [http://www.psat.wa.gov/Publications/01\\_proceedings/sessions/abstract/abstr\\_f.pdf](http://www.psat.wa.gov/Publications/01_proceedings/sessions/abstract/abstr_f.pdf).

28. WHITE, CHESAPEAKE BAY FIELD GUIDE, *supra* note 13, at 18.

29. *Id.* at 19. By contrast Puget Sound’s watershed consists of Washington State and British Columbia.

30. *Id.* at 20.

31. The variety of habitats has been accompanied by “*niche expansion*” by those surviving species. *Id.* at 21. See also EDWARD O. WILSON, *THE DIVERSITY OF LIFE* 95, 112 (Belknap Press, 1992) (describing adaptive radiation as “the spread of species of common ancestry into different niches,” and how vulnerable those radiated groups are to extinction). Rodgers, when discussing

coupled with the lack of predators and availability of food, mean that the Bay supports large populations of “a relatively small number of resident species,”<sup>32</sup> including larval fish, oysters, and crabs, which “have a permanent, if stressful home.”<sup>33</sup>

Chief among the limiting factors in this generally inhospitable natural environment is the level of dissolved oxygen in the water, which varies seasonally and is influenced by the amount of nutrients floating in the water.<sup>34</sup> While nutrients are important for growth and maintenance of plant life in the Bay, too much can cause algal blooms resulting in turbidity or “cloudy conditions” at the water’s surface.<sup>35</sup> Algal blooms are rapid increases in the phytoplankton algae population of a water body and have detrimental effects on dissolved oxygen levels.<sup>36</sup> Algae use oxygen, rather than produce it, and thereby contribute to the high biological oxygen demand (BOD) in the Bay, leaving less dissolved

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evolution and the process of natural selection, talks about how species “can move towards a specialized and adaptive peak . . . understood simply as a ‘position of high fitness associated with a specific environment.’” William H. Rodgers, Jr., *Where Environmental Law and Biology Meet: Of Pandas’ Thumbs, Statutory Sleepers, and Effective Law*, 65 U. COLO. L. REV. 25, 52 (1993) (quoting MONROE STRICKBERGER, *EVOLUTION* 465 (1990)).

32. WHITE, CHESAPEAKE BAY FIELD GUIDE, *supra* note 13, at 21. These species exhibit a high degree of adaptation, “the process by which organic design and behavior is brought into close compatibility with the physical environment.” Rodgers, *supra* note 31, at 63.

33. WHITE, CHESAPEAKE BAY FIELD GUIDE, *supra* note 13, at 18.

34. *Id.* at 21. Dissolved oxygen is the amount of oxygen present in a given body of water measured in milligrams per liter (“mg/l”). Chesapeake Bay Program, Dissolved Oxygen: Supporting Life in the Bay, <http://www.chesapeakebay.net/do.htm> (last visited Dec. 8, 2006). Fish need oxygen levels above 4 mg/l to survive; 6–9 mg/l is optimal. See WHITE, CHESAPEAKE BAY FIELD GUIDE, *supra* note 13, at 21.

35. WHITE, CHESAPEAKE BAY FIELD GUIDE, *supra* note 13, at 21. Turbidity is a measure of water quality and is affected by suspended solids such as clay, silt, and organic matter, including algae and other microscopic organisms that interfere with the passage of light through the water column. See Sheila Murphy, City of Boulder/USGS Water Quality Monitoring, BASIN: General Information on Turbidity, <http://bcn.boulder.co.us/basin/data/BACT/info/Turb.html> (last visited Dec. 8, 2006).

36. Nutrient Pollution, <http://www.chesapeakebay.net/info/nutr1.cfm> (“Excess amounts of phosphorus and nitrogen cause rapid growth of phytoplankton, creating dense populations, or blooms. These blooms become so dense that they reduce the amount of sunlight . . . Unconsumed algae will ultimately sink and be decomposed by bacteria in a process that depletes bottom waters of oxygen.”). Algae blooms are also a problem in Hood Canal. The resultant low levels of dissolved oxygen in those waters have caused extensive fish kills and may threaten “the long-term viability of marine life” in the Canal. PUGET SOUND ACTION TEAM, *supra* note 2, at ii. Dissolved oxygen levels in the Sound ranked third among water quality problems in the Sound and represented 264 problems, or twenty percent of the total water quality problems in the Sound. *Id.* at 11. The Puget Sound Action Team, in 2004, awarded nearly \$800,000 in state and federal grants to reduce nutrients in Hood Canal. *Id.* at 19.



oxygen available for other aquatic life.<sup>37</sup> The most significant source of oxygen in the Bay is the exchange of oxygen at the surface of the water where algal blooms occur.<sup>38</sup>

Algal blooms also block sunlight from reaching submerged aquatic vegetation, which inhibits their photosynthesis and oxygen production.<sup>39</sup> This causes the algae and the submerged aquatic grasses to die, fall to the Bay floor, and decompose.<sup>40</sup> As these underwater grasses and algae decompose, they use dissolved oxygen that would otherwise be available to living organisms, and further decrease dissolved oxygen levels in the Bay, creating a positive feedback loop.<sup>41</sup> This oxygen use contributes to the water's BOD level<sup>42</sup> and the decomposition of organic matter robs living organisms of the oxygen they need to survive. Decomposing algae also contribute to the water's turbidity by blocking sunlight that is critical for photosynthesis and the growth of submerged aquatic vegetation. A decline in photosynthesis further lowers both dissolved

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37. Chesapeake Bay Program, Dissolved Oxygen: Supporting Life in the Bay, <http://www.chesapeakebay.net/do.htm> (last visited July 23, 2007).

38. See MD. DEP'T OF NAT. RES., MARYLAND CLEAN MARINA GUIDEBOOK 35 (1998) (noting the importance of the microlayer (floating water surface) and how pollution in the microlayer can affect the aquatic food web), available at <http://www.dnrweb.dnr.state.md.us/download/cleanmarina/6Petrole.pdf>; Chesapeake Bay Program, Dissolved Oxygen: Supporting Life in the Bay, <http://chesapeakebay.net/domechanics.htm> (stating "[m]ost of the oxygen in water comes from the atmosphere") (last visited Aug. 18, 2007).

39. See Murphy, *supra* note 35.

40. Chesapeake Bay Program, Nutrient Pollution, <http://www.chesapeakebay.net/nutr1.htm> (last visited Dec. 8, 2006). A similar problem may be afflicting the eelgrass in Puget Sound, which like the Bay's underwater grasses, play a critical role in the Sound's ecosystem providing habitat for a broad variety of fish, marine birds, invertebrates, and microbes. See PUGET SOUND ACTION TEAM, *supra* note 2, at 32. Eelgrass beds provide a migratory corridor for salmon and nursery habitat for species with significant ecological, commercial, and recreation value like young salmon and rockfish, herring, and crab. See *id.* Between 2002 and 2003, the Washington State Department of Natural Resources noted a four percent Soundwide decline in eelgrass beds, including Hood Canal, where algae blooms have reduced water clarity and dissolved oxygen levels. See *id.*

41. See Alvin Toffler, *Foreword* to ILYA PRIGOGINE & ISABELLE STENGERS, ORDER OUT OF CHAOS: MAN'S NEW DIALOGUE WITH NATURE xv (Bantam Books 1984) (saying "all systems contain subsystems, which are continually 'fluctuating,' any one or combination of which fluctuations "may become so powerful, as a result of positive feedback, that it shatters the preexisting organization," at which point "it is inherently impossible to determine in advance which direction change will take: whether the system will disintegrate into 'chaos' or leap to a new, more differentiated, higher level of 'order' or organization").

42. BOD measures the amount of oxygen consumed by microorganisms in decomposing organic matter in a body of water. See EPA, Monitoring and Assessing Water Quality: Dissolved Oxygen and Biochemical Oxygen Demand, <http://www.epa.gov/volunteer/stream/stream.pdf> (last visited Dec. 8, 2006).

oxygen levels and the productivity of those areas,<sup>43</sup> and thereby creates another destructive positive feedback loop.<sup>44</sup>

Low dissolved oxygen levels caused by nutrient enrichment are one of the most serious problems facing the Bay.<sup>45</sup> The entire Maryland portion of the Bay has been impaired by excess nutrient pollution since 1996.<sup>46</sup> But, little progress has been made in improving the Bay's low dissolved oxygen levels.<sup>47</sup> More than ninety-four percent of monitoring stations recording dissolved oxygen levels in the Maryland portion of the Bay and its tributaries reported dissolved oxygen levels below average; ten of those stations established new record lows for that month, while six stations reported readings at levels too low to sustain a healthy ecosystem.<sup>48</sup> The Chesapeake Bay Program reported that 2005 had among the lowest readings of dissolved oxygen since 1993 with approximately ten percent of the Bay recording dissolved oxygen levels approaching zero.<sup>49</sup> Such low dissolved oxygen levels cannot sustain most aquatic life.<sup>50</sup>

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43. WHITE, CHESAPEAKE BAY FIELD GUIDE, *supra* note 13, at 21–22.

44. Although water clarity was better in 2005, according to the Chesapeake Bay Program, the long-term trend is downward. *See* CHESAPEAKE BAY 2005 PART I, *supra* note 5, at 6.

45. EPA, Mid-Atlantic Integrated Assessment: Eutrophication, <http://www.epa.gov/maia/html/eutroph.html> (last visited Oct. 31, 2006). Low dissolved oxygen levels are also a problem adversely affecting water bodies throughout the world and are “now a critical concern in Puget Sound,” especially in sensitive areas that are in parts of the Sound that do not exchange water with the ocean frequently, such as Hood Canal. *See* PUGET SOUND ACTION TEAM, *supra* note 2, at 16.

46. *See* EPA, CHESAPEAKE BAY UAAS 4–5 (2006), [http://www.epa.gov/waterscience/standards/uaa/pdf/cs\\_chesapeake.pdf](http://www.epa.gov/waterscience/standards/uaa/pdf/cs_chesapeake.pdf). In 1987, Maryland, Virginia, Pennsylvania, the District of Columbia, and EPA, as part of the Chesapeake Bay Program, agreed to reduce the amount of nutrients in the Bay by forty percent by 2000. This date passed without making significant inroads in the problem. So, the Bay Program announced even more stringent reduction targets in 2003. *See also* Chesapeake Bay Program, Reducing Nutrient Pollution, <http://www.chesapeakebay.net/nutr2.htm> (last visited Aug. 19, 2007).

47. According to the Chesapeake Bay Foundation's 2006 State of the Bay Report, the Bay received failing scores for nitrogen levels, dissolved oxygen, and water clarity. *See* CHESAPEAKE BAY FOUND., STATE OF THE BAY REPORT 3–5 (2006), [http://www.cbf.org/site/DocServer/SOTB\\_2006.pdf](http://www.cbf.org/site/DocServer/SOTB_2006.pdf).

48. *See* Chesapeake Bay Found., *Bay Resources: Chesapeake Bay 2004 Dissolved Oxygen Levels*, [http://www.cbf.org/site/PageServer?pagename=resources\\_facts\\_DOLevels\\_2004](http://www.cbf.org/site/PageServer?pagename=resources_facts_DOLevels_2004) (last visited Sept. 21, 2007).

49. Chesapeake Bay Found., *Save the Bay, Chesapeake suffers near-record “dead zone”* (saying “This was the second-worst dead zone ever recorded for the month of August and the worst since 1993, according to EPA's Chesapeake Bay Program. More disturbing is that about 10 percent of the Bay had almost zero oxygen from August 8–11, the timeframe during which the data were collected.”). *See also* CHESAPEAKE BAY 2005 PART I, *supra* note 5, at 5, 13 (reporting, based on

Dead zones,<sup>51</sup> areas in the Bay with hypoxic and anoxic levels of dissolved oxygen, first observed in the Bay in the 1970s,<sup>52</sup> have been increasing.<sup>53</sup> Over the past forty years, the volume of hypoxic and anoxic water<sup>54</sup> in the Bay has more than tripled;<sup>55</sup> the deep water dead zone is even expanding into major Bay tributaries, including the Potomac and York rivers and into the Eastern Bay.<sup>56</sup> In July of 2005, data from the Chesapeake Bay Program revealed that approximately forty percent of the Bay's mainstem, beginning just below Baltimore and extending one hundred miles south to Hampton Roads, Virginia, is now dead.<sup>57</sup>

Low dissolved oxygen levels harm the Bay and impair the achievement of its designated uses such as protection of fish and aquatic life as well as recreational fishing.<sup>58</sup> Low dissolved oxygen levels can kill and stress species, reducing populations of fish and shellfish.<sup>59</sup> If

water quality data collected during 2003–2005, only twenty-nine percent of the Bay's waters met dissolved oxygen standards during the summer and saying “[s]ummer 2005 saw near record low dissolved oxygen conditions in many parts of the Bay”).

50. See CHESAPEAKE BAY PROGRAM, TOO MUCH OF A GOOD THING: FISH KILLS ILLUSTRATE HARMFUL EFFECTS OF EXCESS NUTRIENTS ON BAY ECOSYSTEM (2006), <http://www.chesapeakebay.net/newsfishkills110906.htm> (reporting depleted Dissolved Oxygen levels from excess nutrients resulted in several fish kills in 2006) (last visited Sept. 14, 2007). The Bay's benthic community also has suffered from low dissolved oxygen levels during the summer, with only forty-one percent considered healthy in 2005; while only nine percent of the Bay's phytoplankton were considered healthy. See CHESAPEAKE BAY 2005 PART I, *supra* note 5, at 10.

51. See Martin Freed, *Dead Zone: A Threat to the Chesapeake*, THE FISHERMAN, Jan. 20, 2005, at 11.

52. Dead Zone (ecology), [http://en.wikipedia.org/wiki/Dead\\_zone\\_%28ecology%29](http://en.wikipedia.org/wiki/Dead_zone_%28ecology%29) (last visited Aug. 19, 2007).

53. See Chesapeake Bay Found. Fact Sheet, *The Chesapeake Bay's Dead Zone: Increased nutrient runoff leaves too little oxygen in 40% of the Bay's mainstem in July*, [http://www.cbf.org/site/DocServer/DeadZoneFactSheet\\_May06.pdf?docID=5583](http://www.cbf.org/site/DocServer/DeadZoneFactSheet_May06.pdf?docID=5583), at 4 (saying low dissolved oxygen levels have become “dramatically more common and widespread since the 1950s” and are “lasting longer, dropping lower, and spreading farther throughout the system, shrinking habitat for crabs, fish, and oysters, and stressing many organisms”).

54. Hypoxic water is water in which dissolved oxygen levels are significantly reduced, generally considered to be between 2 and 5 mg/l; anoxic waters are waters without any oxygen at all.

55. See Chesapeake Bay Found. Fact Sheet, *supra* note 53, at 2.

56. *Id.* at 1–2 (saying “one of the largest areas of oxygen depleted water seen since monitoring began [twenty] years ago”).

57. *Id.* at 1.

58. See MD. CODE REGS. § 26.08.02.02(B)(1)(a)–(c) (2007) (describing designated uses).

59. For example, in 2003, more than 50,000 perch died in Hood Canal, having suffocated because sections of the Canal were nearly without oxygen. See PUGET SOUND ACTION TEAM, *supra* note 2, at 16.

dissolved oxygen levels fall below 2 milligrams per liter (mg/l)—severely hypoxic, or anoxic, levels—most of the organisms in the affected area must relocate to areas with higher dissolved oxygen levels<sup>60</sup> or they will suffocate and die.<sup>61</sup> Left behind is a less diverse estuarine system—one more tolerant of low dissolved oxygen levels, but less commercially and recreationally valuable.<sup>62</sup> Some species, such as clams and oysters, cannot relocate to escape low dissolved oxygen levels; instead they die when levels drop below 2 mg/l.<sup>63</sup> Fish kills may result after only a few hours of dissolved oxygen levels at this level and are an increasingly common occurrence in the Bay.<sup>64</sup> Hypoxic dissolved oxygen levels stress species, making them more susceptible to injury and illness from other environmental stressors in the water.<sup>65</sup> These low dissolved oxygen levels reduce the ability of fish immune systems to fend off opportunistic infections, thereby increasing the likelihood that such species will become ill or die.<sup>66</sup> Low dissolved oxygen levels and increased turbidity from decomposing algae also kill vital bay grasses<sup>67</sup> that provide food, habitat,<sup>68</sup> and shelter for aquatic creatures such as the

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60. See Mich. Dep't of Envtl. Quality ("DEQ"), Biochemical Oxygen Demand and NPDES Permitting, <http://www.deq.state.mi.us/documents/deq-swq-npdes-BiochemicalOxygenDemand.pdf> (last visited Dec. 8, 2006).

61. See Sheila Murphy, City of Boulder/USGS Water Quality Monitoring, BASIN: General Information on Dissolved Oxygen, <http://bcn.boulder.co.us/basin/data/BACT/info/DO.html> (last visited Dec. 8, 2006) ("When dissolved oxygen concentrations drop . . . [s]pecies that need high concentrations of dissolved oxygen, such as mayfly nymphs, stonefly nymphs, caddisfly larvae, pike, trout, and bass will move out or die."); Chesapeake Bay Program, Dissolved Oxygen Backgrounder at 2, [http://www.chesapeakebay.net/pubs/doc-do\\_101\\_backgrounder.pdf](http://www.chesapeakebay.net/pubs/doc-do_101_backgrounder.pdf) (last visited Dec. 8, 2006).

62. See Murphy, *supra* note 61; Mich. DEQ, *supra* note 60.

63. See EPA, *supra* note 9. Oysters, once considered one of the most important commercial fisheries in the Bay, have been decimated by over-harvesting, pollution, and diseases. See Chesapeake Bay Program, CHESAPEAKE BAY 2005 PART I, *supra* note 5, at 12.

64. See Mich. DEQ, *supra* note 59, at 1; See Chesapeake Bay Program, *supra* note 49.

65. See CADUTO, POND AND BROOK: A GUIDE TO NATURE IN FRESHWATER ENVIRONMENT 39 (Univ. Press New England 1990).

66. See Mac Law, *Differential Diagnosis of Ulcerative Lesions in Fish*, 109 ENVTL. HEALTH PERSPECTIVES 618, 685 (2001).

67. See Chesapeake Bay Program, Dissolved Oxygen: The Mechanics, [http://www.chesapeakebay.net/info/dissolved\\_oxygen\\_mechanics.cfm](http://www.chesapeakebay.net/info/dissolved_oxygen_mechanics.cfm) (last visited Sept. 1, 2007).

68. See ENVIRONMENTAL PROTECTION AGENCY, *supra* note 45.

blue crab and summer flounder.<sup>69</sup> When Bay grasses die, spawning and nursery habitat is destroyed and fish and waterfowl have less to eat.<sup>70</sup>

Well-oxygenated water is the foundation of any healthy estuarine system, including both the Bay and Puget Sound. Individuals, organizations, and government agencies have spent a tremendous amount of human capital and dollars<sup>71</sup> on improving the Bay's dissolved oxygen levels and the clarity of its waters, as well as reducing the amount of algae in those waters.<sup>72</sup> Yet, water quality and aquatic-based habitat continues to decline,<sup>73</sup> "the overall ecosystem health of the Bay remains degraded" and "actions taken to date have not yet been sufficient to restore the health of the Bay."<sup>74</sup> However, there is one action regulators could take to reduce nutrient loadings to the Bay: prohibit or limit the practice of chumming. Chumming and its

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69. See Chesapeake Bay Program, Dissolved Oxygen Backgrounder, *supra* note 61, at 5.

70. Chesapeake Bay Program, *Bay Grasses*, <http://www.chesapeakebay.net/baygras.htm> (last visited July 25, 2007) (saying underwater bay grasses protect crustaceans and juvenile fish from larger predators and waterfowl, and both resident and migratory waterfowl feed on bay grasses).

71. From 1995–2004, the six Bay watershed states and EPA have spent \$2.5 billion to reduce nutrient and sediment loadings to the Bay. See CHESAPEAKE BAY 2005 PART II, *supra* note 4, at 3. Another \$1.8 billion was spent during the period on restoring underwater grasses and wetlands, managing fisheries such as striped bass and menhaden more effectively, and protecting watersheds. *Id.* at 5–9.

72. These efforts began in earnest in 1983 with an agreement between the states of Maryland, Virginia, and Pennsylvania, the District of Columbia and the U.S. Environmental Protection Agency to clean up the Bay. See *Overview of the Bay Program*, <http://chesapeakebay.net/info/overview.cfm> (last visited Sept. 1, 2007). The signatories promised that the Bay would be clean by 2000. Fahrenthold, *What Would It Take to Clean Up the Bay by 2010?*, *supra* note 4, at A1. Puget Sound appears to be suffering a similar fate as "the building blocks" of a healthy Sound, "clean water, abundant habitat, and an intact food web – continue to be eroded," reflecting a "silent and slow motion crisis" putting at risk the Sound's "diverse web of life." PUGET SOUND ACTION TEAM, *supra* note 2, at 59.

73. John Page Williams, Chesapeake Bay Found., *Save the Bay, Warning Signs: Dead Zones, Algal Blooms, and Fish Kills* 11 (Summer 2007) (referring to the Bay's dead zone as reflecting "a massive amount of lost habitat"). See also Fahrenthold, *What Would It Take to Clean Up the Bay by 2010?*, *supra* note 4, at A1. To illustrate the enormity of the remaining challenge, Bay area states have indicated that they will need "at least \$2 billion" to implement agricultural measures to control runoff and another \$6 billion and many years to upgrade hundreds of antiquated sewage treatment plants. *Id.* at A2. Maryland, which has only replaced or brought up to code 11,000 of the 360,000 units, will need 580 years to complete its inventory of repairs at current funding levels. *Id.* at A2.

74. CHESAPEAKE BAY PART I, *supra* note 5, at Title page. The Puget Sound Action Team appears to have reached a similar conclusion. See Puget Sound Action Team, *STATE OF THE SOUND*, *supra* note 2, at 59 (commenting that the "efforts to keep even with, or get ahead" of the multiple problems afflicting the Sound have not been sufficient to avoid the prospect of significant harm, noting in particular that the declining populations of the Sound's living resources "may signal a broader systemic problem").

contribution to the Bay's ill health are described in the next section of this article.

## II. CHUMMING'S CONTRIBUTIONS TO THE BAY'S PROBLEMS

Chumming involves the discharge of a slurry of decomposed or decomposing baitfish, usually from a fishing vessel.<sup>75</sup> The slurry may contain whole fish, chunks of fish, or a ground mixture of fish and other aquatic organisms such as shellfish and worms. The goal of chumming is to attract game species like striped bass, and it is used extensively by Maryland's recreational fishing industry.<sup>76</sup> However, chumming contributes to the destructive positive feedback loops responsible for the Bay's downward spiral by reducing dissolved oxygen levels and increasing the turbidity of the Bay's water.

Atlantic menhaden is the most commonly used chumming material along the Atlantic seaboard.<sup>77</sup> Anglers often purchase menhaden chum in blocks<sup>78</sup> and grind the chum into a "soup" that they spoon into the water<sup>79</sup> at regular intervals while their vessels drift with the current.<sup>80</sup> This allows pieces of chum, about the size of a thumbnail, to drift through the water creating a "chum line."<sup>81</sup> Sometimes, anglers lower the entire chum block into the water in a chum bucket, pot, or bag.<sup>82</sup> They are encouraged to lower their selected container and agitate it in the water "so a nice cloud of chum flows out."<sup>83</sup> Both techniques allow copious amounts of chum pieces and fish oils to escape and float through the water column, creating a "slick."<sup>84</sup>

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75. See KEN SCHULTZ, KEN SCHULTZ'S FISHING ENCYCLOPEDIA 385 (Wiley ed. 1999).

76. *Id.*

77. *Id.*

78. *Id.*

79. *Id.*

80. *Id.*

81. *Id.*

82. *Id.* Chum buckets are normally five-gallon plastic buckets perforated with one-inch holes. *Id.*

83. Lenny Rudow, *Summer Chumming*, THE FISHERMAN, June 30, 2006, at 7.

84. ED RUSSELL & BILL MAY, FLYFISHER'S GUIDE TO CHESAPEAKE BAY: INCLUDES LIGHT TACKLE 17 (2002). The combination of fish pieces and oil on the water's surface is referred to as a "slick" because "oils released from the pulverized fish will float and leave a fine film that flattens the water slightly." Sarah Gardner, *Fly Rod Rock: Slick Stripers*, THE FISHERMAN, Oct. 6, 1994, at 23.

Fishing experts recommend that anglers use fifty pounds of chum per day per vessel<sup>85</sup> because a chum slick is only effective for distances of up to three hundred yards behind the boat.<sup>86</sup> It is common for several vessels—a “chum fleet”—to engage in chumming simultaneously in the same location.<sup>87</sup> Many independent anglers and charter boats compete for catches simultaneously in locations known to produce large yields from chumming.<sup>88</sup> This often results in more than one hundred fishing boats descending upon a single chumming location at the same time.<sup>89</sup>

With fifty pounds of chum recommended per vessel and as many as one hundred vessels present at a particular fishing location at one time, as much as 5,000 pounds of chum can conceivably be discharged at each discrete chumming location in the Bay daily. There are twenty of these prime chumming locations in the Bay, which means as much as 100,000 pounds of chum may be discharged into the Bay in a single day.<sup>90</sup>

When compared to nutrient discharges from sewage treatment plants and farm fields, chumming is a relatively small, localized source of pollution to the Bay’s waters. However, the impact of chumming is both serious and far-reaching for at least four reasons.<sup>91</sup>

First, chumming lowers dissolved oxygen levels in discrete fishing locations in the Bay by increasing BOD. Chumming contributes no dissolved oxygen to the water because it is dead or decaying organic matter; instead, as the chum that is not consumed by fish further decomposes, it increases BOD by using available dissolved oxygen. Decomposition of organic matter like chum robs living organisms of the oxygen they need to survive. This oxygen use contributes to the water’s

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85. SCHULTZ, *supra* note 75, at 382. See generally LEFTY KREH, L.L. BEAN, SALTWATER FLY-FISHING HANDBOOK 145 (2001) (saying “[p]erhaps the most important aspect of chumming is that once you start chumming, don’t stop”).

86. Gardner, *Fly Rod Rock*, *supra* note 84, at 24.

87. Md. Dep’t of Natural Res., Fisheries Serv., The Maryland Fishing Report July 14, 2004, <http://www.dnr.state.md.us/fisheries/fishingreport/fishingrptArchive/frarchives2004/0714chesapeake.html> (last visited Aug. 31, 2007) (referencing the chumming fleet). Rudow, *supra* note 83, at 6.

88. *Id.*

89. *Id.*

90. The Maryland Fishing Report, Chesapeake Bay & Tributaries Report, (July 16, 2003), <http://www.dnr.maryland.gov/fisheries/fishingreport/fishingrptArchive/frarchives2003/chesapeake071603.html> (last visited July 25, 2007) (listing popular chumming spots on the Bay).

91. The “butterfly effect,” first identified by Massachusetts Institute of Technology meteorologist Edward Lorenz, and used to describe how “tiny differences in input might quickly become substantial differences in output,” illustrates the effect of chumming on the Bay’s overall water quality. Worster, *supra* note 1, at 407.

BOD level. The higher the water's BOD level, the less dissolved oxygen there is for living organisms.<sup>92</sup> Pristine waters typically have a five-day BOD level of no more than 1 mg/l.<sup>93</sup> Efficiently treated municipal wastewater has a BOD value of about 20 mg/l, and untreated raw wastewater has a BOD of 200 mg/l.<sup>94</sup> Three separate tests of frozen and non-frozen chum samples similar to those used in the Bay revealed BOD levels from 227,000 mg/l to 330,000 mg/l.<sup>95</sup>

Second, chum functions as a nutrient-rich fertilizer for algal blooms, which lead to increased absorption of dissolved oxygen. During the organisms' respiration period, these organisms use rather than produce oxygen, and thereby contribute to the high BOD levels in the Bay, making less dissolved oxygen available for aquatic life.<sup>96</sup> Both algal blooms and the slick of fish oils and fish parts that collect on the surface of the water block sunlight. This inhibits the exchange of oxygen at the water's surface, the most significant source of oxygen in the Bay.<sup>97</sup> Blocking sunlight from submerged aquatic vegetation also inhibits photosynthesis and oxygen production in the water column, causing the algae, as well as submerged aquatic grasses, to die, fall to the Bay floor, and decompose.<sup>98</sup> As the underwater grasses and algal blooms decompose, they use dissolved oxygen that would otherwise be available to living organisms, and thereby further lowering dissolved oxygen levels in the Bay and setting in motion one of the destructive positive feedback loops previously described.<sup>99</sup>

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92. EPA, Monitoring and Assessing Water Quality: Dissolved Oxygen and Biochemical Oxygen Demand, <http://www.epa.gov/volunteer/stream/vms52.html> (last visited Dec. 8, 2006).

93. Wilkes Univ. Ctr. for Envtl. Quality, Environmental Engineering & Environmental Sciences, Water Quality Terms, Glossary, <http://www.water-research.net/glossary.htm> (saying, "a sample with a 5 day BOD between 1 and 2 mg O/L indicates a very clean water, 3.0 to 5.0 mg O/L indicates a moderately clean water and > 5 mg O/L indicates a nearby pollution source") (last visited Sept. 14, 2007).

94. METCALF & EDDY, WASTEWATER ENGINEERING: TREATMENT AND REUSE 64 (2002).

95. See Martel Certificate of Analysis (Apr. 15, 2004) (App. B); Enviro-Chem Labs. Final Report of Analyses (Feb. 28, 2004) (App. C); Microbac Labs., Inc., Test Results (Jan. 30, 2004) (App. D). The independent labs sampled frozen, menhaden chum samples, similar to the chum used in commercial and recreational chumming on the Bay.

96. *Id.*

97. See Md. Dep't of Nat. Res., *supra* note 38 (noting how pollution in the important microlayer can affect the aquatic food web); Chesapeake Bay Program, *supra* note 49.

98. Chesapeake Bay Program, Nutrient Pollution, *supra* note 40 (last visited Dec. 8, 2006).

99. Chumming also directly increases water turbidity by clouding the water with pieces of chum of varying sizes and fish oils. These "chum clouds" greatly reduce water clarity and prevent sunlight from reaching underwater Bay grasses, which kills them. As the dead grasses decompose, they fuel



Chumming's contribution to the Bay's eutrophication and loss of biodiversity problems is vividly illustrated by the rapid and sensational decline of "the Hill," "one of the most productive and popular chumming spots" on the Bay,<sup>100</sup> into a virtual dead zone by 2006. Data from the monitoring station closest to the Hill reported average minimum dissolved oxygen levels in 2005, well below the 5 mg/l necessary for most species to survive,<sup>101</sup> and during seven months of that year, recorded severely hypoxic dissolved oxygen levels ranging from 1.30 mg/l to 3.8 mg/l.<sup>102</sup>

Third, although open to some debate, chumming may be both a direct and indirect source of bacterial disease among game fish, including striped bass.<sup>103</sup> The biological material present in chum may serve as a vector for the transmission of diseases and infections to game species.<sup>104</sup> Because striped bass have historically fed on menhaden,<sup>105</sup> menhaden

harmful algal blooms that ultimately reduce dissolved oxygen levels and increase turbidity, setting in motion another harmful positive feedback loop.

100. Lenny Rudow, *Chum the Hill For Rockfish Thrills*, THE FISHERMAN, Oct. 7, 1999, at 16. This excess patronage resulted in "untold gallons" of chum being poured into this location. *Id.* at 17.

101. MDNR, *Fixed Station Monthly Monitoring, Choptank River-Outer Choptank*, [http://mddnr.chesapeakebay.net/bay\\_cond/bay\\_cond.cfm?param=bdo&station=EE21](http://mddnr.chesapeakebay.net/bay_cond/bay_cond.cfm?param=bdo&station=EE21) (last visited Dec. 8, 2006).

102. *Id.* Maximum average dissolved oxygen levels during the summer, when dissolved oxygen levels are at their lowest and chumming at its highest, barely met the 5 mg/l level necessary to support many species. *Id.* Warmer Bay water cannot hold as much oxygen as colder water. EPA, Technical Support Document, *supra* note 47, at 15. Also, during the summer, due to the unique hydrology of the Bay, vertical mixing of water occurs with less intensity, and as a result, deeper waters do not receive needed DO from shallower waters. *Id.* at 16; *see also* Jay L. Taft, et al., *Seasonal Oxygen Depletion in Chesapeake Bay*, 3 ESTUARIES 242, 242 (Dec. 1980).

103. The two most common theories as to why bacterial disease has emerged in striped bass in the Chesapeake Bay are that the disease is caused by excess nutrient loadings into the Bay, causing eutrophication that reduces the amount of summer refuges in the Bay for striped bass forcing the fish into "sub-optimal and stressful habitat during the warm summer months," and overharvesting of key prey species like Atlantic menhaden. *See* Wolfgang K. Vogelbein, John M. Hoenig & David T. Gauthier, *Epizootic mycobacteriosis in Chesapeake Bay striped bass: What is the fate of infected fish?*, USGS/NOAA Workshop on Mycobacteriosis in Striped Bass (May 7-10), at 28.

104. DICK RUSSELL, STRIPER WARS: AN AMERICAN FISH STORY 205 (2005) (noting that most of the literature describes the transmission of mycobacteriosis through feeding on contaminated material); Andrew S. Kane et al., *Mycobacteria as environmental portent in Chesapeake Bay fish*, EMERGING DISEASES DISPATCH, Vol. 13, No. 2 (Feb. 2007), [http://www.cdc.gov/EID/content/13/2/06\\_0558.htm](http://www.cdc.gov/EID/content/13/2/06_0558.htm). (noting that menhaden "is an essential link in the food chain" and "[t]he prevalence of infection in Atlantic menhaden . . . may indicate the potential of this fish to amplify spread to other species"); *cf.* Ellen K. Silbergeld, *Pfiesteria: Harmful Algal Blooms as Indicators of Human-Ecosystem Interactions*, 82 ENVTL. RES. SECTION A 97, 100 (2000), available at [http://www.jhsph.edu/clf/PDF%20Files/Health\\_conf\\_pfiesteria.pdf](http://www.jhsph.edu/clf/PDF%20Files/Health_conf_pfiesteria.pdf).

105. RUSSELL, *supra* note 104, at 214 (noting that in the early 1990s menhaden accounted for

chum is used to attract them. With over ninety percent of young-of-the-year menhaden suffering from *Pfiesteria*-like dinoflagellates (mycobacteria) or fungal infections in some areas of the Bay,<sup>106</sup> the possibility of infecting game species through menhaden chum is not insignificant.<sup>107</sup> The Maryland Fish and Wildlife Health Program reported in 2006 that the prevalence of disease in striped bass collected from pound nets increased from twenty-five percent in 1998 to sixty percent in 2005.<sup>108</sup> This increase in mortality is particularly problematic for the Bay's striped bass population given their below average reproduction in 2006.<sup>109</sup> One indication that chum may be the cause of this increase in striped bass mortality is that this increase is not occurring in striped bass populations outside the Bay, which are feeding on live menhaden.<sup>110</sup>

Chumming also has the potential to increase indirectly the incidence of disease among game fish and other species by negatively affecting their immune systems. Striped bass, for example, are often underweight and malnourished as a result of the lack of plentiful live menhaden that normally provide them with much-needed fats,<sup>111</sup> as well as because of

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between thirty-seven and sixty-six percent of the striped bass's diet, but by 1998–1999, menhaden accounted for only twelve to twenty-seven percent of the diet).

106. See Kane et al., *supra* note 104, at tbl. 2 (noting up to fifty percent of menhaden were infected).

107. While live menhaden can transmit mycobacteriosis to fish who eat them, it stands to reason that the amount of infection spread by chum may be greater because of the heavier concentration of infected fish parts in chum, as opposed to in whole fish in the wild, easier transmission of bacteria among pieces of fish as opposed to among whole fish, and the presence of fish oil to which the mycobacteria attach. Although bacteria, viruses, and other disease causing microbes or pathogens are a serious problem in the Sound, causing beach closings and infected shellfish, the sources of these problems appear to be untreated sewage, failing septic systems, and animal waste. See PUGET SOUND ACTION TEAM, *supra* note 2, at 16, 19.

108. Md. Dep't of Natural Res., Fisheries Serv., *Fishing Report*, Jan. 17, 2006, <http://www.dnr.state.md.us/fisheries/fishingreport/fishingrptArchive/frarchives2006/06reviewchESApeake.asp> ("Prevalence of disease in fish collected from pound nets has increased from 25% in 1998 to 60% in 2005, and may have leveled off since 2004.") (last visited Sept. 2, 2007). See also RUSSELL, *supra* note 104, at 208, 209 (saying, "two recent independent studies reveal, alarmingly so, that natural mortality in striped bass has been rising since 1998" and in September 2003 "natural mortality had increased fivefold over the previous five years").

109. Southern Md. Online, Ches. Bay Striped Bass Reproduction Rate Below-Average in 2006, <http://somd.com/news/headlines/2006/4680.shtml>. (last visited July 26, 2007).

110. Maryland Saltwater Sportfishermen's Ass'n., Press Release, *Maryland DNR 2006 Young-of-Year Striped Bass Survey Indicates Below-Average Reproduction*, Oct. 2006, <http://www.mssa.net/subpages/news-102606yoy.html> (last visited Feb. 14, 2007).

111. See RUSSELL, *supra* note 104, at 214 (noting that the menhaden population decreased eighty

the Bay's low dissolved oxygen levels and poor water quality. These environmental stressors may increase the susceptibility of striped bass to opportunistic skin pathogens such as mycobacteria and fungi.<sup>112</sup>

And fourth, chumming is putting additional pressure on menhaden, an essential Bay species that is already in steep decline. Menhaden is an important source of food for game fish like striped bass, weakfish, and bluefish.<sup>113</sup> The striped bass population has resurged at the same time that the menhaden population has plunged, thus leading to weight loss, a higher incidence of disease, and possibly a shorter life span in striped bass.<sup>114</sup> Loons also feed on menhaden and have experienced a sharp decrease in the size of their flocks.<sup>115</sup> The absence of menhaden schools has also caused a reduction in active osprey nests and in osprey chick survival.<sup>116</sup> Menhaden feed on plankton, including the Bay's overabundant algae, and thus also perform an important water quality function for the Bay.<sup>117</sup> The number of menhaden along the Atlantic seaboard is currently nearing the population's historically low levels in the 1960s when the fish was declared over-fished, and that population may now be on the verge of collapsing.<sup>118</sup> This threat has caused considerable concern among scientists.<sup>119</sup>

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percent between 1960 and 2000 and that striped bass weighed, on average, about forty percent less than fish of the same age in the late 1950s).

112. See Mac Law, *Differential Diagnosis of Ulcerative Lesions in Fish*, 109 ENVTL. HEALTH PERSPECTIVES 618, 685 (Oct. 2001), available at <http://www.ehponline.org/members/2001/suppl-5/681-686law/EHP109s5p681PDF.pdf>; E.J. Noga, et al., *Acute Stress Causes Skin Ulceration in Striped Bass and Hybrid Bass (Morone)*, 35 VETERINARIAN PATHOLOGY 102, 102 (1998) (finding that stress may induce lesions on striped bass which can increase their susceptibility to opportunistic skin pathogens).

113. CHESAPEAKE BAY FOUND., 32 SAVE THE BAY, *At Last, a Limit: Menhaden Industry Capped*, at 2 (Sept. 2006).

114. *Id.* at 4.

115. RUSSELL, *supra* note 104, at 227.

116. *Id.* (also noting that "a similar pattern" is being observed in other areas along the Eastern seaboard).

117. See *id.* at 219 (describing menhaden as "a critical species in the flow of energy and nutrients, billions of silvery sea-strainers that improve water quality and hold down algae growth").

118. Coastal Conservation Ass'n Md., Position Papers, Atlantic Menhaden, [http://www.ccamd.org/advocacy/position\\_papers/menhaden\\_management.htm](http://www.ccamd.org/advocacy/position_papers/menhaden_management.htm) (last visited Aug. 31, 2007). See also RUSSELL, *supra* note 104, at 226 (describing how menhaden recruitment, the number of new menhaden, "has plummeted," dropping from 4.4 billion fish per year between 1975-1991 to 500 million in 2001, "the lowest figure ever recorded").

119. See Chesapeake Bay Ecological Found. Inc., Atlantic Menhaden, <http://www.chesbay.org/forageFish/menhaden.asp>.

### III. MISGUIDED AND OUTDATED REGULATORY THINKING ABOUT COMPLEX SYSTEMS

Despite chumming's contribution to low dissolved oxygen levels, water turbidity, and loss of biodiversity in the Bay, neither the U.S. Environmental Protection Agency (EPA) nor Maryland's Department of the Environment (MDE) has elected to regulate the practice. EPA has not established effluent limits for chumming, despite doing so for the fish processing industry,<sup>120</sup> and MDE has not sought to regulate chumming, even though it runs afoul of the State's water quality anti-degradation policies.<sup>121</sup> Although the importance of recreational fishing to Maryland's economy may explain some of the State's reluctance to prohibit or limit chumming, an equally availing reason for governmental inertia may be that the chumming is thought to be an insignificant part of the Bay's eutrophication problem when compared to nutrient contributions from sewage treatment plants and farm fields.<sup>122</sup> However, that argument assumes that larger targets are better, which this article argues is not the case.

Big is not always better in an estuarine environment, in part because pollutants from smaller sources have a way of aggregating into larger problems and, in part, because small quantities of pollutants can set off cascades of problems that may result in irreversible or catastrophic consequences.<sup>123</sup> Yet, small sources of pollution like chumming rarely attract the regulator's attention due to the mistaken belief that correcting those problems will not bring the same rate of return as tackling larger ones.<sup>124</sup> This type of thinking reflects an over-reliance on economic

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120. See 40 C.F.R. § 408.152(a) (2007) (establishing effluent limitations for the fish meal processing industry).

121. See MD. CODE REGS. § 26.08.02.04(A) (2007) (requiring that state waters "shall be protected and maintained for existing uses"); *id.* § 26.08.02.04(F) ("[w]ater which does not meet the standards established for it shall be improved to meet the standards").

122. Bay watershed states estimate that they will need at least \$2 billion dollars to implement measures to prevent soil, manure and fertilizers washing off of farm fields into the Bay or its tributaries and another \$6 billion to upgrade sewage treatment plants. See Fahrenthold, *What Would It Take to Clean up the Bay by 2010*, *supra* note 4, at A02. Sewage treatment plants, septic systems, discharges from boaters and other recreation activities, waste from farm animals and pets, fertilizers, stormwater runoff, and wood waste, contribute nutrients to Puget Sound. See PUGET SOUND ACTION TEAM, *supra* note 2, at 16.

123. See, e.g., Toffler, *supra* note 41, at xvii (noting how the smallest of disturbances can create large perturbations in systems sometimes leading to their collapse or complete restructuring in "far from equilibrium" situations).

124. An example of a small source of pollution on Puget Sound is the onsite septic systems, of

approaches, such as bioeconomics and the cost-benefit analysis. But economic approaches are not a reliable basis for selecting regulatory targets or evaluating their success in complex, evolving natural systems like estuaries. Economic approaches require stable, non-changing problems, and are therefore ill-suited to estuaries.<sup>125</sup> Economic approaches also discount future risks and undervalue the importance of maintaining a healthy, biologically diverse environment. The precautionary principle, on the other hand, concerns itself with protecting the natural environment from the risk of future harms, especially harms that might be irreversible or catastrophic because such harms cannot be “adequately captured in the standard economic measure of value.”<sup>126</sup>

The precautionary principle also discounts the importance of scientific uncertainty as a barrier to protective regulation, and is particularly well-suited to guide management decisions in an estuarine environment where so much is uncertain about how those systems work and the impact of changes to them.

Economics has been part of the thinking about the natural world for centuries.<sup>127</sup> Bioeconomics<sup>128</sup> and later cost-benefit analysis<sup>129</sup> reflect

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which there are approximately 472,000. See PUGET SOUND ACTION TEAM, *supra* note 2, at 19. Failing septic systems contribute untreated sewage and pathogens to the Sound and even when functioning properly do not reduce nitrogen in human waste. See *id.* While efforts are underway to assist local jurisdictions, businesses, and private individuals to upgrade these systems in accordance with statewide policies and standards, see *id.* at 19–20, the State Board of Health lacks authority to regulate these systems, which displaces this burden onto other state agencies and local governments. See *id.* at 22.

125. See Frank Ackerman & Lisa Heinzerling, *Pricing the Priceless: Cost-benefit Analysis of Environmental Protection*, 150 U. PA. L. REV. 1553, 1572 (2002) (saying that cost-benefit analysis is based on a flawed “world view [that] assumes stable problems, with control costs that are stable or declining over time”).

126. Sunstein, *supra* note 11, at 856–57.

127. See WORSTER, *supra* note 1, at 37 (saying economics and nature were first joined in 1658, when Sir Kenelm Digby spoke about the “oeconomy of nature,” a thought which carried through into the eighteenth century and in which “God was seen as the Supreme Economist who had designed the earth household and as the housekeeper who kept it functioning productively”). Worster goes on to explain that in the nineteenth century the word “ecology” replaced “oeconomy,” but true to its origins was still “imbued with a political and economic as well as Christian view of nature”—that the world must “be somehow managed for maximum output.” *Id.*

128. Originally developed by Gary Becker, the term “bioeconomics” refers to an area of economics in which sociobiology is applied to explain human behavior in a capitalist economic system. See EconomyProfessor.com, Bioeconomics, <http://www.economyprofessor.com/economictheories/bioeconomics.php> (last visited June 4, 2007). Becker argued that the economic approach could be applied to explain and predict all types of

that dialectical collaboration. However, some ecologists, like Edward O. Wilson, disapproved of bioeconomics' traditional econometric approach because it is based on "market price and tourist dollars," and thus "will always underestimate the true value of wild species."<sup>130</sup> He also criticizes cost-benefit analysis because it "consistently undervalue[s] the net benefits conferrable by species since it is much easier to measure the costs of conservation than the ultimate gains."<sup>131</sup> According to Wilson, "[i]f a price can be put on something, that something can be devalued, sold, and discarded."<sup>132</sup> "It would be folly," he laments, "to let any species die by the sole use of the criterion of economic return, however

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human actions because human behavior can be seen as involving participants who maximize their utility from a constant set of preferences. *Id.* These same principles were applied in the 1950s to study the dynamics of living resources, using mathematical models that defined nature as an economic system, each unit of which is tasked with the job of producing, manufacturing, and consuming. *See* WORSTER, *supra* note 1, at 291 (saying "all organisms are 'traders' or 'economic persons'; they must work to earn their way, either by producing food or by rendering services, and they must enter into commercial relations with one another"). Bioeconomics introduced economic concepts like "interdependence and cooperation," "the primacy of efficiency and productivity," and "a managerial ethos" into the vocabulary of ecologists. *Id.* at 293–94. The bioeconomics model materialized as part of the "New Ecology," in which "ecology . . . emerged as a full blown science of natural economics." *Id.* at 311. *See also id.* at 313 (describing the model's flow charts as revealing "all the energy lines mov[ing] smartly along, converging here and shooting off there, looping back to where they began and following the thermodynamic arrows in a mannerly march toward exit points," all leading to a highly managed environment).

129. Cost-benefit analysis, which has become a standard part of evaluating whether government intervention is advisable, involves the comparison of the "social benefits" of a given policy to its "opportunity costs—the social value foregone when the resources in question are moved away from alternative economic activities into the specific project" that is the subject of the policy. PERCIVAL, SCHROEDER, MILLER & LEAPE, *ENVIRONMENTAL REGULATION: LAW, SCIENCE, AND POLICY* 30–31 (5th ed. 2006).

130. WILSON, *supra* note 31, at 308.

131. *Id.* at 310. *See also* Rodgers, *supra* note 10, at 214 (expressing "sympathy with the idea that nonmarket human preferences are presumptively as important as the dollar votes of economic theory"); Frank Ackerman & Lisa Heinzerling, *Pricing the Priceless: Cost-benefit Analysis of Environmental Protection*, 150 U. PA. L. REV. 1553, 1563 (2002) (criticizing cost-benefit analysis for relying on "inaccurate and implausible" economic approaches to valuation, for using discounting procedures that "trivialize[s] future harms and the irreversibility of some environmental problems," for relying on "aggregate, monetized benefits [that] excludes questions of fairness and morality," and for being "neither objective nor transparent"). Ackerman and Heinzerling also point out that "[s]ome environmental benefits never have been subjected to rigorous economic evaluation" and, as a result, "their importance is frequently ignored," while "[t]here is also a tendency . . . to overestimate the costs of regulations in advance of their implementation." *Id.* at 1579–80.

132. WILSON, *supra* note 31, at 348.

potent, simply because the name of that species happens to be written in red ink.”<sup>133</sup>

An additional problem with these economic approaches is that they require a stable, non-changing predicate set of problems to work. For example, the bioeconomics model is premised on the idea that “the most natural state of nature was balance.”<sup>134</sup> Eugene Odum, a leading ecologist of the last century who did much of his work on the Bay, was one of the most forceful proponents of this view and a supporter of the bioeconomics model precisely because it is premised on the existence of a stable, non-changing environment.<sup>135</sup>

Although the bioeconomics model has endured,<sup>136</sup> its foundational principle that nature is a “perfectly manageable system of simple, linear, rational order”<sup>137</sup> has not. That premise has been replaced by a much messier picture— “[i]nstead of order happily emerging out of chaos, it was chaos that kept boiling up from the darkness, breaking down order”<sup>138</sup>—throwing into sharp relief the shortcomings of that model. Nature became “a world of unique and unpredictable individual events,” challenging scientists to understand how it worked.<sup>139</sup> a non-linear place where there are “simply too many variables to plot all the lines of

133. *Id.* at 310. *See also* Ackerman & Heinzerling, *supra* note 131, at 1564 (stating that cost-benefit analysis is “fundamentally incapable of delivering on its promise of more economically efficient decisions about protecting human, life, health, and the environment . . . [and] is inherently unreliable”).

134. WORSTER, *supra* note 1, at 389; *see also* WILSON, *supra* note 31, at 304 (advocating the use of bioeconomic assays for entire ecosystems). The view that ecosystems were constantly moving towards homeostasis, that point at which the system was in balance after waging an “endless, but successful struggle” against disturbing forces, *see* WORSTER, *supra* note 1, at 366, led to a theory of ecosystem management, the principle goal of which was to achieve a “steady state” or equilibrium, what Worster calls a “no growth economy,” *id.* at 367. Showing how prescient he was, Odum worried that “man-generated CO<sub>2</sub> and dust pollution might be making this precarious balance still more and more ‘unsteady.’” EUGENE P. ODUM, *FUNDAMENTALS OF ECOLOGY*, 271–72 (3d ed. 1971), *quoted in* WORSTER, *supra* note 1, at 368. Edward O. Wilson was also a proponent of ecological equilibrium and believed that changes to the physical environment could be reversed and “held rock-steady in a state close to optimum for human welfare,” and that while losses to biological diversity “cannot be redeemed, its rate can be slowed to the barely perceptible levels of prehistory,” achieving “at least an equilibrium . . . in the birth and death of species.” WILSON, *supra* note 31, at 282.

135. *See* WORSTER, *supra* note 1, at 311.

136. *See id.*

137. *Id.* at 406.

138. *Id.* at 407.

139. *Id.* at 400 (quoting Daniel Simberloff, *A Succession of Paradigms in Ecology: Essentialism to Materialism and Probabilism*, 43 *SYNTHESE* 24, 25–26 (1980)).

influence, of cause and effect.”<sup>140</sup> Odum’s view of ecosystems as “permanent entities engraved on the face of the earth” succumbed to a world of evolving, constantly changing, always different patterns,<sup>141</sup> in which “[e]ach organic system is so rich in feedbacks, homeostatic devices, and potential multiple pathways that a complete description is quite impossible.”<sup>142</sup> Even with respect to the preservation of biodiversity—the only ecological imperative and management goal most ecologists can agree to<sup>143</sup>—there is uncertainty. For example, scientists disagree about which are the “keystone species,”<sup>144</sup> the extinction of which “would bring down other species with it, possibly so extensively as to alter the physical structure of the habitat itself.”<sup>145</sup>

As with the bioeconomics model, cost-benefit analysis simply cannot work in an inherently unstable environment where predicting how that environment will respond to stress is almost certain to fail and where the consequences of doing nothing can be severe.<sup>146</sup> Cost-benefit analysis is premised on the same flawed “world view [that] assumes stable problems, with control costs that are stable or declining over time,” and those who use it find “precautionary investment in environmental

140. WORSTER, *supra* note 1, at 407.

141. *Id.* at 412; *see also* Rodgers, *supra* note 31, at 47 (stating “[t]he study of evolutionary biology is the study of systems that: [*inter alia*] display chaotic, nonlinear, and unpredictable characteristics”).

142. ERNST MAHR MAYR, *THE GROWTH OF BIOLOGICAL THOUGHT: DIVERSITY, EVOLUTION, AND INHERITANCE* 59 (1982), *quoted in* Rodgers, *supra* note 31, at 47 n.140.

143. *See* WORSTER, *supra* note 1, at 418–20.

144. WILSON, *supra* note 29, at 309. Wilson describes “keystone species” as the “biggest players” in an ecosystem, the removal of which “causes a substantial part of the community to change drastically,” *id.* at 164, and likens their loss to “a drill accidentally striking a powerline. It causes lights to go out all over.” *Id.* at 348. Rodgers notes that in evolution “there is no turning back”: once a species is “eliminated by extinction [it] will be gone forever.” Rodgers, *Biology and the Law*, *supra* note 31, at 51. *See also id.* at 51 n.162, (quoting SALVADOR E. LURIA ET AL., *A VIEW OF LIFE* 645 (1981) (“The principles of irreversibility and lack of momentum teach us something important about the nature of evolution. There are no definite directions, no strict causal determinism producing identical results in similar circumstances. The path of environmental change through time is tortuous and undirected.”)).

145. *See* WILSON, *supra* note 29, at 309 (stating keystone species “might as easily include any of the tiny invertebrates, algae, and microorganisms that teem in the substratum and that also possess most of its protoplasm and move the mass of nutrients”).

146. An additional problem relying on the artifact of cost-benefit analysis may be that regulators focus on the amount of pollution a given source contributes to the environment and ignore any benefit to the receiving environment, in part because those benefits are so difficult to calculate. This approach necessarily prejudices targets that offer less reduction, but may have equal or even better environmental benefits.



protection to be a needless expense.”<sup>147</sup> Making regulatory decisions on the basis of a favorable cost-benefit analysis also makes no sense in a world in flux because the approach “systematically downgrades the importance of the future” by relying on “predictive methodologies” that do not include the possibility of “catastrophic and irreversible events.”<sup>148</sup> Yet the possibility of such events occurring is a constant reality in constantly evolving and changing natural systems like estuaries.

Equilibrium ecologists like Odum, who believed that undisturbed natural systems sought stasis,<sup>149</sup> and advocates of the bioeconomics model assume they can determine what level of disturbance was safe for an ecosystem. In a world in which “[n]o organism functions independently of its environment, and no environment can be changed without changing the organisms that are part of it,”<sup>150</sup> what is a normal harvest or yield from these systems is highly uncertain.<sup>151</sup> In a world in which even the smallest changes in the environment of any place can substantially impact some place else,<sup>152</sup> and in a world in which even the smallest “perturbations or fluctuations can become amplified into gigantic, structure-breaking waves,”<sup>153</sup> regulatory targets simply cannot be chosen with any degree of certainty. Economic approaches for

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147. Ackerman & Heinzerling, *Pricing the Priceless*, *supra* note 131, at 1572.

148. *Id.* at 1570.

149. See WORSTER, *supra* note 1, at 366 (saying that Odum believed that every ecosystem was “either moving toward or had already achieved . . . a healthy state of order, or what he called ‘homeostasis’”).

150. Rodgers, *Biology and the Law*, *supra* note 31, at 53.

151. See WORSTER, *supra* note 1, at 416–17. When talking about the National Environmental Policy Act and procedural fairness, Rodgers says while “fruitful lines of inquiry could be developed along conventional efficiency lines” on the issue of how to allocate resources in the face of uncertainty, a more ethical approach to the problem of “speculative spillover effects,” one that is fair to “ourselves, future generations, and nonhuman residents of the planet,” is to “discover and forewarn those subject to risk.” Rodgers, *Theories of Judicial Review*, *supra* note 10, at 226.

152. See WORSTER, *supra* note 1, at 407 (describing “the butterfly effect”); see also PREGOGINE & STENGERS, *ORDER OUT OF CHAOS*, *supra* note 41, at 188 (stating “the more complex a system is, the more numerous are the types of fluctuations that threaten its stability”). Rodgers makes an interesting point about solving commons problems by the creation of tradable property rights and the effect of that approach on entitlements, like tribal fishing rights, noting that the concept of “efficiency” attacks on those entitlements “take the form of the desirability of repudiating the entitlement so that it can be placed in the hands of those who assign it a ‘higher’ value or who can produce ‘more’ with it.” Rodgers, *supra* note 10, at 221. Here, the narrow focus of Bay area regulators on large sources of pollution suffers from the same type of myopia, in which efficiency is elevated over what here is an entitlement to a biologically diverse ecosystem. *Cf. id.*

153. TOFFLER, *supra* note 41, at xvii.

selecting among regulatory targets, therefore, have no utility in such environments: their underlying premises are inapplicable.

The precautionary principle offers a better approach for selecting regulatory targets in a complex, evolving natural system. As a concept of international customary law, the precautionary principle says if something is potentially dangerous, then, in the face of scientific uncertainty, the prudent thing to do is to intervene and limit the risk.<sup>154</sup> That principle offers an alternative approach to managing complex natural systems like the Bay, where there is significant scientific uncertainty about how the system works and about the impacts of changes to it, and where harm to the system could be irreversible<sup>155</sup> or catastrophic<sup>156</sup>—*i.e.* the potentially irreversible, catastrophic loss of biodiversity.

Where harm may be irreversible, Cass Sunstein recommends that “special precautions” be taken,<sup>157</sup> and that regulators “invest resources to preserve flexibility for the future.”<sup>158</sup> When there is potential for

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154. See Cass R. Sunstein, *Irreversible and Catastrophic*, *supra* note 11, at 848–50 (noting and discussing various permutations of the Precautionary Principle as applied to global warming, injunctions in environmental cases, genetic modification of food, protection of endangered species, and terrorism). A similar expression of precaution can be found in American case law. See, e.g., *Ethyl Corp. v. EPA*, 541 F.2d 1, 28 (D.C. Cir. 1976) (en banc) (“Where a statute is precautionary in nature, the evidence difficult to come by, uncertain, or conflicting because it is on the frontiers of scientific knowledge, the regulations designed to protect the public health, and the decision that of an expert administrator, we will not demand rigorous step-by-step proof of cause and effect. Such proof may be impossible to obtain if the precautionary purpose of the statute is to be served.”). See also Daniel A. Farber, *Probabilities Behaving Badly: Complexity Theory and Environmental Uncertainty*, 37 U.C. DAVIS L. REV. 145, 168 (2003) (quoting Principle 15 of the *Rio Declaration on Environment and Development*, Report of the United Nations Conference on Environment and Development, G.A. Res. 48/190, 48 U.N. GAOR Supp. No. 49 at 167, U.N. Doc. A/48/49 (1992), quoted in DAVID HUNTER, JAMES SALZMAN, & DURWOOD ZELKE, INTERNATIONAL LAW AND POLICY (2d ed. 2002)) (“In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.”).

155. See Sunstein, *Irreversible and Catastrophic*, *supra* note 11, at 860 (defining irreversibility in the context of an environmental effect as being when the “restoration to the status quo is impossible or at best extremely difficult”).

156. See *id.* at 869 (saying “a catastrophic harm rests on the magnitude of the adverse effects”).

157. *Id.* at 841; see also *id.* at 866 (saying when there is a risk of irreversible losses “it makes sense to pay for an option to avoid” that risk).

158. *Id.* at 896. See also Farber, *Probabilities Behaving Badly*, *supra* note 154, at 171 (“When an environmental problem involves a complex dynamic system and seems likely to follow a power function, insurance should become a major factor in decision-making. When the problem involves broad societal impacts that cannot be easily handled by public or private risk-sharing mechanisms, it

catastrophic harm, like the collapse of an ecosystem, but a low probability of the harm occurring,<sup>159</sup> Sunstein recognizes that people are likely to “treat the risk as essentially zero” and pay little to prevent it,<sup>160</sup> especially when “the costs of precautions are incurred immediately,” while its “benefits will not be enjoyed until decades later.”<sup>161</sup> Under such circumstances, “people are likely to be extremely averse to precautionary steps, even if they are justified.”<sup>162</sup> This will also be true for regulators who have every incentive to delay undertaking costly protective action where the popular perception is that the risk of harm is extremely low.<sup>163</sup> In those situations, the precautionary principle directs that the regulator take action before the risk is realized.<sup>164</sup>

Eliminating chumming could improve the health of the Bay and its resident species. It would eliminate an additional source of nutrients to the Bay and a potential health threat to one of the Bay’s most important species, striped bass, as well as take pressure off of a vitally important food and filter fish, menhaden. Precautionary principles, rather than economic metrics, should guide the choices of regulators in a stochastic environment like the Bay, when faced with a risk of irreversible and potentially catastrophic dimensions. Chumming’s contribution to the potentially irreversible positive feedback loops ultimately leading to lower dissolved oxygen levels in the water column and loss of the Bay’s

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is worth making substantial investments to hedge against the possibility of disaster.”). Power laws are a feature of complexity theory that predict that “[t]he expected harm may be much higher than the midpoint of the range (the statistical median) or the most likely level of harm (the statistical mode)” where the difference in results could be huge. *Id.* at 172.

159. See Sunstein, *Irreversible and Catastrophic*, *supra* note 11, at 874.

160. *Id.* at 870–71. See also Cass R. Sunstein, *Precautions Against What? The Availability Heuristic and Cross-Cultural Risk Perception*, 57 ALA. L. REV. 75, 89 (2005) (discussing the “availability heuristic” and how peoples’ perceptions of risks are influenced by whether the risk is “cognitively available”).

161. Sunstein, *Irreversible and Catastrophic*, *supra* note 11, at 875.

162. *Id.*

163. See *id.* (speaking about elected officials). See also Ackerman & Heinzerling, *Pricing the Priceless*, *supra* note 131, at 1571 (worrying that “[t]oo many years of delay might mean that the polar ice cap melts, the spent uranium leaks out of the containment ponds, the hazardous waste seeps into groundwater and basements and backyards – at which point we cannot put the genie back in the bottle at any reasonable cost (or perhaps not at all)”).

164. Farber’s analysis of power laws, those situations when usual statistical assumptions about probabilities that a certain risk will occur “break down” and “where the chance of nasty surprises becomes a major part of risk analysis,” provides another rationale for applying precautionary principles in complex systems where power laws are more likely to function. Farber, *Probabilities Behaving Badly*, *supra* note 154, at 172–73.

biodiversity is clear. However, the perception that chumming creates a low risk of harm because it is a small contribution to the Bay's problems creates a false perception in regulators of how urgent the problem really is. Cost-benefit analysis would counsel regulators to stay the course of doing nothing to prohibit or limit chumming until catastrophe strikes; the precautionary principle advises that they intervene because the potentially irreversible and catastrophic loss of biodiversity "is the folly . . . our descendents are least likely to forgive us [for]."<sup>165</sup>

## CONCLUSION

The Bay is an invaluable resource for Maryland and the rest of the country. Despite efforts to repair damage to the Bay done over the years, more than ninety percent of its waters remain impaired, largely due to nutrification. Chumming contributes to the Bay's poor health because chum, a nutrient, uses dissolved oxygen critical to aquatic life and increases water turbidity, setting in motion destructive positive feedback loops. Chum may also transmit diseases to species that feed on it and contribute to the decline of menhaden, a critical filter and food fish. Although prohibiting chumming would help with the Bay's dissolved oxygen problem, improve water clarity and the exchange of oxygen at the surface, lessen stress on striped bass and other Bay species, and reduce pressure on menhaden, neither EPA nor Maryland has undertaken steps to regulate the practice, let alone stop it.

The story of chumming, however, is bigger than a tale of regulatory inertia because it reveals serious flaws in how complex systems are understood and approached by regulators. Bay area regulators are stuck in an outdated view of ecology and its bioeconomics paradigm, both of which presume that a balance in nature can be achieved and disturbances managed or corrected based on economic metrics, like those resulting from the application of cost-benefit analysis. A more contemporary view would reveal that what appear to be small changes to complex natural

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165. WORSTER, *NATURE'S ECONOMY*, *supra* note 1, at 419 (quoting WILSON, *BIOPHILIA* at 121 (Cambridge Mass. 1984)). Edward O. Wilson proposes "a practical ethic . . . a set of rules invented to address problems so complex or stretching so far into the future as to place their solution beyond ordinary discourse." See WILSON, *THE DIVERSITY OF LIFE*, *supra* note 31, at 312 (finding environmental problems "innately ethical"). An advocate for "the strong hand of protective law" to preserve biological wealth, he asserts that the government has a "moral responsibility in the conservation of biodiversity," comparable in seriousness to protecting public health and national security. *Id.* at 342. He also argues that because "bio-diversity is deemed an irreplaceable public resource, its protection should be bound into the legal canon." *Id.*

systems may in fact be large ones and to ignore them may threaten the biological diversity of those systems. Regulators need to realize that their reluctance to address small sources of environmental degradation in complex, fluctuating natural systems is imprudent, and that when it comes to biodiversity, “[t]he ethical imperative should therefore be, first of all, prudence.”<sup>166</sup>

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166. WILSON, *THE DIVERSITY OF LIFE*, *supra* note 31, at 351.