

PROGRAMMATIC ENVIRONMENTAL ASSESSMENT

**FOR THE
Prevention, Control, and Mitigation of
Harmful Algal Blooms Program**



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**NATIONAL OCEAN SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
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COVER SHEET

Proposed Action: The National Oceanic and Atmospheric Administration Prevention, Control, and Mitigation of Harmful Algal Blooms Program proposes to provide funding for the field demonstration of harmful algal bloom control techniques. The funding period is for five years. The areas of performance are those areas under the purview of NOAA.

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Abstract: Harmful algal blooms cause a wide variety of environmental, economic, and human health problems. The growing frequency and magnitude of harmful algal blooms has created a pressing need for in situ control in coastal waters. Field demonstration of harmful algal bloom control techniques is needed to fill the gap between laboratory research and larger scale implementation. The Prevention, Control, and Mitigation of Harmful Algal Blooms Program proposes to provide funding for the field demonstration of harmful algal bloom control techniques. This Programmatic Environmental Assessment has been prepared to comply with National Environmental Policy Act of 1969 (42 U.S.C. § 4231 *et seq.*), as amended. This document assesses the potential environmental effects associated with demonstration phase projects within the Prevention, Control, and Mitigation of Harmful Algal Blooms Program under the purview of NOAA (i.e., within coastal waters of the United States and the Great Lakes).

Cover Photo: A bloom of harmful algal species *Lingulodinium polyedrum* off the coast of La Jolla, San Diego County, California. This species has been associated with fish and shellfish mortality events, but its threat to human health is still being evaluated. Photo credit: Kai Schumann, California Department of Public Health volunteer (NOAA National Ocean Service, 2013).

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ABBREVIATIONS AND ACRONYMS

ASP	Amnesic Shellfish Poisoning
BOD	Biochemical Oxygen Demand
C.F.R.	Code of Federal Regulations
CEQ	Council on Environmental Quality
CFP	Ciguatera Fish Poisoning
Corps	United States Department of the Army Corps of Engineers
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
DO	Dissolved Oxygen
DSP	Diarrhetic Shellfish Poisoning
E.O.	Executive Order
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ERL	Effects Range Low
ESA	Endangered Species Act
FONSI	Finding of No Significant Impact
FY	Fiscal Year
HAB	Harmful Algal Bloom
HACP	Habitat Area of Particular Concern
MBTA	Migratory Bird Treaty Act
mg/L	milligrams per liter
MMPA	Marine Mammal Protection Act
MPA	Marine Protected Area
MSA	Magnuson-Stevens Fishery Conservation and Management Act
NCCOS	National Centers for Coastal Ocean Science
NEPA	National Environmental Policy Act
NERRS	National Estuarine Research Reserve System
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NSP	Neurotoxic Shellfish Poisoning
PCM	Prevention, Control, and Mitigation
PEA	Programmatic Environmental Assessment
PSP	Paralytic Shellfish Poisoning
RDDTT Plan	National Scientific Development, Demonstration, and Technology Transfer Plan on Reducing Impacts from Harmful Algal Blooms
RFMC	Regional Fishery Management Council
SAV	Submerged Aquatic Vegetation
SEA	Supplemental Environmental Assessment
SEIS-APM	Supplemental Environmental Impact Statement for Aquatic Plant Management
spp.	Species

U.S. United States
U.S.C. United States Code
USFWS United States Fish and Wildlife Service

1.0 INTRODUCTION AND BACKGROUND

1.1 INTRODUCTION

The National Oceanic and Atmospheric Administration (NOAA) Prevention, Control, and Mitigation of Harmful Algal Blooms (PCMHAB) Program proposes to provide funding for field demonstration of select harmful algal bloom (HAB) control techniques. The PCMHAB Program is a competitive research program established under the Harmful Algal Bloom and Hypoxia Research and Control Act of 1998 (33 U.S.C. 4001 *et seq.*), as amended. Notice of implementation of the PCMHAB Program was published in the Federal Register in 2009 (74 Fed. Reg. 20465). The PCMHAB Program is a component of the larger *National Scientific Development, Demonstration, and Technology Transfer Plan on Reducing Impacts from Harmful Algal Blooms* (RDDTT Plan). The goal of the RDDTT Plan is to protect public health, economies, communities, ecosystems, and fisheries while demonstrating and transferring techniques for the prevention, control, and mitigation of HABs. Additionally, the RDDTT Plan establishes a national HAB Event Response Program and implements a Core Infrastructure Program to support HAB research. The PCMHAB Program addresses the first component of the RDDTT Plan by advancing promising techniques from laboratory investigation to field demonstration, and transferring those techniques to end users. Projects within all three phases (development, demonstration, and transfer) are supported under the PCMHAB Program.

This Programmatic Environmental Assessment (PEA) is prepared to comply with the National Environmental Policy Act (NEPA) of 1969 (42 U.S.C. § 4231 *et seq.*), as amended. As such, this PEA assesses the potential environmental effects associated with demonstration phase projects within the PCMHAB Program and under the purview of NOAA (i.e., within coastal waters of the United States (U.S.) and the Great Lakes). The purpose of the proposed action is to provide funding for the advancement of the scientific understanding through the field demonstration of promising HAB control techniques. Under the proposed action, “demonstration” is defined as the minimum amount of a control method anticipated to decrease, but not necessarily eliminate, a HAB. Demonstration is explicitly envisioned to be limited in size and scale. The area treated is anticipated to be less than an acre in size through a limited number of applications. Further, demonstration will be limited to waters already suffering severe ecological harm (e.g., areas with existing fish kills, sick or distressed animals). This PEA addresses a subset of possible HAB control techniques that are expected to be viable for field demonstration within the next five-year period of program funding. Therefore, actions to be considered under this PEA are those that are likely to be ready for field demonstration between fiscal years (FY) 2015-2020.

1.2 PROJECT NEED

The PCMHAB program seeks to provide a coordinated research initiative to advance knowledge on methods and strategies capable of reducing the numbers and/or toxicity of harmful algal blooms. While PCMHAB has begun developing several promising control methods in the laboratory, the program has not funded field-demonstration of these techniques. Advancing the state of scientific knowledge on these methods and strategies through the demonstration phase is critical based on the significant environmental, human health, and socioeconomic impact of harmful algal blooms.

Also known as red tides, brown tides, or green tides, the term “harmful algal bloom” has been used by the scientific community to describe a diverse array of blooms of algae and cyanobacteria that produce:

- Toxic effects on humans and other organisms;
- Physical impairment of fish and shellfish;
- Nuisance conditions from odors and discoloration of water; or
- Overwhelming effects on ecosystems such as severe oxygen depletion (hypoxia) or overgrowth.

Impacts from HABs occur on a wide range of temporal and spatial scales, and may be felt in across an ecosystem. The impact HABs may have on an ecosystem is also varied; an algal species may do little to no harm in one ecosystem and devastate another. Some blooms can disrupt entire ecological communities simply due to their accumulated biomass, by contributing to the creation of oxygen-depleted hypoxic zones as their biomass decomposes. HABs also harm other organisms through predation, the production of deadly toxins and biochemical compounds, their morphological characteristics, or by decreasing light penetration through the water column (Glibert et al., 2005). Additionally, HAB toxins can cause a variety of human poisoning syndromes through either direct exposure to the organism's toxins or through the consumption of contaminated fish or shellfish (Glibert et al., 2005).

The average economic impact of HABs in the U.S. coastal waters is conservatively estimated at over \$82 million per year (Anderson et al., 2000; NOAA NCCOS, 2011). This loss is associated with reduction in shellfish harvests, tourism, recreational opportunities, and medical costs, among others (see Table 1-1).

Table 1-1. Average impact of HABs on the American economy from 1987-2000. Adapted from “The economic effects of harmful algal blooms” by Hoagland and Scatasta (2006).

Economic Sector:	Impact (in millions of dollars per year):
Commercial fisheries	\$38
Public health	\$37
Recreation and tourism	\$4
Coastal monitoring and management	\$3
Total:	\$82

The PCMHAB PEA will encompass projects in coastal portions of all U.S. coastal states (including the Great Lakes), since all are routinely impacted by HABs (Anderson et al., 2008; Lewitus et al., 2012). Some HABs occur naturally, but human activities that disturb ecosystems, such as increased nutrient inputs and pollution, climate change, food web alterations, and introduced species, have been linked to the increased occurrence of some HABs. Many species are being found in regions that were previously unaffected by or not known to have HAB problems (Reardon, 1989; Eisler, 1997; Glibert et al., 2005; Pokrzwinski, 2012).

1.3 PROJECT PURPOSE

The Harmful Algal Bloom and Hypoxia Research and Control Act required the development of four interagency reports and plans to assess HABs within the U.S. and update priorities for Federal research and response programs. As a result of these requirements, the RDDTT Plan was developed. The plan includes three essential objectives: funding for the development, demonstration, and transfer of techniques for the prevention, control and mitigation of HABs; development and implementation of a national HAB Event Response Program; and establishment of a Core Infrastructure Program to

support HAB research and response. The PCMHAB Program is an integral part of the RDDTT Plan. The purpose of the PCMHAB Program is to provide support to competitive peer-reviewed projects by funding the development and demonstration phases of PCM research.

Eligible applicants are institutions of higher education, other non-profits, state, local, Indian Tribal Governments, commercial organizations, U.S. Territories and Federal agencies that possess the statutory authority to receive financial assistance.

1.4 PROGRAMMATIC APPROACH TO NATIONAL ENVIRONMENTAL POLICY ACT COMPLIANCE

The projects approved and funded under the PCMHAB Program are Federal activities and, as such, must comply with NEPA. Because the PCMHAB Program would occur over many different locations across the Atlantic and Pacific Oceans, the Gulf of Mexico, and the Great Lakes, and would be implemented at various points in time over the next five years, it was determined that a programmatic approach would be the most efficient in terms of an overall NEPA analysis. A programmatic analysis at a conceptual level of detail provides early identification and analysis of potential impacts, methods to mitigate anticipated impacts, and a strategy to address issues at a tiered level of analysis, if necessary.

Preparing a PEA serves several purposes. First, it provides a format for a comprehensive impact analysis by taking a view of the planned PCMHAB activities as a whole. This is accomplished by assembling and analyzing the broadest range of potential direct, indirect, and cumulative impacts associated with a suite of techniques likely to be viable for field demonstration within the next five years through the PCMHAB.

A PEA also sets up a framework for addressing the time-and location-specific aspects of proposed PCMHAB projects through the use of a site-specific tiered analysis, if warranted. In Tier 1, of the PEA, NOAA has prepared an analysis at a program-level, broad scale. In Tier 2, one or more project specific EAs would be written to examine individual projects in greater detail, if required. Tier 2 may also include the application of a categorical exclusion if a proposed project meets the criteria for categorical exclusion (NOAA NOA 216-6). Supplemental Environmental Assessments (SEA) may also be written if research indicates a new methodology, not covered in this PEA, is ready for field demonstration. Tiering of environmental documents in this manner makes subsequent assessments more specific concerning the potential effects a specific control technique will have on a specific area, without duplicating paperwork and analysis from a previous assessment.

1.5 SUMMARY OF KEY COMPLIANCE REQUIREMENTS

NOAA is responsible, through the NEPA process, for ensuring that decision makers have adequate information to make an informed decision regarding the project. The implementation of the PCMHAB Program requires the applicants to obtain proper work permits, comply with the provisions of all Federal and state regulations, and notify appropriate organizations before performing any project using an approved control method. Additional action by applicants may be required to ensure compliance with the other Federal regulations identified below.

1.5.1 Clean Water Act

The Clean Water Act (CWA) of 1972 (33 U.S.C. § 1251 *et seq.*) is the primary Federal law that protects the Nation's waters, including lakes, rivers, aquifers, and coastal areas. The primary objective of the CWA is to restore and maintain the integrity of the Nation's waters. Jurisdictional

waters of the U.S. are regulated resources and are subject to Federal authority under Section 404 of the CWA. Areas meeting the waters of the U.S. definition are under the jurisdiction of the U.S. Army Corps of Engineers (Corps). Anyone proposing to conduct a project that requires a Federal permit or involves dredging or fill activities that may result in a discharge to waters of the U.S. must also obtain a CWA Section 401 Water Quality Certification, verifying that the project activities would comply with state water quality standards. Compliance with this law may require additional action from the PCMHAB applicant depending upon the control method being used.

1.5.2 Coastal Zone Management Act

The Coastal Zone Management Act (CZMA) of 1972 (16 U.S.C. § 1451 *et seq.*) requires that “any Federal activity within or outside of the coastal zone that affects any land or water use or natural resource of the coastal zone” shall be “consistent to the maximum extent practicable with the enforceable policies” of a federally-approved state coastal zone management program (State agency). There are three categories of federal activities that are subject to consistency review by a State agency. The first is direct federal agency activity, which means any activity or project performed by a federal agency or by a contractor for the benefit of a federal agency. The second involves a federal license, federal permit or other federal approval. An example of this second category would be an activity requiring a Section 404 CWA permit issued by the U.S. Army Corps of Engineers. The third category involves state and local activities or project for which federal financial assistance is sought. Prior to carrying out any of these federal activities, the proposed action is subject to consistency review by the State’s coastal zone management program, and one must comply with the “consistency” regulations promulgated by the Secretary of Commerce (15 C.F.R. 930) under CZMA. Compliance with this law may require additional action from the PCMHAB applicant.

1.5.3 Endangered Species Act

The Endangered Species Act (ESA) of 1973 (16 U.S.C. § 1531 *et seq.*) and subsequent amendments provide for the conservation of threatened and endangered species of animals and plants, and the habitats in which they are found. The ESA prohibits jeopardizing threatened and endangered species or adversely modifying critical habitats essential to their survival. Generally, the U.S. Fish and Wildlife Service (USFWS) manage land and freshwater species while the National Marine Fisheries Service (NMFS) manages marine species, including anadromous fish such as salmon. The USFWS also has responsibility for some marine animals such as nesting sea turtles, walrus, polar bears, sea otters, and manatees. ESA Section 7 requires consultation with the NMFS and the USFWS to determine whether any endangered or threatened species under their jurisdiction may be negatively affected by a proposed action. Compliance with this law may require additional action from the PCMHAB applicant.

1.5.4 Executive Order 11990, Protection of Wetlands

This Executive Order (E.O.) requires Federal agencies to minimize the destruction, loss, or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands in carrying out the agency's responsibilities. The goal of the PCMHAB Program is to grow closer to in situ control of HABs and reduce their impacts on environmental resources, including their indirect impact on wetlands. Compliance with this law may require additional action from the applicant depending upon the control method and the likelihood of impacts to wetlands. Should impacts to wetlands be expected, the PCMHAB applicant would be required to consult with and obtain permits from all appropriate Federal, state, and local agencies.

1.5.5 Magnuson-Stevens Fishery Conservation and Management Act

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) of 1975 (16 U.S.C. § 1801-1882) establishes U.S. jurisdiction from the seaward boundary of the coastal states out to 200 nautical miles for the purpose of managing fisheries resources. The MSA is the principal Federal statute that provides for the management of marine fisheries in the U.S. The purposes of the MSA include: (1) conservation and management of the fishery resources of the U.S.; (2) promotion of domestic commercial and recreational fishing; (3) preparation and implementation of Fishery Management Plans; (4) establishment of Regional Fishery Management Councils (RFMCs); (5) development of fisheries that are underutilized or not utilized; and (6) protection of Essential Fish Habitat (EFH).

EFH is defined as those waters and substrate necessary to fish or invertebrates for spawning, breeding, feeding, or growth to maturity. Areas designated as EFH contain habitat essential to the long-term survival and health of U.S. fisheries. Under provisions of the MSA, eight RFMCs were established for the New England, Mid-Atlantic, South Atlantic, Caribbean, Gulf of Mexico, Pacific, Western Pacific, and North Pacific regions. Should a PCM HAB project authorize, fund, or undertake, or propose to authorize, fund, or undertake actions that may affect EFH, consultation with NMFS is required. Habitat areas of particular concern or HAPCs are considered high priority areas for conservation, management, and research. HAPCs are subsets of EFH that merit special attention because they are rare, sensitive, stressed by development, or important to ecosystem function. Should a PCM HAB project authorize, fund, or undertake or propose to authorize, fund, or undertake actions that may adversely affect EFH within a HAPC, the PCM HAB project will be more carefully scrutinized during consultations with NMFS, and may require extra study and mitigation planning compared to surrounding areas. HAPC locations can be found using the EFH mapper <http://www.habitat.noaa.gov/protection/efh/efhmapper/>. RFMCs may, or in the case of anadromous fisheries must, comment on PCM HAB projects affecting fishery habitat, including EFH during this consultation or during the public comment period for the PEA.

1.5.6 National Historic Preservation Act

The National Historic Preservation Act (NHPA) of 1966 (16 U.S.C. § 470 *et seq.*) establishes historic preservation as a national policy and defines it as the protection, rehabilitation, restoration, and reconstruction of districts, sites, buildings, structures, and objects that are significant in American history, architecture, archaeology, or engineering. Section 106 of NHPA requires Federal agencies to take into account the effects of their undertakings on historic properties that are potentially eligible for listing on the National Register of Historic Places. In general, demonstration phase projects are excluded, as a means of mitigation, from deploying control methods in areas listed on the National Register of Historic Places in an effort to protect these resources. Compliance with this law may require additional action from the applicant depending upon the control method being used and the site of application.

1.5.7 National Marine Sanctuaries Act

Section 304(d) of the National Marine Sanctuaries Act (NMSA; 16 U.S.C. § 1431 *et seq.*) establishes that federal agency actions internal or external to a national marine sanctuary, including private activities authorized by licenses, leases, or permits, that are likely to destroy, cause the loss of or injure any sanctuary resource are subject to consultations with NOAA's Office of National Marine Sanctuaries. Each federal agency proposing such an action must provide a written statement describing the action and its potential effects on sanctuary resources no later than 45 days before the final approval of the action. In addition, sanctuary regulations (15 C.F.R. pt. 922) promulgated by the Secretary of Commerce under the NMSA may require a sanctuary permit or authorization for certain

actions that would otherwise be prohibited. Compliance with this law may require additional action from the PCMHAB applicant if the proposed action is likely to impact sanctuary resources or qualities.

1.5.8 Protection of Children from Environmental Health Risks and Safety Risks

Executive Order 13045 on Children's Health and Safety directs Federal agency, to the extent permitted by law and appropriate, to make it a high priority to identify and assess environmental health and safety risks that may disproportionately affect children, and to ensure that its policies, programs, activities, and standards address these risks. The Executive Order recognizes that some physiological and behavioral traits of children render them more susceptible and vulnerable than adults to environmental health and safety risks. Children may have a higher exposure level to contaminants because they generally eat more food, drink more water, and have higher inhalation rates relative to their size. Children also exhibit behaviors such as spending excessive amounts of time in contact with the ground and frequently putting their hands and objects in their mouths that can also lead to much higher exposure levels to environmental contaminants. In addition, a child's neurological, immunological, digestive, and other bodily systems are also potentially more susceptible to exposure related health effects. It has been well established that lower levels of exposure can have a negative toxicological effect in children as opposed to adults, and childhood exposures to contaminants can have long-term negative health effects. Examples include life-long neurological deficits resulting from exposure to lead, mercury, and other metals, and the increased susceptibility to particulate matter and other asthma triggers in the environment. In general, demonstration phase projects are excluded, as a means of mitigation, from deploying control methods in proximity to areas where children are known to congregate. Compliance with this law may require additional action from the applicant depending upon the control method being used and the site of application.

1.5.9 Rivers and Harbors Act

Section 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. § 401 *et seq.*) gives the Corps the authority to regulate structures or work in or affecting navigable waters of the U.S. Structures include any pier, wharf, bulkhead, etc. Work includes dredging, filling, excavation, or other modifications to navigable waters of the U.S. Some of the proposed control measures may involve dredging or filling, and as such, may require additional action from the PCMHAB applicant in order to comply with the Rivers and Harbors Act.

1.5.10 Consultation and Coordination with Indian Tribal Governments

Executive Order 13175, "Consultation and Coordination with Indian Tribal Governments" (November 6, 2000), requires each Federal agency to establish procedures for meaningful consultation and coordination with tribal officials in the development of Federal policies that have tribal implications.

The procedures outlined in the NOAA Procedures for Government-to-Government Consultation with Federally Recognized Indian Tribes and Alaska Natives (NOAA Tribal Consultation Handbook) provide guidance to NOAA to support a more consistent, effective and proactive approach to conducting tribal consultations. This Handbook is intended to improve NOAA's management of its relations and cooperative activities with Indian Tribes, and to provide for meaningful and timely input from Tribes into the Federal decision-making process on policy matters having substantial direct effects on them. Policies that have tribal implications refer to regulations, legislative comments or actions that have substantial direct effects on one or more Indian Tribes, on

the relationship between the Federal government and Indian Tribes, or on the distribution of power and responsibilities between the Federal government and Indian Tribes. While science, charting, and observations are not described in the Handbook as actions likely to require consultation, a tribe could request consultation on any NOAA action it believes has tribal implications.

As a matter of courtesy, if a HAB control demonstration project is planned to occur in an area of tribal jurisdiction or the action is believed to impact tribal concerns, the applicable Indian Tribes will be consulted.

1.5.11 National Ocean Policy (Executive Order 13547)

Executive Order 13547 – Stewardship of the Ocean, Our Coasts, and the Great Lakes -- establishes a national policy to ensure the protection, maintenance, and restoration of the health of ocean, coastal, and Great Lakes ecosystems and resources, enhance the sustainability of ocean and coastal economies, preserve our maritime heritage, support sustainable uses and access, provide for adaptive management to enhance our understanding of and capacity to respond to climate change and ocean acidification, and coordinate with our national security and foreign policy interests.

1.5.12 Invasive Species (Executive Order 13112)

Executive Order 13112 requires federal agencies to use authorities to prevent introduction of invasive species respond to and control invasions in a cost effective and environmentally sound manner, and to provide for restoration of native species and habitat conditions in ecosystems that have been invaded.

1.5.13 Marine Mammal Protection Act

The Marine Mammal Protection Act (MMPA) of 1972 (16 United States Code [U.S.C.] § 1361 et seq.) established, with limited exceptions, a moratorium on the “taking” of marine mammals in waters or on lands under U.S. jurisdiction. The act further regulates “takes” of marine mammals in the global commons (that is, the high seas) by vessels or persons under U.S. jurisdiction. The term “take,” as defined in Section 3 (16 U.S.C. § 1362 [13]) of the MMPA, means “to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal.” “Harassment” was further defined in the 1994 amendments to the MMPA, which provided two levels of harassment: Level A (potential injury) and Level B (potential behavioral disturbance).

The MMPA directs the Secretary of Commerce to allow, upon request, the incidental, but not intentional, taking of small numbers of marine mammals by U.S. citizens who engage in a specified activity (other than commercial fishing) within a specified geographical region if NMFS finds that the taking will have a negligible impact on the species or stock(s), and will not have an unmitigable adverse impact on the availability of the species or stock(s) for subsistence uses (where relevant). The authorization must set forth the permissible methods of taking, other means of attaining the least practicable adverse impact on the species or stock and its habitat, and requirements pertaining to the mitigation, monitoring, and reporting of such taking.

This makes conservation of healthy and stable ecosystems as much a priority as conservation of the individual organism. Baseline data for marine mammals is incorporated by reference from the NOAA website (<http://www.nmfs.noaa.gov/pr/species/mammals>).

1.5.14 Wilderness Act

Public Law 88-577, the Wilderness Act, signed September 3, 1964, created the legal definition of wilderness in the US, and protected 9.1 million acres of federal land. It created the National Wilderness Preservation System (NWPS). Currently the NWPS has designated 757 areas encompassing 109.5 million acres of federal owned land in 44 states and Puerto Rico as wilderness. Four different federal agencies administer these wilderness areas: U.S. Forest Service, U.S. National Park Service, U.S. Bureau of Land Management, and the U.S. Fish and Wildlife Service. A list of U.S. Wilderness Areas, by state, is incorporated by reference from <http://www.wilderness.net/NWPS/stateView?state=AK>. This list should be reviewed prior to any research to determine if the proposed research area is in or near a wilderness area and if any restrictions or permits are needed.

2.0 PROPOSED ACTION AND ALTERNATIVES

As a result of extensive review of numerous planning and technical supporting documents, two possible action alternatives for the Proposed Action emerged that would satisfy the identified purpose and need and scientific objectives. Consequently, the Proposed Action and the No Action Alternative are carried forward for analysis in this PEA. A third Alternative was considered, but rejected prior to the comprehensive analysis. This section describes the three alternatives and the ability of each to meet the purpose and need of supporting competitive peer-reviewed projects by funding the field demonstration of HAB control methods. The analysis of the No Action Alternative represents the baseline to compare the impacts of the Proposed Action.

2.1 THE PROPOSED ACTION (PREFERRED ALTERNATIVE)

The Proposed Action is to fund projects for the field demonstration of HAB control that use methods identified in Table 2-1 below. The Proposed Action includes only those control methods that the National Centers for Coastal Ocean Science (NCCOS) have determined are likely to be field demonstration ready within the next five years. To constrain the scale and limit the potential effects of demonstration phase projects, demonstration will explicitly be limited to one acre or less in size with a limited number of applications. Knowledge gained through these methods would allow for a more informed assessment of the best approach for mitigating individual HABs as well as optimal PCM for HABs in general.

Table 2-1. Control methods included in the Proposed Action.

Physical Control Methods	Chemical Control Methods
Flocculation	Native Macroalgae and Extracts
Sediment Resuspension, Burial, and Removal	Barley Straw
Cell Harvesting and Removal	Biosurfactants
Water Column Mixing	Hydrogen Peroxide
	Copper
	Silica
	Extracted/purified algicidal compounds

2.1.1 Physical Control Methods

Physical controls are those methods that physically remove algal cells from the water column, limit the spatial extent of a bloom by physical barrier or manipulation of abiotic factors, or kill algal cells through physical means. The methods included herein are those that have proven most promising in the laboratory or on the mesocosm scale. These methods are also likely to be more easily constrained in a variable, open aquatic system than are chemical or biological controls. Therefore, these methods are generally the closest to being field-ready for in situ demonstration projects. The physical control methods that are likely to be field demonstration ready by FY2020 and therefore included in the Proposed Action are flocculation; sediment resuspension, burial, and removal; cell harvesting and removal; and water column mixing.

Flocculation

Flocculation is the process of removing microscopic algae through the use of clay and sedimentation. Through repeated collisions and adhesion, large, rapidly sinking aggregates (or flocs)

of algae and clay are formed and settle to the ocean floor. The specific type of clay that is used is dependent upon the type of bloom. Researchers are currently developing modified clays to improve algal removal efficiency. Removal efficiency depends upon many factors, including both flocculant and algal type, concentration and size, flocculant dispersal method (primarily by spraying a liquid slurry on the water surface), water flow, and salinity. If the flocs remain out of the photic zone, the zone in the water column in which light penetrates, the algae would not have an opportunity for photosynthesis, resulting in cell mortality. In some instances, physiochemical interactions occur between the algae and the flocculant, directly resulting in mortality (Beaulieu et al., 2003). Flocculants have also been shown to adsorb, or adhere, to the surface of some types of HAB toxin, removing both intracellular and extracellular toxins (Pierce et al., 2004). They have also been demonstrated, with mixed results, to remove *Microcystis sp.* from the water column.

Sediment Resuspension, Burial, and Removal

Sediment resuspension, burial, and removal activities achieve HAB control through different mechanisms. Resuspension of bottom sediments affects HABs in two ways: one, to resuspend sediments in an area thought to be a seedbed for algal cysts (thick walled dormant cells of algae) with the objective of burying cysts in deeper oxygen-depleted sediments where they are unable to germinate; and two, to resuspend sediments which would act as a natural flocculant to remove algal cells from the water column.

Burial can be achieved by the placement of offsite material over the treatment area. All offsite material would be clean and free of toxins and of similar grain size and composition to sediments of the treatment area. Burial is also achievable through hydraulic suction dredging, where dredged material is removed from one area and discharged over the treatment area. It is also possible to remove the sediment and cysts through dredging and retain the sediments for treatment and disposal instead of discharging the sediments back to the treatment area. Burial and removal activities can also remove algal cysts so they cannot initiate new blooms. Potential impacts from a particular methodology would be evaluated through a tiered NEPA analysis.

Cell Harvesting and Removal

Hydrodynamic separation, centrifugation, pump filtration, and plankton net trawling are all examples of harvesting technologies with the ability to separate algae from water. Hydrodynamic separation and centrifugation are active methods that involve the withdrawal and processing of affected water through either centrifugation or vortex to create concentrated algal cells and water discharge. Pump filtration is also an active removal method involving the withdrawal of affected water in which a screen or filter is used to separate the algae from the water. All active cell-harvesting methods would have screening over the water intake and an appropriate flow rate to prevent impacts to non-target organisms. Potential impacts from a particular cell harvesting methodology would be evaluated through a tiered NEPA analysis.

Water Column Mixing

Water column mixing is a prevention method often used for closed systems such as lakes, reservoirs, and small or semi-enclosed coastal systems. This method consists of mixing the water column with a pump or other water-circulating device. Horizontal mixing of surface waters can create localized water currents that impair algal buoyancy and inhibit the ability to move independently, subsequently removing algae from the photic zone and preventing photosynthesis. Vertical mixing of the water column mixes and aerates bottom waters in order to prevent thermal stratification of the water column and the subsequent warming of surface waters that promotes the

growth of algae. Water column mixing to control an existing bloom would have multiple effects on a given algal species. Vertical mixing of the water column would result in isothermal conditions and a redistribution of nutrients and oxygen, both of which impact algal growth. The water intake would have screening and an appropriate flow rate for the environment in which it is located, to prevent impacts to non-target organisms. There are many products available on the market in use around the country and potential impacts from a particular water column mixing device would be evaluated through a tiered NEPA analysis.

2.1.2 Chemical Control Methods

Chemical controls rely on the release of chemicals that interfere with cellular growth, through a variety of mechanisms, of algal species. There are several chemical control methods likely to be field demonstration ready in the next five years and therefore included in the Proposed Action. These methods include the use of whole macroalgae and macroalgal isolates, barley straw and related extracts/liquors, biosurfactants, hydrogen peroxide, copper, silica, and isolated algicidal compounds.

Native Macroalgae and Isolates

Macroalgae are large subaquatic plants that can be seen without the aid of a microscope. Macroalgae have been known to impact HABs through nutrient competition and the subsequent limitation of HAB forming species, or through allelopathic effects on HAB species. Allelopathy is the inhibition of growth in one species of plant by chemicals produced by another species. The allelochemicals produced by macroalgae have algistatic (algae growth inhibiting) and algicidal (algae killing) properties that prevent the growth of other algae and cause cell mortality. Isolates of the allelochemicals maintain the same algistatic and algicidal properties as the whole macroalgae. The allelochemicals produced by macroalgae quickly degrade in the aquatic environment, thus the use of whole native macroalgae, rather than isolates, would be required to achieve sustained control. A variety of environmental variables can influence the efficacy of allelochemicals, including nutrient concentrations, pH, sunlight, and temperature. Macroalgae that have been shown to exhibit these allelopathic effects include, but are not limited to: *Spirogyra* spp., *Cladophora* spp. (Trochine et al., 2011), *Corallina* spp. (Jeong et al., 2000), *Ecklonia* spp. (Nagayama et al., 2003), *Gracilaria* spp., and *Ulva* spp. (Lu et al., 2011; Nan et al., 2008; Wang et al., 2007).

Barley Straw

The aerobic decomposition of barley straw has been shown to have an allelopathic effect on certain species of microalgae. The exact allelopathic mechanism that causes the inhibitory effect is debated, but barley straw liquor, extract from decomposing barley straw, and whole barley straw have each been shown to have algistatic and algicidal effects. The chemicals responsible for the control effect appear to be heavy phenolic compounds (Waybright et al., 2009) resulting from lignin decomposition (Ball et al., 2001); as well as the transformation of lignin to humic substances (humic substances are substances resulting from the decay of plant matter) and the subsequent formation of hydrogen peroxide in the presence of light and oxygen (Center for Ecology and Hydrology, 2004); though other reports suggest that the phenols instead increase the effects of ester compounds actually primarily responsible for inhibiting algal growth (Choe and Jung, 2002).

Masses of barley straw are used frequently to prevent the growth of algae in freshwater ponds (hUallacháin and Fenton, 2010). These masses are suspended at the water's surface where aerobic decomposition can occur and must be replaced every 4-6 months to continue producing the allelopathic effect. The allelochemical produced from the decomposing straw quickly degrades in the

aquatic environment to non-toxic byproducts and thus large quantities of straw would be required to achieve sustained control (Hagström et al., 2010).

Biosurfactants

Surfactants are compounds that lower the surface tension of a liquid and are used as detergents and emulsifiers. Biosurfactants are surfactants produced naturally by organisms such as bacteria or yeasts, as opposed to chemical surfactants which are man-made. As potential algicides, they have an advantage in terms of their diversity, biodegradability, low environmental toxicity, and biocompatibility (Ahn et al., 2003). Surfactants break down membranes, making them non-functional, often resulting in cell lysis. Some biosurfactants investigated to date for HAB control include surfactin produced by *Bacillus subtilis* (Ahn et al., 2003), sophorolipid produced by *Candida bombicola* (Baek et al., 2003), and rhamnolipid produced by *Pseudomonas aeruginosa* (Wang et al., 2005).

Hydrogen Peroxide

Hydrogen peroxide (H_2O_2) is naturally occurring in aquatic environments and is produced by several HAB species. In the aquatic environment, hydrogen peroxide has a residence time which can last anywhere from hours to days and decomposes into the byproducts water (H_2O) and oxygen (O_2). In the presence of a catalyst, such as ferrous iron (Fe^{II} , Fe^{2+}), decomposition can result in a hydroxyl radical (OH^\cdot) byproduct. The hydroxyl radical is a short-lived, highly reactive oxidant. Hydrogen peroxide has shown the greatest potential for control of HABs of cyanobacteria and the degradation of its toxin, microcystin. Cyanobacteria are more susceptible to the effects of hydrogen peroxide than other organisms given their lack of membrane organelles (Barrington et al., 2013), though can also control dinoflagellates (Burson et al., 2014). Potential impacts from a particular hydrogen peroxide methodology would be evaluated through a tiered NEPA analysis.

Copper

Copper, primarily copper sulfate ($CuSO_4$) and chelated compounds, has been used in situ to control algal blooms in both marine and freshwater environments. Copper has been shown to be toxic to a wide range of organisms and is used for algae control because it interferes with the chemical pathways for photosynthesis and causes cell lysis. Copper based algicides are commercially available for use in freshwater ponds, lakes, and reservoirs. Copper can undergo various transformations in the aquatic environment, including sorption, the process where one substance takes up or holds on to another, onto organic sediments and clays. The use of chelated copper compounds prevents the loss of copper from the water column so that it can remain available for algal control. Although copper may undergo transformation in the aquatic environment, it does not biodegrade.

Silica

Silica is a limiting factor for diatom growth. In a silica-limited environment, the natural assemblage of diatoms would experience reduced primary productivity, allowing HAB species to take over. The application of dissolved silica is expected to encourage the growth of the natural diatoms assemblage that would compete with and control the HAB species. This technique has been tried in closed freshwater environments with inconclusive results (Burkholder and Marshall, 2012).

Isolated Algicidal Compounds

Some bacteria and viruses have algicidal or algistatic effects on phytoplankton, including HAB species (Nakashima et al., 2006; Alamsjah et al., 2005). Compounds from these can be isolated and used as a technique to control HABs. The bacterium *Shewanella* produces an allelochemical that has been shown to inhibit the growth of dinoflagellates. Developing research has shown that isolates from these bacteria maintain their algicidal activity and may be used in situ to control dinoflagellate HABs (Pokrzywinski et al., 2012; Hare et al., 2005).

2.2 NO ACTION ALTERNATIVE

Under the No Action Alternative, projects for the field demonstration of HAB control methods would not be funded. However, the PCMHAB Program would still continue to fund programs in the development phase of control method research. Other existing programs would also continue to focus on reducing the impacts of HABs, although they would provide no support for testing the control techniques in the natural environment.

Understanding why, when, how, and where HABs occur is the basis of the prevention component of the PCMHAB Program. Although research indicates HABs may be prevented, the prevention component would likely only reduce the frequency and spatial extent of blooms, not eliminate them completely. If prevention fails and in situ control as developed by the PCMHAB Program is eliminated, resource managers and event responders would continue to be limited in their ability to curtail the spatial and temporal scales of the HAB.

Options for funding of field demonstration projects would be limited to local, state and/or private entities, where few programs currently exist in coastal environments. This would impede the development of competitive peer-reviewed research and new discoveries in HAB science. Without field demonstration of control methods, the gap between laboratory research and in situ control would remain, unless other funding mechanisms are created. As such, the No Action Alternative does not meet the program purpose and need.

2.3 ALTERNATIVE CONSIDERED BUT ELIMINATED FROM FURTHER ANALYSIS

The Council on Environmental Quality guidance requires that an environmental assessment discuss only reasonable alternatives in detail for an action (40 C.F.R. §§ 1500-1508). The following alternatives were considered, but were eliminated from additional analyses as they do not meet the criteria for a demonstration phase PCMHAB project.

2.3.1 No Laboratory Testing

The NOAA PCMHAB research program is comprised of three phases; research and development, demonstration, and transition to application. Prior to moving into the field demonstration phase, potential PCM techniques must have displayed promise in mitigating HABs in the research and development phase. Only a limited number of possible PCM techniques have been evaluated within a controlled laboratory setting to determine whether they may be an applicable strategy to mitigate a HAB. Therefore, only a limited number of possible techniques will be available for field demonstration during the life of this PEA.

2.3.2 Significant Environmental Impacts Expected

Other techniques, despite showing promise for mitigating HABs in research and development, have been excluded due to high likelihood of significant environmental impacts. For example, a number of macroalgae species have been shown to inhibit the growth of HABs. There

have been a number of examples of non-native, invasive algae causing significant ecological harm following an introduction. Therefore, no field demonstration project involving the introduction of non-native and/or live organisms will be funded through the PCMHAB program. In addition, a number of chemicals, such as sodium hypochlorite, have been shown to reduce a bloom, but have been excluded due to a strong likelihood of significant cumulative environmental impacts. Examples of excluded techniques are shown in Table 2.2.

Table 2-2. Examples of control methods evaluated and excluded.

Method	Description
Bleach	Sodium hypochlorite (bleach, NaHClO ₄) can be produced through the electrolysis of seawater. Exposure to sodium hypochlorite has been shown to cause mortality in red tide producing dinoflagellates. However, due to significant broad-range effects to non-target species, this method has been excluded from the Proposed Action.
Cysteine	Cysteine, in various forms, has shown promise as a mitigation technique for reducing the impact of HAB toxins on fish and shellfish, primarily in operations where fish or other marine life is grown for human consumption. Current application of cysteine is in a closed environment with no effects on the human or natural environment.
Algicidal Bacteria	Some bacterial species have been shown to have inhibitory effects on algal growth and play a role in the decomposition of algal biomass. In some instances, bacterial species may exhibit algicidal effects to specific algal species; however, there are a large number of unknown consequences at this time. This method has been generally excluded from the Proposed Action because there are numerous unknown consequences at this time to cover the method under a PEA. But as explained in section 2.1.2, some isolated compounds from algicidal bacteria that have been shown to inhibit HABs are included within this PEA.
Selective Breeding of Shellfish	Some shellfish which occur in areas prone to HABs have shown resistance to HAB toxins, bioaccumulating them in significantly higher quantities than susceptible shellfish in areas which do not experience HABs. Breeding and planting shellfish to change the ratio of susceptible and resistant shellfish to minimize toxicity has been proposed. This method has been excluded because the use of native shellfish would not require a NEPA analysis.
Light Intensity Manipulation	Currently excluded from field demonstrations through PCMHAB due to lack of laboratory testing of potential impacts on non-target species. May be considered, following this testing, through a supplemental PEA.

3.0 AFFECTED ENVIRONMENT

The alternatives discussed in this PEA may have effects on the environments where HABs are known or likely to occur and impact the same resources as those affected by HABs. In order to evaluate these effects it is first necessary to define the affected environment. For the purposes of this PEA, the affected environment is the U.S. coastal waters, including bays, estuaries, and near-shore habitats, and the Great Lakes. However, the scope of the affected environment for individual demonstration projects will be limited in the scale of application as noted in Sections 1.1 and 2.1.

3.1 PHYSICAL ENVIRONMENT

3.1.1 Water Quality

Water is made of many components, including dissolved gases, dissolved and particulate minerals, metals, organic matter, as well as other compounds such as toxins and contaminants. The parameters used to determine water quality are generally dependent upon the intended use of the water. The water quality parameters most relevant to this analysis are described below.

Water quality is also directly influenced by the phenomenon of stratification. Both freshwater and marine environments have the ability to stratify given the appropriate environmental conditions. Stratification can be caused by differences in salinity or temperature and results in a vertical layering within the waterbody. Without mixing, the lower layer (hypolimnion) can become hypoxic and nutrient-rich from the deposition of organic material, while the upper layer (epilimnion) typically remains oxygenated through surface contact with the air, water currents, and wind movement. Phytoplankton and other plant life use up dissolved nutrients within the epilimnion, leaving it devoid of nutrients. The longer the waterbody remains stratified the greater the differences in salinity and temperature become, making destratification (turnover) within the waterbody more difficult. When the waterbody does turnover, typically due to wind or seasonal changes in temperature or hydrology, nutrients and DO are redistributed throughout the water column.

Phosphorus and Nitrogen Content

Phosphorus and nitrogen are naturally occurring nutrients found in a variety of forms in the environment. Different forms of these nutrients have different effects on water quality and phytoplankton growth depending on the environment in which they occur. Dissolved inorganic nutrients (e.g., nitrate [NO₂₊₃], ammonia [NH₄], or phosphate [PO₄]) are necessary nutrients for aquatic plant growth and are readily available for phytoplankton uptake. Others must undergo transformation in the environment before they are available for phytoplankton uptake. In freshwater systems, phosphorus is the limiting nutrient for phytoplankton growth and in marine systems it is nitrogen. These nutrients enter aquatic systems from point sources such as sewage treatment plant discharge and non-point sources such as stormwater runoff from agricultural and livestock operations. Excess of these nutrients, in their respective systems, can cause water quality problems, including rapid algal growth, submerged aquatic vegetation (SAV) depletion, and eventually, hypoxic zones.

Turbidity

Turbidity is a measure of the loss in transparency of water due to suspended particles. Sediment and particulate matter increases the turbidity of water, thereby decreasing the amount of light penetrating through the water column to SAV and other organisms.

Dissolved Oxygen

Dissolved Oxygen (DO) is the amount of oxygen in the water available for aquatic organisms. For most aquatic life, low levels of DO results in negative health effects, including death (Engle et al., 1999; Miller et al., 2002). Saline environments generally hold less DO than freshwater environments due to the presence of dissolved solids (primarily salt). Aeration of the waterbody through turbulence and mixing as well as the production of oxygen from aquatic plants increases DO. DO is removed from the water through the respiration of aquatic organisms, the decomposition of organic material, and increased water temperature. The amount of DO needed for the microbial decomposition of organic material is known as the biochemical oxygen demand (BOD) (Wackett, 2011). The depletion of DO in a given area results in hypoxia (often defined as dissolved oxygen levels below 2mg/l). Hypoxic areas cause fish kills and create dead zones where aquatic life cannot survive. One such area is the Gulf of Mexico dead zone, off the coast of Louisiana. This dead zone varies seasonally, but can grow up to several thousand square miles (NOAA, 2012).

3.1.2 Noise (in air and under water)

The primary sources of terrestrial noise in the coastal environment are transportation and construction-related activities. Transportation noise includes traffic noise from automobiles, trucks, and motorcycles; railway transportation services; and aircraft (including helicopters) take-offs landings, and overflights from public and private airfields. Construction noise is created during a variety of activities, including but not limited to, construction and demolition projects, site preparation (e.g., land clearing, grading, excavation), and repair and maintenance activities. Noise levels can fluctuate depending on the type, number, and duration of use of heavy equipment for construction activities and can differ in effect by the type of activity, existing site conditions (vegetation to buffer sound) and existing ambient noise levels.

In the marine environment, underwater sound spreads out in space, and is reflected, refracted (changed in direction), and absorbed. Several important factors affecting sound propagation in water include spreading loss, absorption loss, scattering loss, and boundary effects (such as water temperature differences) of the ocean surface and the bottom (Greene, 1995). Natural sources include wind and waves, seismic noise from volcanic and tectonic activity, precipitation, and marine biological activities (Greene, 1995). A wider range of ambient noise levels occurs in water depths less than 600 feet (shallow water).

In addition to ambient noise, some sounds are also introduced into ocean environments from anthropogenic sources. These may include transportation (e.g., aircraft, small and large vessels, and hovercraft), construction and demolition activities (e.g., dredging, tunnel boring, auguring, and pile-driving), hydrocarbon and mineral-related activities (e.g., oil and gas exploration, drilling, production and decommissioning), other energy resource extraction (e.g., windmills, hydro-energy), geological and geophysical surveys (e.g., air guns, electromechanical devices, or marine vibroseis), the use of sonar and pingers for navigation and target detection, explosions (e.g., military ordnance, ship and weapons testing, and offshore demolition), and the conduct of ocean science studies (e.g., seismology, acoustic propagation, and acoustic thermometry).

3.1.3 Aesthetics and Visual Resources

Aesthetics and visual resources define the visual character of an area. These resources can be natural features, vistas, water views, and can include developed features such as architectures, skylines, or other man-made characteristics. The nation's coastal region has thousands of miles of shoreline, bordered by a variety of different landscapes. Additionally, ambient light at night varies dramatically and can influence flora and fauna presence and growth.

3.2 BIOLOGICAL ENVIRONMENT

3.2.1 Submerged Aquatic Vegetation

Submerged aquatic vegetation (SAV), sometimes called seagrass, are aquatic plants that grow in clear, shallow, sub-tidal regions of bays, rivers, and coastal lagoons. These are typically vascular, rooted plants that grow to the water's surface. Algae and floating plants are generally not considered to be SAV. The extent and range of SAV is dependent upon many factors such as type of substrate, temperature, water clarity, salinity, and protection from wave energy. Because SAV require clear water in order to receive the light necessary for photosynthesis, these plants are often used as indicators of ecosystem health and water quality.

These grasses are critical components of coastal ecosystems around the world and serve as a food source for both aquatic and terrestrial organisms, as well as shelter and habitat for a host of resident and migratory aquatic species. SAV also serve a variety of ecosystem functions, including absorbing wave energy, helping to settle out sediments and decrease turbidity, binding the substrate to prevent erosion, filtering polluted runoff, uptake of nutrients, and oxygenation of the water column.

A threat to SAV is poor water quality, primarily water clarity. Increased turbidity prevents sunlight from reaching SAV, reducing the capacity for photosynthesis, subsequently killing the plant. Thus, sunlight is an important factor influencing SAV survival, which makes water clarity critically important. Fewer SAV means less oxygenation of the water and less uptake of nutrients. A decline in SAV has been observed worldwide with increasing frequency over the last few decades (Short and Wyllie-Echeverria, 1996).

3.2.2 Wetlands

Wetlands are defined by regulations implementing the CWA as “those areas that are inundated or saturated by surface water or ground water at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions” and are under the jurisdiction of the Corps pursuant to Section 404 of the CWA. To be delineated as a wetland, an area must exhibit three characteristics: hydric soils, dominance of hydrophytic vegetation, and hydrology.

Wetlands provide a host of valuable ecosystem functions, including flood abatement, erosion control, sequestration and transformation of nutrients, storage of water, food supply, and habitat. Wetlands also possess socioeconomic value for heritage, aesthetics, recreation, food production, and harvesting of resources. Wetlands subject to tidal fluctuation naturally experience extremes in temperature, DO, and salinity; whereas freshwater wetlands are likely to maintain more constant conditions. Coastal wetlands serve as feeding, breeding, and nesting ground for migratory waterfowl, with some waterfowl being completely dependent upon specific coastal wetlands.

3.2.3 Protected Species, Wildlife, Essential Fish Habitat, and Critical Habitats

For this analysis, a variety of aquatic and terrestrial animal species and their habitats are included. Aquatic wildlife may include insects and other invertebrates, as well as fish and shellfish that are not species of interest in aquaculture, commercial, or recreational fisheries, as these are discussed in their respective sections. Terrestrial wildlife may include those organisms that have an aquatic diet or those that use the water for one or more life stages. Pollution, over-fishing, and other human-caused impacts can harm both terrestrial and aquatic species that rely coastal environments.

Marine mammals, sea turtles, and migratory birds are protected species and as such, are included in this analysis. All marine mammals are protected under the Marine Mammal Protection Act (MMPA) of 1972 (16 U.S.C. § 1361 *et seq.*). This act prohibits the taking of marine mammals in U.S. waters and mandates the use of ecosystem based management in order to keep marine mammal populations from declining beyond the point where they are no longer functional parts of their ecosystems. This makes conservation of healthy and stable ecosystems as much a priority as conservation of the individual organism. Baseline data for marine mammals is incorporated by reference from the NOAA website (<http://www.nmfs.noaa.gov/pr/species/mammals>) and the FWS website (http://www.fws.gov/habitatconservation/marine_mammals.html). Other furred mammals that may be found in coastal areas include mink and mice.

Many species of birds spend all or a portion of their life cycle in coastal waters using a variety of habitats at different stages and seasons. Major groups of birds that inhabit these coastal waters include waterfowl, pelagic sea birds, raptors, colonial waterbirds, shorebirds, and passerines. The Fish and Wildlife Improvement Act of 1978 (16 U.S.C. § 742i) and the Migratory Bird Treaty Act (MBTA) of 1918 (16 U.S.C. §§ 703-712) protect identified ecosystems of special importance to migratory birds against pollution, detrimental alterations, and other environmental degradations. The USFWS is responsible for maintaining and updating the list of migratory birds protected under the MBTA; this list is incorporated by reference from the USFWS website (<http://www.fws.gov/migratorybirds/RegulationsPolicies/mbta/mbtandx.html>).

The USFWS also has responsibility for ensuring compliance with the Bald and Golden Eagle Protection Act of 1940 (16 U.S.C. §§ 668-668d), as amended. Under this act, it is unlawful to take, possess, transport, purchase, barter, sell, import, or export bald or golden eagle (alive or dead), including the nest, egg, or any part of the eagle without a permit issued by the USFWS. The Act defines “take” as “pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest, or disturb.” The USFWS, who is responsible for carrying out provisions of this Act, define “disturb” to include a “decrease in its productivity, by substantially interfering with normal breeding, feeding, or sheltering behavior, or nest abandonment.”

Both plant and animal species are eligible for listing as threatened or endangered, and as such, are protected under the Endangered Species Act. Administered jointly by the USFWS and NMFS Office of Protected Resources, the purpose of this act is to protect and recover the species and its ecosystem. Baseline data for threatened and endangered species is incorporated by reference from the USFWS website (<http://www.fws.gov/endangered/index.html>) and the NMFS website (<http://www.nmfs.noaa.gov/pr/species/esa/>). Additional state listed endangered and threatened species may be determined through contact with the appropriate individual state agencies.

Critical habitat was identified in the ESA as habitats that are essential for the conservation of a threatened or endangered species. Critical habitats are specific geographical locations that may require special management or protection. This habitat may include an area that is not currently utilized by the species but may be needed for its recovery. Baseline data for critical habitat is incorporated by reference from the USFWS critical habitat portal website (<http://criticalhabitat.fws.gov/crithab/>).

Under the MSA, EFH is identified as those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. Because marine fish depend on habitat for survival and reproduction, it is important to protect the habitats that sustain and enhance commercial and recreational fisheries. HAPCs, are considered high priority areas for conservation, management,

and research. HAPCs are subsets of EFH that merit special attention because they are rare, sensitive, stressed by development, or important to ecosystem function. The MSA requires RFMCs to identify and describe EFH for each life stage of the managed species within their jurisdiction. Baseline data for EFH is incorporated by reference from the NOAA EFH Mapper website at (<http://www.habitat.noaa.gov/protection/efh/habitatmapper.html>).

3.2.4 Invasive Species

The National Invasive Species Council defines invasive species as “an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health,” and alien species to mean “with respect to a particular ecosystem, any species, including its seeds, eggs, spores, or other biological material capable of propagating that species, that is not native to that ecosystem (E.O. 13112, 1999).” Invasive species are introduced through a variety of ways including, but not limited to ballast water from ships, entanglement in fishing gear, aquaculture escapes, release of unwanted pets or other domestic animals, and transportation of produce. In some cases, the new environment is not well suited for the introduced species and it cannot survive. However, in many cases the new environmental conditions are suited for survival of the invasive species.

Once established in the new environment a variety of scenarios can unfold. Generally, the introduced species proliferates through the ecosystem. In some instances the new species is able to outcompete native species, causing a decline in native populations. In other instances native species are not adapted to the presence of the introduced species and easily succumb to predation, again causing a decline in native populations. Invasive species include a wide variety of organisms, including some HAB species.

3.2.5 Coral Reefs

A coral reef is an ecosystem that includes a collection of biological communities. Coral reefs are one of the most diverse ecosystems in the world (Moberg and Folke, 1999). Corals themselves are sessile animals belonging to the group Cnidaria, along with jellyfish and sea anemones. Most reef forming corals have single celled algae known as zooxanthellae that live within them. Zooxanthellae are what give coral their color; together they have a mutually beneficial relationship. Corals secrete a calcium carbonate skeleton that forms the structure for the reef. This provides protection for the zooxanthellae and compounds needed for photosynthesis, while the zooxanthellae provide food and nutrients for the coral. Both tropical reefs and slow growing cold water corals are faced with a variety of environmental threats including overfishing, coral bleaching, ocean acidification, and disease.

3.2.6 Benthic Environment

The benthic environment is the area at the sediment-water interface in a waterbody. A variety of plants and organisms inhabit this area and their distribution is dependent upon a variety of abiotic factors, such as light availability, salinity, temperature, and DO. Benthos, (organisms residing in the benthic environment) such as worms, mollusks, and crustaceans serve as a food source for organisms higher up the food chain. Many benthos, as well as the fish that feed upon them, are important commercial fisheries, including demersal fish such as flounder and halibut.

The chemistry of both the water and the sediment plays an important role in many interactions in the benthic environment, including decomposition and nutrient transformation at the sediment-water interface. When organisms die and sink to the bottom of the waterbody, along with other organic material, decomposition occurs and uses up DO in the benthic environment. In

addition, the transformation and sequestration of nutrients in the benthic environment is largely dependent upon sediment composition and can have effects on the availability of nutrients for plant growth. Both of these factors can impact the distribution of species within the benthic environment.

3.2.7 Aquaculture

Aquaculture is the farming of aquatic organisms such as fish or shellfish. There are many aquaculture operations for the purpose of conservation and restoration, which farm species of concern for research and to restore depleted wild populations. However, most aquaculture operations are for commercial purposes, for which the goal is to provide a safe and sustainable source of seafood in order to relieve stress on wild populations. Numerous aquacultured species are relevant to this analysis; however, the specific species is dependent upon the geographic location. Major aquaculture industries include salmon, trout, shellfish, and aquatic plants. These organisms are cultured in a variety of ways, including cage, net-pen, suspended, and bottom culture.

Mariculture (aquaculture in the marine environment) is known to leave bio-deposits upon the sediment below and near the operation. These deposits primarily consist of feces and uneaten feed but also include trace metals associated with antifouling paint and other biocides. Bio-deposits can alter the chemistry of the sediment and the benthic community assemblage. The impact to the sediment and benthic environment at an aquaculture facility can also depend largely upon the type of organism being farmed. Different organisms have differing nutrition requirements and thus different feed compositions and subsequently different types and concentrations of excreta. Given fallow periods between farming operations, sediment conditions and community assemblages have been observed returning to pre-farming conditions within periods of weeks to years (Nash, 2001).

3.2.8 Fisheries

The MSA, as amended, authorizes the NMFS to manage fisheries within 3 to 200 miles off the coast of the U.S. to address human impacts on the marine environment and to prioritize identification and management of EFH. The MSA created eight RFMCs, each responsible for the area adjacent to its constituent states (the Exclusive Economic Zone), while individual states manage the fisheries that remain within state waters. These fisheries include a wide variety of both finfish and shellfish.

3.2.9 Cultural environment

Cultural and historic resources are those sites, areas, structures, landmarks, water bodies, and objects significant in American history or culture. These resources are recognized and protected in order to preserve American history and culture for future generations. Many local and state governments have their own nomination and designation programs. The National Park Service operates the National Register of Historic Places and National Historic Landmarks programs. Baseline data is incorporated by reference from the National Park Service National Register of Historic Places Database website (<http://nrhp.focus.nps.gov/natreghome.do?searchtype=natreghome>). The resources relevant to this analysis include submerged and coastal resources. Historic wrecks can be located anywhere in coastal waters due to a variety of reasons, particularly in shallow waters. Known wrecks are typically listed on nautical charts, but are often found around navigational hazards (e.g., shoals or reefs) near shipping lanes. Other wrecks can be found in ship graveyards, where they have been abandoned after their use has expired.

3.2.10 Tribal and Native Communities

Executive Order 13175, “Consultation and Coordination with Indian Tribal Governments” (November 6, 2000), requires each Federal agency to establish procedures for meaningful consultation and coordination with tribal officials in the development of Federal policies that have tribal implications.

The procedures outlined in the NOAA Procedures for Government-to-Government Consultation with Federally Recognized Indian Tribes and Alaska Natives (NOAA Tribal Consultation Handbook) provide guidance to NOAA to support a more consistent, effective and proactive approach to conducting tribal consultations. This Handbook is intended to improve NOAA’s management of its relations and cooperative activities with Indian Tribes, and to provide for meaningful and timely input from Tribes into the Federal decision-making process on policy matters having substantial direct effects on them. Policies that have tribal implications refer to regulations, legislative comments or actions that have substantial direct effects on one or more Indian Tribes, on the relationship between the Federal government and Indian Tribes, or on the distribution of power and responsibilities between the Federal government and Indian Tribes.

3.3 MARINE PROTECTED AREAS

Executive Order 13158, Marine Protected Areas, helps protect natural and cultural resources within the marine environment by strengthening and expanding the Nation’s system of marine protected areas (MPAs). The E.O. defines MPAs to include any area of the marine environment that has been reserved by Federal, state, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein. NOAA maintains an inventory of existing MPAs, which includes National Marine Sanctuaries, National Wildlife Refuges, Marine Preserves, and National Estuarine Research Reserve System sites, among others. Baseline data is incorporated by reference from NOAA’s MPA Inventory website (<http://www.mpa.gov/dataanalysis/mpainventory/mpaviewer/>).

National Marine Sanctuaries are protected areas of the marine environment with special national significance due to their conservation, recreational, ecological, historical, scientific, cultural, archeological, educational, or aesthetic qualities as national marine sanctuaries. The sanctuaries are administered by NOAA’s Office of National Marine Sanctuaries. Baseline data is incorporated by reference from the Office of National Marine Sanctuaries website (<http://sanctuaries.noaa.gov>).

The National Estuarine Research Reserve System (NERRS) is a nationwide network of coastal research reserves cooperatively managed coastal states and universities with funding and technical assistance provided by NOAA. Reserves are established for long-term research, education, and coastal stewardship. Currently, NERRS include 28 reserves across the country; baseline data is incorporated by reference from the NERRS website (<http://nerrs.noaa.gov>).

The Department of Interior operates numerous protected areas, including National Wildlife Refuge, National Parks, and National Seashores. Administered through the U.S. Fish and Wildlife Service, the National Wildlife Refuge system includes over 500 refuges dedicated to the conservation, protection, and enhancement of fish, wildlife, and plants. Through the National Park Service, the Department of Interior also manages over 84,000,000 acres of land for the purpose of protecting those areas of special significance to the American people. Baseline data is incorporated by reference from the U.S. Fish and Wildlife (www.fws.gov) and the National Park Service (www.nps.gov) web sites.

3.4 RECREATION

Recreation includes any activity of leisure done for enjoyment, pleasure, fitness, or fun. Recreational activities considered in this analysis are those activities likely to use aquatic environments, such as fishing, swimming, boating, scuba diving, snorkeling, surfing, and the use of beaches. Some coastal regions rely heavily on tourism revenue from recreational activities, as addressed in sections 3.7 and 4.2.7, Environmental Justice and Socioeconomics.

3.5 LAND USE

Land use, simply put, is the human use of a landscape. Land is typically zoned categorically based upon the intended use. The U.S. Department of Agriculture reported the major uses of land in the U.S. as of 2007 were forestland (30%), grassland, pasture and rangeland (27%), cropland (18%), parks and wildlife areas (14%), miscellaneous use (9%), and urban land (3%) (USDA, 2011). Subsets of these uses include, but are not limited to, recreational areas, barren land, urban residential, rural residential, roadways, rights-of-way, and industry. The coastal environment relevant to this analysis includes a wide variety of land uses.

3.6 ENVIRONMENTAL JUSTICE AND SOCIOECONOMICS

The Environmental Protection Agency (EPA) defines environmental justice as “the fair treatment and meaningful involvement of all people, regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.” Fair treatment means that no group of people, including a racial, ethnic, or socioeconomic group, should bear a disproportionate share of the negative environmental consequences of industrial, municipal, or commercial operations or the execution of Federal, state, local, or tribal programs and policies.

NOAA evaluates impacts on low-income and minority communities as part of the NEPA process in order to comply with E.O. 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low Income Communities and Low Income Populations. Under this E.O., agencies are required to identify and correct programs, policies, and activities that have disproportionately high and adverse human health or environmental effects on minority or low-income populations. The E.O. also tasks Federal agencies with ensuring that public notifications regarding environmental issues are concise, understandable, and readily accessible.

The Federal government has a legal obligation to protect Native American tribal treaty rights, lands, assets, and resources. Given that Native Americans are a minority group, impacts to Native Americans are evaluated under environmental justice for the purposes of this PEA. There are approximately 566 Federally recognized tribes with guaranteed tribal hunting, trapping, and fishing rights, including the right to hunt and fish in “usual and accustomed places” even if these places do not occur on land areas administered as Federal Reservations. States do not have the authority to regulate tribes or their lands, including matters such as environmental control and land use. Many Native American tribes rely on subsistence harvesting of fish and shellfish for food, spiritual, and economic reasons.

3.7 CLIMATE CHANGE

Climate change, as defined by the EPA, is “any significant change in measures of climate lasting for an extended period.” This is different than global warming, although frequently interchanged, because climate change is more than just temperature as it also includes precipitation and wind. Climate change can be caused by a number of natural factors, such as changes in ocean circulation or the variation in the sun’s intensity. Climate change can also be caused by human

activities such as the burning of fossil fuels, which changes the atmosphere's composition. Evidence of global climate change includes warming surface temperatures, melting glaciers, rising sea level, ocean acidification, shifting ranges of plants and animals, as well as changing precipitation patterns.

3.8 HUMAN HEALTH

Human health is the overall condition of a person's mind and body. The primary exposure pathways through which impacts to human health occur, with regards to this PEA, are inhalation of aerosols and ingestion. Inhalation of toxicants can impact the respiratory tract, resulting in throat, nose, and lung irritation. While some toxicants may deposit in the respiratory tract and be coughed out, others can be absorbed into the blood stream through contact with the lining of the lung. The ingestion of toxicants can impact the digestive tract, including the mouth, throat, stomach, and intestines. As the primary purpose of the digestive tract is to breakdown the foods we eat and absorb the necessary nutrients, toxicants that are ingested may also be absorbed into the blood stream and distributed throughout the body. Similar exposure is also a factor in child health and safety. Children are also likely more susceptible to the impacts of toxicants as well as to developmental impairments. Additionally, physical contact with some toxins (e.g., from cyanobacteria) represent a possible route of exposure that can result in irritation to skin, eyes, and mucous membranes.

3.9 CHILD HEALTH

A growing body of scientific knowledge demonstrates that children may suffer disproportionately from environmental health risks and safety risks. These risks arise because: children's neurological, immunological, digestive, and other bodily systems are still developing; children eat more food, drink more fluids, and breath more air in proportion to their body weight than adults; children's size and weight may diminish their protection from standard safety features; and children's behavior patterns may make them more susceptible to accidents because they are less able to protect themselves. Therefore, to the extent permitted by law and appropriate, and consistent with the agency's mission, each Federal agency: (a) shall make it a high priority to identify and assess environmental health risks and safety risks that may disproportionately affect children; and (b) shall ensure that its policies, programs, activities, and standards address disproportionate risks to children that result from environmental health risks or safety risks.

While some HAB control measures might adversely impact child health, neither project activities nor potential minor and transitory environmental impacts are in proximity of areas where children congregate (e.g., schools, recreation areas, child care centers, parks, and residential areas) and are present; therefore this project does not pose a hazard to child health. "Areas where children" congregate is defined per language incorporated by reference from the EPA memo of 8.14.12, Addressing Children's Health through Reviews Conducted Pursuant to the National Environmental Policy Act and Section 309 of the Clean Air Act.

4.0 ENVIRONMENTAL CONSEQUENCES

This section evaluates the potential impacts from the implementation of the No Action Alternative and the Proposed Action. Direct, indirect, and cumulative impacts, as defined in the Council on Environmental Quality (CEQ) Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act (40 Code of the Federal Register [C.F.R.] Parts 1500-1508) have been considered for each alternative.

4.1 THE PROPOSED ACTION

The Proposed Action is to fund projects for the field demonstration of specific PCMHAB techniques that fit under the physical and chemical control method categories (see Table 2-1). The Proposed Action includes only those methods that would be applicable to environments under NOAA's purview and that the NCCOS have determined are likely to be field demonstration ready within the next five years. Demonstration phase projects would be localized and on a small scale, as indicated in Sections 1.1 and 2.1. Most methods would involve limited applications that are not anticipated to be significant. Specific projects funded through PCMHAB will be evaluated through a tier 2 consistency memorandum, unless deemed to be covered through a Categorical Exclusion.

As described in section 1.1 and 2.1 demonstrations of the Proposed Actions will be occurring in environments that are already significantly affected by a HAB. While the Proposed Action is not anticipated to result in significant benefits to the environment, the small scale and scope of PCM application relative to the large scale and scope of the HAB will also not result in additional or cumulative environmental impacts. None of the control methods included in the Proposed Action would have an effect on land use, nor would any control method disproportionately affect a minority or low-income population. In addition, given the limited temporal and spatial scale of demonstration phase projects, the Proposed Action is not expected to have an impact on the local or regional economy. Therefore, Land Use, Environmental Justice, and Socioeconomic impacts are excluded from further consideration.

4.1.1 Physical Control Methods

Physical controls are those methods that physically remove algal cells from the water column, limit the spatial extent of a bloom by physical barrier or manipulation of abiotic factors, or kill algal cells through physical means. The methods included herein are those that have proven most promising in the laboratory or on the mesocosm scale. The physical control methods that are likely to be field demonstration ready by FY2020 and therefore included in the Proposed Action are flocculation, sediment resuspension, burial, and removal, cell harvesting and removal, and water column mixing. The potential effects of each of these methods on the affected environment are discussed below.

4.1.1.1 Physical Environment

Water Quality

Flocculation and sediment resuspension, burial, and removal activities would increase turbidity; however, this effect is not expected to be significant as particles would immediately begin settling from the water column and would not result in long-term or permanent changes to water clarity. Microbial decomposition of flocced/sedimented HAB cells would result in changes to DO and nutrient content and the increased BOD created by the decomposing HAB cells would contribute

the development of hypoxia and/or hydrogen sulfide toxicity, depending upon existing water quality conditions. However, in most environments subjected to HABs, these water quality conditions are already negatively impacted. In addition, the limited extent of proposed action would result in possible water quality effects that are temporary and localized. Further, it is likely that the proposed actions may result in slight improvements in water quality. Therefore flocked/sedimented HABs would not substantially result in increased direct, indirect, or cumulative significant impacts.

The flocculant alone may also have the ability to temporarily increase or decrease nutrients in the water column, depending on the type and modification of the flocculant. Similarly, sediment resuspension, burial, and removal activities also have the ability to increase or decrease the flux of nutrients into the water column, given particular sediment-water interactions. Generally, larger, open systems would experience a lower severity of effects and for a shorter duration of time than smaller, enclosed systems that may experience a lower rate of water mixing/circulation. However, these effects are not expected to significantly impact the water quality of the water body given the limited size of a demonstration phase project and the interaction that is required by a number of environmental variables to result in these effects.

The resuspension of bottom sediments can release contaminants such as chemicals, heavy metals, or other toxins which had previously settled from the water column. Due to the potential for reintroduction of contaminants to overlying waters, sediment resuspension, burial, and removal activities could result in significant impacts to water quality. The exclusion of this control method in areas with known sediment contamination, as a means of mitigation, would preclude significant impacts to water quality (see Section 5.1). Another means of mitigation would be to characterize the contaminated soils and develop a mitigation plan for their use, isolation, treatment, or disposal. If mitigation is not feasible, the proposed action will not be conducted.

Cell harvesting and removal activities could indirectly alter nutrient concentrations in the water column through the removal of nutrient-fixing organisms. This effect would not be significant, as the natural phytoplankton community would be expected to equilibrate after removal of the dominant HAB species and nutrient competition interactions would return to pre-treatment conditions.

Vertical water column mixing could result in isothermal conditions with a more uniform distribution of salinity, nutrients and DO; while horizontal mixing would increase DO in surface waters. Though these are direct changes to a stratified system, these changes would generally improve water quality. Water column mixing activities which feature a benthic water intake would increase turbidity. However, this effect would not be significant as the increase would not be to a degree that would be harmful to other organisms. In addition, this effect would be temporary, as turbidity levels would return to pre-treatment levels upon cessation of the control method. The redistribution of nutrients in the water column is simply a redistribution of the nutrients already present within the waterbody. This effect would not be significant as it would not result in a continued flux of nutrients into the water column. Given the already highly degraded water quality condition of systems suffering from HABs, see section 4.2.1, Water Quality, physical control methods are not anticipated to result in additional significant impacts.

Noise

None of the proposed alternative methodologies would significantly increase the ambient noise levels. While the methods are being deployed and results analyzed, there may be transient, temporary, small-scale increases in noise due to small boat operations, water pumps, or human interactions.

Aesthetics and Visual Resources

The amount of ambient light, particularly at night, can influence the presence of sea turtles during nesting/egg-laying season and when the baby turtles hatch to return to the ocean. High levels of light on the land side of the beach can disrupt sea turtle behavior. None of the proposed PCMHAB techniques need to be conducted at night, so are explicitly exclude from night demonstration. Therefore there will be no change to the “dark-night” and no disruption of sea turtle behavior.

4.1.1.2 Biological Environment

Submerged Aquatic Vegetation

Projects using physical control methods not located within or directly adjacent to SAV would not have a direct effect on SAV. However, if a physical control method project is located within or adjacent to SAV, an effect is expected. SAV beds naturally accumulate more particulate matter than unvegetated areas due to a reduction in water current and wave energy within the bed. Flocculation and sediment resuspension, burial, and removal activities increase turbidity and have the capacity to bury SAV, preventing the light penetration necessary for photosynthesis. While high depositional rates can stimulate the growth of some SAV species, others are more susceptible to sedimentation, which can reduce the development of seedlings and tubers. Given the greater accumulation of organic matter within SAV beds and the production of sulfides during anaerobic microbial decomposition, SAV beds can have greater sulfide production than surrounding unvegetated areas. Depending upon existing water quality conditions and hydrodynamics within the project area, the increased BOD created by the decomposing HAB cells could reduce DO levels and contribute to the development of hypoxia or hydrogen sulfide toxicity, resulting in SAV mortality.

The exclusion of flocculation and sediment resuspension, burial, and removal activities over SAV, as a means of mitigation, would preclude significant impacts to SAV. If a project is unable to be redesigned to prevent significant impacts to SAV and mitigation is not feasible, the project will require further analysis under a project specific EIS in order to be funded for demonstration through the PCMHAB program.

In those instances where water column mixing features a benthic intake and SAV is present, the method could result in increased turbidity and localized changes in water circulation patterns. These effects are not expected to be significant enough to result in SAV mortality because they are limited in duration and/or intensity.

It is not expected that the cell harvesting and removal method would have an effect on SAV as these activities occur at the water’s surface.

Wetlands

Physical control methods would only be used in open water where HABs occur. As such, none of the physical control methods (flocculation, sediment resuspension, burial, and removal, cell harvesting and removal, and water column mixing) would directly affect wetlands. Each of the methods have the potential to result in indirect effects to wetlands through the means discussed in section, 4.1.1.1, Water Quality; however, these effects were determined to be not significant, as long as mitigation is performed in areas with sediment contamination (see Section 5.1).

Protected Species, Wildlife, Essential Fish Habitat, and Critical Habitats

Impacts to these resources would be the same impacts that are thoroughly discussed in the Submerged Aquatic Vegetation, Wildlife, and Benthic Environment sections. These impacts would remain the same for similar species and habitat, regardless of an official listing or designation. Flocculation would affect wildlife in several ways, including indirectly through the effects discussed in section 4.1.1.1, Water Quality, which were determined to be not significant as they would be temporary and localized. Other effects of flocculation on wildlife include reduced clearance rates and reduced shell and tissue growth rates in bivalves (Archambault et al., 2004), temporary coughing in fish (Rensel and Anderson, 2004), and decreased feeding activity of visual predators (Beaulieu et al., 2003). None of these effects are expected to be significant as they would not last in sufficient duration to cause harm, and do not significantly exceed the effects of the HAB itself. Entrainment of non-target plankton during sedimentation would occur, affecting species with a planktonic life stage. However, this effect would not be significant because the control method is used over a limited area in discrete events which is not expected to result in reduced recruitment or reduced larval survivorship for a particular population. It is possible that flocculation may foul bird feathers, but testing would not be done in areas of bird aggregation, such as nesting colonies of waterbirds, and numbers of impacted birds would be minimal and temporary.

Sediment resuspension, burial, and removal activities would also affect wildlife in the ways discussed in section 4.1.1.1, Water Quality, which were determined to be not significant. Other effects include attracting fish to the treatment area due to the suspension of benthic macroinvertebrates, capture of non-target species in removal activities, and burial of non-target species. Burial and removal activities would result in the capture and burial of some individuals; however, mortality would not be significant because it would not have a measurable effect on the population. These activities could also result in a temporary loss of prey for some species until the benthic community recovered. This effect would also not result in significant impacts to wildlife since they would not impact populations as a whole and the area would be re-colonized after the treatment.

Cell harvesting and removal activities would entrain non-target species. Cell harvesting and removal activities which use water withdrawal would have an appropriate flow rate for the environment which it is located and be fitted with screening to prevent the entrainment of larger organisms. While this control method would result in mortality for some individuals, given the scale of demonstration phase project, the mortality rate would not be significant because it is not expected to have a measurable effect upon the population.

Vertical water column mixing activities would destratify systems and create turbulence at the water's surface which interferes with algal buoyancy. Many fish use deeper, cooler waters for behavioral thermoregulation. Vertical water column mixing activities would create isothermal conditions in the vicinity of the mixing device, causing discontinuity in the thermal refuge. This effect would not be significant as demonstration phase projects are limited in size and duration, and would not result in isothermal conditions throughout the waterbody. The creation of turbulence at the water's surface would interfere with the buoyancy of non-target phytoplankton. However, this effect would also not be significant because phytoplankton are extremely abundant and would return to the native community composition after cessation of the control method. Just as with cell harvesting and removal activities, the water intake would have an appropriate flow rate for the environment which it is located and be fitted with screening to prevent the entrainment of larger organisms.

NOAA's PCMHAB Program will coordinate with DOI, NMFS, and the appropriate state and local agencies for site-specific projects as required under the MSA, ESA, MMPA, MBTA, and relevant federal, state and local laws. Each project will be reviewed for potential impacts species and

habitats covered by these environmental statutes. If necessary, informal consultation with such agencies will be conducted. If it is determined that a particular project would have no effect on these resources, then no further evaluation would be required. If the coordination concludes that effects on these resources may occur, formal consultation would be initiated and either a project-specific SEA or EIS will be prepared.

Coral Reefs

Each of the physical control methods has the potential to adversely affect coral reefs if used over a coral reef. Clear water is necessary to support photosynthesis of the zooxanthellae. Several of the physical control methods can result in increased turbidity and/or increased water currents over a reef which could prohibit photosynthesis and abrade the coral. Cell harvesting has the potential to remove the zooxanthallae, remove or damage the coral, and remove sources of food. Water column mixing activities which feature a benthic intake would increase turbidity; however, turbidity levels would return to pre-treatment levels upon cessation of the control method. Although these effects are temporary in nature, when combined with other problems facing coral reefs, physical control methods could result in cumulative impacts to coral reefs. The exclusion of these control methods over coral reefs, as a means of mitigation, precludes significant impacts to coral reefs. If exclusion is not feasible, the project will require a project-specific SEA or EIS as well as coordination with appropriate Federal and state agencies to minimize and offset any adverse impacts and ensure no long-term or cumulative impacts occur. The PCMHAB program will not fund a PCM demonstration projects over coral reefs that have not undertaken a project-specific SEA or EIS.

Invasive Species

None of the control methods included in the Proposed Action have the potential to introduce or promote the spread of an invasive species. The use of whole macroalgae has been conditioned by the mitigation measures in section 5.0, Mitigation and Monitoring, to only include the use of native or naturalized species, as to eliminate any opportunity for the introduction or spread of an invasive species. Materials not native to the demonstration area/region are subject to mitigation measures outlined in section 5.0.

Benthic Environment

Flocculation would affect the benthic environment through the means discussed in section 4.1.1.1, Water Quality, which were determined to be not significant, as well as through the burial and deposition of the flocculent and flocced material. Depending upon existing water quality conditions and the hydrodynamics in the project area, an accumulation of flocced HAB cells in the benthic environment could contribute to the development of hypoxia or hydrogen sulfide toxicity. An accumulation of flocced material could burry sessile organisms and result in mortality; however, some research has shown that benthic communities have remained unchanged even after years of clay flocculation (Hagström et al., 2010). The hydrology at the treatment site will also largely determine the impact flocculation has on the benthic environment, as higher energy environments which keep particles suspended for longer periods of time may be more detrimental to bivalves than lower energy environments where sedimentation can occur more quickly (Archambault et al., 2004; Beaulieu et al., 2003). While mortality to some individuals may occur, this effect is not expected to be significant because the limited spatial scale of a demonstration phase project. Furthermore, the burial and deposition of flocced material is not expected to be greater than would otherwise occur over the life of an uncontrolled bloom.

The intensity of effects resulting from sediment resuspension, burial, and removal activities largely depends upon sediment composition and hydrodynamics at the treatment site. Areas where the sediment is composed of larger grain sizes, such as sandy areas, would experience a very brief increase in turbidity, as these particles would settle quickly. Areas with a finer sediment composition would experience an increase in turbidity for a greater period of time, as the particles would remain suspended longer. In either case, this effect is not expected to be significant as these activities are discrete events which are not expected to decrease water clarity for a duration which would cause harm to other organisms. Many motile benthic organisms would be able to leave the treatment area during application of the control method. These activities could result in mortality to those organisms that are sessile or have limited motility. However, this effect would not be significant as the area would be re-colonized following completion of the activities and the mortality of individuals would not have a measurable effect on the population.

While sediment burial and removal activities may eliminate or mitigate the presence of HAB cysts in the benthic environment, resuspension activities can resuspend previously interred cysts. Many HAB cysts are known to germinate when resuspended, even after many years of burial (Keafer et al., 1992 and Anderson et al., 2005). Additionally, resting cysts of some species have been shown to be even more toxic than corresponding motile stages (Dale et al., 1978). One objective of sediment resuspension is to disturb bottom sediments in order to inter HAB cysts in hypoxic sediments to prevent germination. If burial does not occur, HAB cysts would have been resuspended into overlying waters.

Cell harvesting and removal activities occur at the water's surface where they have no effect on the benthic environment. The intake for a water column mixing device would have an appropriate flow rate for the environment which it is located and be fitted with screening to prevent the entrainment of organisms. Water column mixing activities which feature a benthic water intake would increase turbidity, although, not to a degree which would be harmful to benthos as turbidity levels would return to pre-treatment levels upon cessation of the control method.

Aquaculture

Clay flocculation was developed as a control method in Japan and Korea for the treatment of HABs at mariculture facilities (Sengco and Anderson, 2004). The increased suspended particulate matter has been shown to cause temporary coughing in fish (Rensel and Anderson, 2004). However, this effect has not been shown to be significant as it does not result in fish mortality and limits on the scale and frequency of application would likely preclude indirect and/or sub-lethal effects. Flocculation would have effects on aquaculture operations taking place in the benthic environment, such as shellfish production, due to the non-significant impacts discussed in sections 4.1.1.1, Water Quality; 4.1.1.2, Protected Species, Wildlife, Essential Fish Habitat, and Critical Habitats; and 4.1.1.2, Benthic Environment. In the wild, these effects would not be significant as mortality of individuals is not expected to have a measurable effect upon the population. Within an aquaculture operation, mortality is expected to be moderate, particularly when compared to adverse effects associated with the HAB.

Sediment resuspension, burial, and removal activities would disturb sediments within aquaculture operations, resulting in the same effects discussed in sections 4.1.1.1, Water Quality; 4.1.1.2, Protected Species, Wildlife, Essential Fish Habitat, and Critical Habitat; and 4.1.1.2, Benthic Environment. These activities would not only increase turbidity, but also resuspend nutrients and bio-solids, as well as trace metals associated with antifouling paint and other biocides used in aquaculture operations. To determine the magnitude of the effects that would result from the resuspension of these sediments, further NEPA analyses may be required.

Cell harvesting and removal activities would occur at the water's surface with no effect on water quality or the benthic environment. Water column mixing activities which feature a benthic water intake have the potential to resuspend sediments below aquaculture operations, as discussed above for sediment resuspension, burial, and removal activities. Water column mixing activities without a benthic water intake would not disturb the sediments beneath the aquaculture facility and as such, would not have any adverse effects on aquaculture operations.

For all the physical control methods, temporary impacts would be associated with the removal of beneficial phytoplankton/food source species. These temporary effects would be negligible as phytoplankton are extremely abundant and would return to the native community composition after cessation of the control method. In general, demonstration phase projects within or directly adjacent to privately leased areas for aquaculture operations must coordinate with and obtain approval from appropriate stakeholders and regulators.

4.1.1.3 Cultural Environment, Tribal and Native Communities

For all physical control methods, impacts are anticipated to be minor and temporary. Given the unique nature of these resources and variation in environmental conditions between locations, the evaluation of specific impacts to these resources from physical control methods at a programmatic level would not provide any useful information to decision makers. Rather, a project-specific evaluation would be appropriate for assessing impacts to these resources. The use of flocculation or sediment resuspension could make subsistence harvesting by native communities temporarily unavailable, but these areas would already be closed to harvesting due to the presence of a HAB. While science, charting, and observations are not described in the Handbook as actions likely to require consultation, a tribe could request consultation on any NOAA action it believes has tribal implications. As a matter of courtesy, if a HAB control demonstration project is planned to occur in an area of tribal jurisdiction or the action is believed to impact tribal concerns, the applicable Indian Tribes will be consulted.

4.1.1.4 Marine Protected Areas

Potential impacts resulting from physical control methods are anticipated to be the same as those described in sections 4.1.1.1, Physical Environment and 4.1.1.2, Biological Environment. Therefore, the Proposed Action is generally excluded from Marine Protected Areas and known cultural and historic resource unless mitigation measures are identified through the project-specific evaluation and coordination with and approval from appropriate Federal, state, and local authorities has occurred.

4.1.1.5 Recreation

For all of the physical control methods, temporary impacts would be associated with the use or placement of equipment within a waterbody for application of the method. These temporary impacts are not expected to be significant because work would be minimal compared to current activities and existing uses. Upon completion of the treatment and removal of equipment, recreational activities would return to normal. Additionally, flocculation and sediment resuspension may make recreation activities undesirable while the control method is being tested. However, the duration and limited size of the control method (see sections 1.1 and 2.1) being tested is not long enough to result in significant effects.

4.1.1.6 Human and Child Health

Flocculants would be clean and free of toxins and would not be modified in a way that would introduce toxins into the environment. As such, flocculation would not affect human health.

As discussed in section 4.1.1.1, Water Quality, the resuspension of contaminated bottom sediments has the potential to affect water quality, which could in turn affect human health. The exclusion of this control method in areas with known sediment contamination, as a means of mitigation, would preclude significant impacts to water quality and thus human health. If mitigation is not feasible, the project would require a project-specific SEA or EIS and coordination with Federal, state, and/or local authorities which regulate these activities, and which may have expertise on the contamination and means for preventing impacts to human health.

Cell harvesting and removal activities do not involve the introduction of materials into the human environment and would not alter the natural environment in such a way as to affect human health.

Water column mixing activities that do not feature a benthic intake do not involve the introduction of materials into the human environment and would not alter the natural environment in such a way as to effect human health. However, water column mixing activities that feature a benthic intake, if used within an aquaculture operation, have the potential to resuspend trace metals associated with antifouling paint and other biocides that are used in aquaculture operations. The effects on human health that would result from the resuspension of these materials are unknown. In general, demonstration phase projects within or directly adjacent to privately leased areas for aquaculture operations must coordinate with and obtain approval from appropriate stakeholders and regulators. Through this coordination, potential impacts to human health may be reduced through the use of project-specific mitigation measures, or the project may require a project-specific SEA or EIS to ensure the project would not affect human health.

Impacts to child health and safety are anticipated to be similar to those outlined previously for Human Health. Further, PCM control methods will only be demonstrated in environments that are not located near children or locations where children may recreate since HABs preclude the use of, or nearby, environments by children.

4.1.2 Chemical Control Methods

Chemical control methods rely on the release of compounds that either cause cell lysis or which prevent the photosynthesis of algal species. There are several chemical control methods likely to be field demonstration ready in the next five years and therefore included in the Proposed Action. These methods include the use of whole macroalgae and macroalgal isolates, barley straw and barley straw extracts/liquors, biosurfactants, hydrogen peroxide, copper, silica, and isolated algicidal compounds.

The Washington State Department of Ecology published a Supplemental Environmental Impact Statement for Freshwater Aquatic Plant Management (SEIS-APM) in July 2000, revised in 2001. This document supplements the original 1980 and 1992 EISs and assesses the impacts of copper on the aquatic and human environment. The SEIS provides technical background and references scientific literature relevant to the proposed action and is therefore incorporated by reference.

4.1.2.1 Physical Environment

Water Quality

In the case of toxin-producing HABs, the chemical controls which induce cell lysis would cause the release of toxins into the waterbody. Controlled HABs are expected to have a lower cell density and be smaller in spatial scale than uncontrolled HABs. Therefore, the one-time release of toxins from the application of a chemical control is expected to be less than what would be produced from a sustained bloom with uncontrolled growth. Given the already highly degraded water quality condition of systems suffering from HABs, see section 4.2.1, Water Quality, chemical control methods are not anticipated to result in additional significant impacts.

Each of the chemical control methods would affect water quality through changes in nutrient content and DO. These methods would increase the nutrient content of the waterbody either through the direct addition of organic material or by causing HAB cell lysis, which would release nutrients into the waterbody. This release would be a one-time event and would not permanently alter water quality. Depending upon existing water quality conditions and hydrodynamics within the project area, the increased BOD created by the decomposing HAB cells could reduce DO levels and contribute to the development of hypoxia. Generally, wide spread or prolonged hypoxia would be unlikely to result in open systems due to water mixing/circulation. The decrease in DO from the decomposition of a controlled bloom is expected to be both lower in intensity and smaller in scale than an uncontrolled bloom, as a controlled bloom would have a lower cell density and be smaller in spatial extent.

The use of whole barley straw would temporarily increase turbidity from the increase in particulate matter and as soluble organic compounds are leached from the decomposing straw when it is first placed in the water. This effect would not diminish overall water clarity as the soluble compounds would quickly dilute and disperse in the receiving water and particulate matter would settle from the water column.

Copper compounds are water-soluble and dissipate within hours to days, depending on environmental factors, as the free copper ion is adsorbed to sediments and organic material. As such, copper would not persist in toxic levels in the water column. However, copper is a naturally occurring trace element and would persist indefinitely in its elemental form in the sediments, as discussed further in section 4.1.2.2, Benthic Environment. The EPA provides a threshold of 1.3 mg/L of copper in drinking water (EPA, 2012). Given the limited spatial scale of demonstration phase projects and limited number of application, the use of copper is not expected to exceed this threshold.

4.1.2.2 Biological Environment

Submerged Aquatic Vegetation

Each of the chemical control methods would have an indirect effect on SAV. After treatment, dead HAB cells would settle from the water column and begin decomposition. The increased BOD created by the decomposing HAB cells, depending upon existing water quality conditions, could reduce DO levels and contribute to the development of hypoxia or hydrogen sulfide toxicity, resulting in SAV mortality. Given the nationwide decline of SAV, these effects may result in significant impacts. The exclusion of chemical controls over or adjacent to SAV, as a means of mitigation, would preclude significant impacts to SAV. If a project is unable to be redesigned to reduce impacts and mitigation is not feasible, the project may require a project-specific SEA or EIS.

The use of whole macroalgae as a control method serves two purposes, to elicit an allelopathic effect and to inhibit HABs through nutrient competition. Although the purpose of using

macroalgae is to reduce the amount of nutrients available for growth, HABs occur in nutrient-rich environments and macroalgae would not be expected to reduce nutrient availability to a level which would limit SAV growth. In addition, the limited spatial scale of demonstration phase projects would only produce localized nutrient reductions as opposed to reducing the nutrient content of the entire waterbody, and the limited number of applications would preclude any lasting effects.

As noted in the SEIS-APM, copper bioaccumulates in plants and animals in varying amounts dependent upon environmental conditions and species; however, biomagnification does not appear to occur. The use of copper may result in SAV mortality if SAV are within the treatment area. The exclusion of copper as a control method within or adjacent to an SAV, as a means of mitigation, would preclude significant impacts to SAV.

Wetlands

The chemical control methods would be applied in open water where HABs occur and would not have a direct effect on wetlands. Each of the methods have the potential to result in indirect effects to wetlands through the means discussed in sections 4.1.2.1, Water Quality and 4.1.2.2, Benthic Environment; however, these effects were determined to be not significant when the specified mitigation is used.

Protected Species, Wildlife, Essential Fish Habitat, and Critical Habitats

As previously discussed in section 4.1.2.1, Water Quality, some of the chemical controls induce cell lysis which may cause the release of toxins into the waterbody. This could result in a discrete mortality event for a variety of species, as compared to the sustained mortalities which would occur from uncontrolled toxic HABs. These single mortality events are expected to be smaller, with regards to the number of individuals, than sustained mortality events caused by uncontrolled HABs. Controlled HABs would have a lower density of toxin producing cells and would be smaller in spatial scale, therefore reducing the amount and spread of toxin.

The effect reduced levels of DO would have on wildlife depends on the existing water quality conditions and the hydrology in the project area. If the area is already hypoxic, then the chemical control methods would not have a change on the existing environment that would affect wildlife. However, decreasing DO levels could exacerbate existing water quality problems and promote the development of hypoxic areas which would cause the relocation of motile organisms and potentially cause mortality to those organisms that cannot relocate. Again, the decrease in DO from the decomposition of a controlled bloom is expected to be both lower in intensity and smaller in scale than an uncontrolled bloom, and as such would result in the relocation and/or mortality of fewer organisms than would occur without the control method.

The use of whole barley straw would provide habitat for aquatic detritivore invertebrates which would feed upon the decomposing barley straw. These invertebrates are a valuable food source for many waterfowl and a variety of fish, which would be attracted to the project area by the increased food supply. Waterfowl may also be attracted to floating straw masses as a place to rest, forage or roost. Attraction of waterfowl to floating straw masses is not expected to cause nuisance to surrounding land use or recreational areas. Given the limited spatial scale of demonstration phase projects, the attraction of fish, waterfowl, or other wildlife to the project area is not anticipated to change the distribution of local populations nor place any stress on local food resources.

The use of whole macroalgae may attract zooplankton, fish, and other wildlife to the treatment area, both as a food source and as an area of refuge. Given the limited spatial scale of

demonstration phase projects, the attraction of fish or other wildlife to the project area is not anticipated to change the distribution of local populations nor place any stress on local food resources. The allelochemicals from whole macroalgae and isolates of those allelochemicals are also known to have algicidal and algistatic properties against phytoplankton. Their indiscriminate nature would result in the inhibition or mortality of non-target phytoplankton species. However, the use of whole macroalgae is different from the application of an allelochemical isolate over a bloom. The use of whole macroalgae works preventatively to control the size of a HAB, by inhibiting growth through nutrient competition and allelopathic interaction. Control through this means is not anticipated to result in the death of an entire bloom, rather it is expected to restrict the growth and spread of the bloom. This may temporarily reduce phytoplankton diversity in the project area; however, these effects would not be significant because phytoplankton are extremely abundant and the assemblage would return to its native composition after treatment.

In both laboratory and in situ experiments, low concentrations of hydrogen peroxide and biosurfactants have been shown to control HABs. Use of low concentrations in demonstration phase projects would preclude these chemicals from causing harm to other non-target organisms, including zooplankton and macrofauna. Concentrations which are known to result in harm to non-target species exceed those which have been observed to be effective for bloom control (Mathijs et al., 2011). Higher doses have been found to reduce both phytoplankton and zooplankton abundance, but effects to larger organisms were minimal (Burson et al., 2014). Hydrogen peroxide and biosurfactants quickly degrade into non-toxic byproducts in the aquatic environment and would no longer possess harmful properties. The low concentration used in demonstration phase projects and limited number of applications would limit impacts beyond those already occurring as a result of a HAB.

As detailed in the SEIS-APM, copper can bioaccumulate in both plants and animals. The sensitivity of a particular organism to copper varies between species and is dependent upon a number of environmental variables such as organic matter content, pH, temperature, water hardness, and initial dosage concentration. Copper can be highly toxic for a variety of species, in particular, aquatic invertebrates and salmonids. Effects to fish and other vertebrates include disruption in hormone activity, reductions in growth rate, and respiratory distress leading to mortality. The use of copper may result in mortality to those species that cannot relocate from the project area. However, given the limited spatial scale of demonstration phase projects, limited number of applications and brief residency time in the water column, mortality is not expected to be significant. In addition, the use of mitigation measures discussed in section 5.0, Mitigation and Monitoring, would preclude impacts to many aquatic organisms.

As a limiting factor for growth, the addition of dissolved silica would encourage, indiscriminately, the growth of the existing diatom community. Given that silica is naturally occurring and is required for growth, no negative impacts are expected from the application of silica.

As highlighted by a 2007 seabird mortality event in Monterey Bay, possible foam production caused by biosurfactant application may impact seabirds and other marine life. During the 2007 event, secretions from the algae *Akashiwo sanguinea* combined with wave action to produce a foam on the sea surface that impaired feather waterproofing and leading towards hypothermia and death.

Shewanella are naturally occurring marine bacteria that can be present in fish, shellfish, and seawater. *Shewanella* are found throughout aquatic environments around the world and have been shown to produce discriminate bioactive compounds with algicidal affects to dinoflagellates (Hare et al., 2005). This technique uses isolates from naturally occurring marine bacteria to control toxic dinoflagellate blooms. According to Hare et al. (2005), *Shewanella* IRI-160 had a growth-inhibiting effect on all three dinoflagellate species tested, including *P. piscicida* (potentially toxic zoospores),

Prorocentrum minimum, and *Gyrodinium uncatenum*. This bacterium did not have a negative effect on the growth of any of the other four common estuarine non-dinoflagellate species tested, and in fact had a slight stimulatory effect on a diatom, a prasinophyte, a cryptophyte, and a raphidophyte. Given that these bacteria are naturally occurring, no negative impacts are expected from the use of these isolated algicidal compounds.

Invasive Species

With the exception of the use of whole native macroalgae, none of the control methods included in the Proposed Action have the potential to introduce or promote the spread of an invasive species if proper mitigation related to the transport of materials, boats, and other equipment between water bodies, including those outlined in section 5.0, are followed. The use of whole macroalgae has been conditioned by the mitigation measures in section 5.0, Mitigation and Monitoring, to only include the use of native or naturalized species, as to eliminate any opportunity for the introduction or spread of an invasive species.

Coral Reefs

Corals are known to produce a large number of secondary metabolites. Many exhibit allelopathic effects, including inhibition of polyp activity and necrosis. The zooxanthellae that live within coral are dinoflagellates that could be inhibited by both barley straw and macroalgal isolates and be more susceptible to allelopathic effects. When stressed, such as during a HAB, corals expel the zooxanthellae that live within them. If the coral go for an extended period of time without re-taking the zooxanthellae the coral will die. The use of any of the chemical controls over a reef that has expelled its zooxanthellae could result in the mortality of these photosynthetic organisms. Although the inhibition would only be temporary, when combined with other problems facing coral reefs, these methods could result in cumulative impacts. As such, the exclusion of these control methods over coral reefs, as a means of mitigation, precludes significant impacts to coral reefs (see Section 5.1)

Benthic Environment

None of the chemical control methods described in the Proposed Action, with the exception of copper, would directly affect the benthic environment. However, after treatment, dead HAB cells would settle to the benthic environment where they would begin to decompose. Decomposing HAB cells would reduce DO and release toxins as discussed in section 4.1.2.1, Water Quality, thereby having an indirect effect on the benthic environment. Depending on the hydrodynamic conditions at the treatment site and existing water quality conditions, an accumulation of decomposing HAB cells, as a result of all chemical controls, can lead to hypoxia and the development of hydrogen sulfide toxicity. This may cause mortality for those benthos which are unable to relocate.

The use of whole macroalgae would involve floating or suspending macroalgal rafts near the water's surface where they have access to sunlight and may out compete HABs for nutrients. As discussed previously in section 4.1.2.2, Protected Species, Wildlife, Essential Fish Habitat, and Critical Habitat, this method is expected to restrict the size of a HAB and is not expected to result in the death of a bloom that would sink and cause problems in the benthic environment. This control method would be removed from the treatment area upon completion of the project and would not have an effect on the benthic environment.

The accumulation of toxic HAB cells would increase the amount of toxins in the benthic environment. This discrete deposition of toxins could be greater in concentration than would result

from natural deposition; however, the total amount of toxin is expected to be less than would naturally occur over the life of an uncontrolled bloom. The resultant mortality from this discrete event is not expected to be significant given the limited spatial scale of demonstration phase projects and in comparison to the mortality that would result over the life of an uncontrolled bloom.

Sediments are a sink for copper in the aquatic environment. The adsorption of copper onto organic particulates and sediments creates an accumulation of copper in the benthic environment which remains concentrated in upper sediments due to bacterial mechanisms (SEIS-APM, 2001). Copper does not readily desorb from sediments and given its elemental nature, copper can persist in this sediment phase indefinitely. The amount of copper accumulated in benthic sediments is variable across environments as it is dependent upon a number of factors, including organic content, particle size distribution, and pH (SEIS-APM, 2001). While the sensitivity of benthos to copper also varies widely between species, some mortality to benthos would occur. NOAA developed Sediment Quality Guidelines through its National Status and Trends Program. To mitigate the toxic effects of copper, all projects using this control method must test for background levels of copper in the sediments to ensure that the project does not exceed the established Effects Range Low (ERL) value. This value represents a concentration, below which effects are rarely observed.

Aquaculture

Development of the macroalgal control method stemmed from integrated mariculture. In these systems, macroalgae is grown with finfish to uptake and transform the nutrients from fish waste, reducing the overall nutrient content of effluent from the mariculture operation while developing an additional source of revenue. As such, the use of whole macroalgae would not have an adverse effect on aquaculture.

The low dosages of the chemical controls used in demonstration phase projects prevent mortality to many species. In addition, all of the chemical controls degrade into non-toxic byproducts and do not bioaccumulate, with the exception of copper. Copper is toxic to many organisms and does bioaccumulate; however, the use of approved copper algicides, when properly applied at the maximum allowable dosage for aquatic plant management, presents no restrictions on fish or shellfish consumption following treatment (SEIS-APM, 2001). *Shewanella* bacteria can contaminate fish and shellfish harvests, making them unpalatable for human consumption due to off-odors and off-flavors (Gram and Huss, 1996). The chemical controls would have the same effects on aquacultured organisms as they would on other organisms, as discussed in sections 4.1.2.1, Water Quality; 4.1.2.1, Protected Species, Wildlife, Essential Fish Habitat, and Critical Habitat; and 4.1.2.1, Benthic Environment. In general, demonstration phase projects within or directly adjacent to privately leased areas for aquaculture operations must coordinate with and obtain approval from appropriate stakeholders and regulators.

4.1.2.3 Cultural Environment and Tribal and Native Communities

For all physical control methods, impacts are anticipated to be minor and temporary. Given the unique nature of these resources and variation in environmental conditions between locations, the evaluation of specific impacts to these resources from physical control methods at a programmatic level would not provide any useful information to decision makers. Rather, a project-specific evaluation would be appropriate for assessing impacts to these resources. The use of flocculation or sediment resuspension could make subsistence harvesting by native communities temporarily unavailable, but these areas would already be closed to harvesting due to the presence of a HAB. Any field demonstrations occurring on tribal lands would require full coordination and collaboration with appropriate tribal entities.

4.1.2.4 Marine Protected Areas

Chemical control methods may impact Marine Protected Areas, as described in 4.1.2.1, Physical Environment and 4.1.2.2, Biological Environment. As such, the Proposed Action is generally excluded from Marine Protected Areas and known cultural and historic resource unless mitigation measures are identified through the project-specific evaluation and coordination with and approval from appropriate Federal, state, and local authorities has occurred.

4.1.2.5 Recreation

Recreational activities may be temporarily restricted from the treatment area during application of any of the chemical control methods. However, areas would not be required to be closed for any length of time after treatment and activities could resume once equipment is removed from the treatment area. In addition, none of the chemical controls are volatile, thus no effects are expected from overspray or aerial drift. In high energy environments, biosurfactants may foam at the water's surface. While these foams are naturally occurring and non-toxic, a negative aesthetic appearance may detract from recreation surrounding the treatment area. Recreational areas are often closed during a HAB event; therefore, the application of control measures would not add further impact.

4.1.2.6 Human and Child Health

At the levels used in demonstration phase projects, none of the chemical controls would have a direct impact on human health. As discussed previously in section 4.1.2.1, Water Quality, the lysing of toxic HAB cells would release toxins into the waterbody, many of which are known to cause a variety of poisoning syndromes. However, the possible one-time release of toxins from the application of a chemical control method would be less than what would be produced from a sustained bloom with uncontrolled growth. This is particularly true in the case of toxins aerosolized by wave action, which have been known to cause respiratory distress for coastal residents. An uncontrolled bloom producing such toxins can persist for weeks and affect many people, whereas the possible one-time release of toxins from a controlled bloom would be a discrete event.

Impacts to child health and safety are anticipated to be similar to those outlined previously for Human Health. Further, PCM control methods will only be demonstrated in environments that are not located near children or locations where children may recreate since HABs preclude the use of, or nearby, environments by children.

4.2 THE NO ACTION ALTERNATIVE

The No Action Alternative would inherently result in continued impacts from HABs to the environment and coastal communities and would not benefit from knowledge gained through the Proposed Action. The No Action Alternative would preclude any impacts from field demonstration projects. Under the No Action Alternative, the gap between laboratory research and testing of control methods would remain. Other existing programs would continue to focus on reducing the impacts of HABs, although they would not provide support for testing the control techniques in the environment. Research indicates some HABs may be prevented; however, prevention would likely only reduce the frequency, spatial extent, and toxicity of blooms, not eliminate them completely. If control methods, as developed by the PCMHAB Program, cannot be tested, resource managers and event responders would not have the knowledge that would be gained from environmental testing. As such, this

section evaluates the effect of HABs on the affected environment previously discussed in section 3.0, Affected Environment.

4.2.1 Physical Environment

Water Quality

HABs, like other phytoplankton species, can impact water quality by both causing and exacerbating existing water quality problems. HABs can contribute to increased turbidity by clouding the water column and increasing light attenuation due to an increase in suspended particles. Increased turbidity can result in other indirect impacts, such as increased surface water temperatures. HABs can also contribute to decreased levels of DO. For example, while high concentrations of algae can temporarily oxygenate the water column, once the algae dies, decomposition strips DO from the water. In addition, high biomass of algae can cause daily swings in oxygen, oxygenating it during the day but depleting it at night. This is also true with regards to the organisms killed by HABs, such as large fish kills. In areas already experiencing degraded water quality, large HAB events or large scale animal mortality events (such as fish kills or jubilees) can contribute to the development of hypoxia or anoxia, leaving these areas unavailable as habitat to higher organisms such as fish and shellfish. Nutrients released from decomposing HABs, or the organisms in which they kill can further exacerbate the existing HAB problem by fueling additional blooms. Some HABs can also temporarily raise and lower the pH of surrounding water, causing stress to fish and other aquatic organisms.

HABs produce a variety of toxins which can also degrade water quality. Human illness, as well as lethal and sub-lethal effects to marine mammals, sea turtles, fish, and shellfish have been attributed to these toxins and are further discussed in sections 4.2.2.3, Protected Species, Wildlife, Essential Fish Habitat, and Critical Habitat and 4.2.8, Human and Child Health. When combined with other factors contributing to the degradation of water quality, such as point source pollution and stormwater runoff, not taking steps towards achieving in situ control and implementing the No Action Alternative would result in continued impacts to water quality.

4.2.2 Biological Environment

Submerged Aquatic Vegetation

Planktonic HABs can impact SAV by restricting light penetration through the water column, subsequently preventing photosynthesis. This can prevent new growth and directly cause SAV mortality. Some HABs can cover SAV, reducing light exposure and, perhaps, restrict access to required nutrients. The death and loss of SAV can cause a host of other direct and indirect effects, including the release of nutrients into the water from decomposing SAV, loss of water column nutrient removal capacity of live SAV, and decreased erosion and sediment control functions from the loss of rooted vegetation. Nutrient release from decaying SAV and the loss of nutrient uptake that these SAV could have provided represent a potential net increase of water column nutrient concentration and a potential increase for further HABs. A decrease in sediment stability could result in resuspension of bottom sediments leading to further erosion of SAV, increased turbidity, and a further reduction in light penetration needed for photosynthesis. In addition, some epiphytes, which are plants that grow upon other plants, or in this case SAV, can bioaccumulate HAB toxins. Bioaccumulation occurs when organisms sequester toxins, or other substances, at higher concentrations than would occur in the surrounding environment. This makes the SAV toxic to organisms and provides an avenue for the transfer of HAB toxins through the food web.

Wetlands

HABs occur in open water and do not directly affect wetlands; however, HABs can impact wetlands indirectly by contributing to existing water quality problems. Decomposing organisms killed by HABs, such as large fish kills, can wash into wetlands, and depending on the water quality conditions, contribute to the development of hypoxic or anoxic areas. Many organisms use wetlands as nurseries; impacts to wetland resources could have impacts on the food chain that not only affect local wildlife but also migratory waterfowl.

Protected Species, Wildlife, Essential Fish Habitat, and Critical Habitat

At least 60 species of HABs are known to be toxic to fish. HABs can be both acutely and chronically toxic to plankton, macroinvertebrates, and vertebrates. Effects may include death, lethargy, paralysis, cell and tissue damage, as well as reductions in movement, hatching, fecundity, growth, recruitment, feeding, filtration, and protein synthesis (Landsberg, 2002). Due to the array of organisms impacted by HABs and the variety of effects, HABs can impact whole food webs (Van Dolah et al., 2001).

Some cyanobacteria produce highly neurotoxic anatoxin-a(s), which sickens and kills many vertebrates, including ducks, geese, and mice (Carmichael, 2001). The dinoflagellate *Karenia brevis* produces hemolytic and neurotoxic brevetoxin, which causes NSP and is responsible for the mortality of fish, birds, and mammals (Wang, 2008). *Pfiesteria* spp., common in shallow, eutrophic estuaries, injure and kill finfish, shellfish, mammals, and birds through both direct consumption of fish and released toxins. In 1999, *Pseudo-nitzschia australis* killed at least 100 brown pelicans in Monterey Bay, California, after the birds ate anchovies high in domoic acid produced by that diatom (Buck et al., 1992).

In addition to being acutely toxic, many HABs produce toxins which bioaccumulate and biomagnify. For example, freshwater mussels have been documented to bioaccumulate HAB toxins within their tissues over 100 times greater than toxins in the surrounding water (Miller et al., 2010). Biomagnification is what allows the toxins to impact organisms higher up the food chain. As lower order organisms such as plants, shellfish, marine mammals, fish, and possibly sea turtles bioaccumulate toxins, the higher order organisms that feed upon them, such as marine mammals, birds, and possibly sea turtles are ingesting toxins at lethal concentrations. Research shows that HAB toxins are persistent in the environment, and because of bioaccumulation and biomagnification, toxins are able to impact wildlife long after a HAB has ended (Flewelling et al., 2005; Van Dolah et al., 2001). Some HABs also have the ability to impact organisms directly through the production of foams, which reduce the waterproofing in waterfowl plumage, resulting in hypothermia and mortality (Jessup et al., 2009). Other species of HABs have morphological adaptations, such as barbed spines, which can cause wildlife mortality when ingested or inhaled (Horner et al., 1997, Glibert and Pitcher, 2005). Specific examples of species impacted by HABs can be found in Appendix E, Examples of Specific Wildlife Impacts.

Critical habitat is essential to the conservation of a particular threatened and endangered species; alteration and/or loss of that habitat could pose significant consequences to the survival and recovery of that species. Critical habitat has been identified for several species which have been impacted by HABs, and is located in areas where HABs are known to occur. EFH has been identified in areas where HABs are known to occur and for several species that have been impacted by HABs. Depending on the type of EFH present, the impacts from HABs may include those discussed in this section as well as sections 4.2.2, Submerged Aquatic Vegetation; 4.2.2, Coral Reefs; and 4.2.2,

Benthic Environment. Under the No Action Alternative, advances in HAB science would be limited and slow to develop, leaving EFH and other critical habitat at risk during future HABs.

Invasive Species

HABs may be transported to new areas via the transplanting or relocation of shellfish, and through ballast water in ships. If ecological conditions are right, as with the spread of other invasive species, the algae could grow and thrive in the new environment. Without effective means to control a bloom, the No Action Alternative may continue to indirectly facilitate the spread of invasive HABs.

Coral Reefs

HABs can impact coral reefs through direct overgrowth on the reef and by preventing sunlight from penetrating the water column. For example, blooms of the benthic cyanobacteria (*Lyngba* spp.) can form mats that cover and eventually smother coral reefs and seagrass beds (Paul et al., 2005). When stressed, corals expel the photosynthetic zooxanthellae that live within them, a phenomenon known as coral bleaching. If conditions persist and the zooxanthellae do not return to support the symbiotic relationship, the coral will starve, resulting in a reduction in the trophic diversity of the reef community.

Benthic Environment

The benthic environment is affected by HABs in the same manner as discussed in section 4.2.2, Protected Species, Wildlife, Essential Fish Habitat, and Critical Habitat. HABs also have direct effects on benthos, such as causing shell closure and reduced feeding in bivalves. The impact the HAB would have on the bivalve is dependent on both the type of bivalve and type of algae (Hegaret et al., 2007). Some bivalves close their shells when exposed to particular HABs, while others remain open. HABs can also cause a trophic mismatch between benthic filter feeders and the available food source, as each is specially adapted to filter out a specific size range of particles. Typically, when a bloom occurs it is the dominant, and sometimes the only, species present; this can result in a nutritionally inadequate food source. If the algae are too large or too small, then a feeding mismatch can occur. Even if the filter feeder is not killed directly by the bloom, it may experience effects of reduced fitness and stress from reduced feeding rates or poor food quality.

Additionally, some HAB species can produce cysts that remain in the sediments of the benthic environment and can even pass through the gut of shellfish. Under the proper environmental conditions and resuspension of benthic sediments, the cysts in the sediment and those egested by the shellfish (Hegaret et al., 2008) can germinate and populate the water column with viable algal cells. Cysts can remain dormant for years and are easily transported into new areas when resuspended in the water column.

As the bloom uses up the local supply of nutrients and dies, the organisms sink to the bottom. There, they provide another pathway for marine toxins to enter the food chain. Bottom foragers, like demersal fish and shellfish, ingest the toxins and are in turn eaten by organisms higher in the food chain. As mentioned previously, the natural decomposition of the algal cells, as well as the decomposition of organisms killed by HABs, use DO, potentially exacerbating existing water quality problems and leaving benthic environment hypoxic or even anoxic. Mobile benthic organisms may be able to relocate to more oxygen rich waters. However, the low levels of DO may be lethal for some of these organisms. Under the No Action Alternative, HABs would continue to negatively impact the benthic environment.

Aquaculture

Aquaculture, is a growing global industry. As the world's human population increases and global wild stocks of fish and shellfish decline (Pauly et al., 2002; Naylor, 2000), farmed seafood production has been steadily increasing (NMFS, 2013). Global production of farmed fish and shellfish more than doubled between 1985-2000 (Naylor et al., 2000). While aquaculture can reduce fishing pressure on wild stock, there are a number of HAB events that can cause significant impacts within aquaculture settings (Deeds et al., 2002; Chang et al., 1990). Chang et al. (1990) provides an example of the devastating impacts a HAB event can cause within an aquaculture setting. In 1989, a bloom of the toxic red tide alga *Heterosigma* in a New Zealand salmon aquaculture farm resulted in losses of approximately \$17 million (New Zealand dollars). In the Chesapeake Bay, the dinoflagellate *Prorocentrum minimum* has been responsible for aquaculture shellfish kills (Tango et al., 2005). In other situations, HABs of cyanobacteria have been known to cause off-putting flavors and odors in farmed fish (Rodgers, 2008). Yet another concern of the impact of HABs on aquaculture is the introduction of HABs into new environments through the movement of organisms from one location to another (Hegaret et al., 2008).

The economic impact of HABs on aquaculture is discussed in section 4.2.7, Environmental Justice and Socioeconomics. Under the No Action Alternative, blooms would continue to impact aquaculture operations. These industries would be forced to rely heavily on preventative and mitigation measures in order to reduce losses due to HABs.

Fisheries

A variety of fish and shellfish species are impacted by HABs. Fisheries feel these impacts when fish are killed directly by HABs or their toxins, or when toxins accumulate in fish and shellfish, causing harvesting bans. Mortality events have been documented for fishery species such as the Pacific oyster, Eastern oyster, herring, Atlantic salmon, menhaden, gar, trout, whiting, cod, and scallop (Van Dolah et al., 2000; Anderson, 2004; Anderson et al., 2008). Both farmed and wild species are affected by uncontrolled HAB occurrences due a variety of HAB species and associated toxins. An outbreak of the PSP causing species *Alexandrium fundyense* off the coast of New England prompted the closure of 40,000 square kilometers of Federal shellfish grounds in 2005 resulting in losses of over \$15 million in Massachusetts alone (Anderson et al., 2005).

Annual impacts to fisheries in U.S. dollars vary from \$13 to \$25 million with average annual impacts of \$18 million (Hoagland et al., 2002). This figure is likely grossly underestimated because not all states document the acreage closed or the value of the resource that was not harvested due to a HAB-related closure. This estimation is further complicated by the transfer of shellfishing efforts from closed areas to areas that remained open and by fishermen switching to the fishing of other species from fisheries that were not closed. In addition, the estimates do not include the value of wild fish kills or of lost opportunities for harvesting untapped shellfish resources (Anderson et al., 2000). The ultimate causes of fish kills are often unclear as state officials cannot always indicate which events were caused directly by HABs and which were due to other causes, such as low DO as a result of several variables. Under the No Action Alternative, fisheries would continue to decline and experience economic loss due to HAB occurrences.

4.2.3 Cultural Environment and Tribal and Native Communities

Many tribal and native communities have a strong relationship with coastal resources, both from a subsistence and cultural perspective. HABs, particularly those causing human health issues, can have significant impacts on native communities. For example, the Quinault Indian Nation have a

strong cultural relationship with razor clam, which are harvested from exposed tidal flats in the Pacific Northwest. Razor clams in this region are highly susceptible to harbor domoic acid, which causes amnesic shellfish poisoning (see section 4.2.8, Human and Child Health), leading to closures of shellfish beds and significant cultural and economic losses. Additionally, the Swinomish people are not able to rely on fish and shellfish at a subsistence level, as guaranteed by treaty, due to the concern over toxins in the food supply, some of which are caused by HABs (Swinomish Indian Tribal Community, 2006). Under the No Action Alternative, these quantifiable economic losses would continue.

4.2.4 Marine Protected Areas

HABs have the potential to directly and indirectly affect MPAs by negatively impacting coral reefs, spawning and nursery grounds, threatened species, and cultural resources. MPAs are specific geographical areas which contain a wide array of habitat and as such, may be impacted by HABs through the effects discussed in sections 4.2.1, Water Quality; 4.2.2, Submerged Aquatic Vegetation; 4.2.2, Wetlands; 4.2.2, Protected Species, Wildlife, Essential Fish Habitat, and Critical Habitat; 4.2.2, Coral Reefs; and 4.2.2, Benthic Environment. Under the No Action Alternative, HABs would continue to degrade the value of these aquatic resources.

4.2.5 Recreation

Due to increased light, water temperatures, and water column stability, HABs are more frequent in summer months when water-dependent recreational activities are at their peak. Human exposure to HABs can cause a wide array of health problems, detailed in section 4.2.8, Human and Child Health and as such, recreational activities such as swimming, boating, or beach walking, may be restricted during blooms. Many coastal areas have HAB response plans that would close beaches and other waterways when HABs pose a threat to human health. In Florida, for example, recurrent red tides have been estimated to cause over \$20 million in tourism-related losses every year (Anderson et al., 2000). Under the No Action Alternative, HABs would continue to directly degrade the amenity value of many of our Nation's coastal resources.

4.2.6 Land Use

The land use of a particular area can contribute to the development of HABs by warming surface waters through point source effluent releases, through changes in hydrology, or by increasing nutrient input to surrounding waters. HABs in turn can have an impact on land use, including vacation destinations, commercial fishing areas, parks, wildlife refuges, commercial shipping destinations, military operations, aquaculture sites, and educational and research sites. HABs can result in the closure of commercial fishing areas and restrictions on aquaculture sites. Fish and other organisms killed by HABs can wash ashore during and after a bloom, reducing the amenity value of beaches and other recreational areas, further resulting in socioeconomic impacts for the area, as discussed in section 4.2.7, Environmental Justice and Socioeconomics. The location of commercial shipping destinations and naval military operations may also be more prone to HABs, as ballast water is known to spread blooms to new areas. As such, land use could potentially introduce HABs to an area where they may not otherwise occur.

An emerging concern is the impact of HABs on desalination plants, which can have two effects: one, the presence of a large algal biomass can cause operational problems by fouling the reverse osmosis membranes that filter and desalinate the water; and two, the type and concentration of the toxin can determine how effective reverse osmosis membranes are at removing toxins. Due to

the uncertainty in the ability of the treatment process to remove some HAB toxins, large HAB events have caused desalination plants to shut down during blooms (Caron et al., 2010). The desalination and pretreatment process can also concentrate HAB toxins in the brine (byproduct of the desalination process). Without treatment of the brine, discharge back into the waterbody could impact the surrounding environment. Analysis for the presence of HAB toxins is costly and methods may not be available to test for all toxins. Under the No Action Alternative, advances in HAB science would be limited and slow to develop, without development of these techniques HABs may continue to impact surrounding land uses.

4.2.7 Environmental Justice and Socioeconomics

Socioeconomic impacts are those impacts on society due to an economic change. The economic ramifications of HABs have been felt nationwide, primarily due to impacts on fisheries, aquaculture, human health, and recreation/tourism. HABs cause shellfish fishery closures, wild and farmed fish mortalities, and consumer avoidance of seafood. While adverse health effects and lost sales of fishery products are direct costs, “constrained development or investment decisions in coastal aquaculture due to the threat from outbreaks of toxic algae are examples of poorly understood or poorly quantified indirect or hidden costs” (Anderson et al., 2000).

The 2008 Fisheries Economics of the U.S. report by NOAA (NMFS, 2010) indicates the commercial seafood industry in Maryland and Virginia alone contributed \$2 billion in sales, \$1 billion in income, and more than 41,000 jobs to the local economy. Fishery-associated economic losses in the Chesapeake Bay are primarily due to overharvesting and poor water quality in-part due to HABs. In one year alone, *Pfiesteria* outbreaks in the Chesapeake Bay cost Maryland fisheries and seafood markets \$43 million dollars (Lipton, 1998). It is estimated that the value of Virginia’s seafood harvest declined by 30% from 1994 to 2004 (CBF, 2012). With declines this severe, watermen in the Chesapeake Bay have had to seek alternative sources of income, often breaking from generations of tradition as a waterman.

The Chesapeake Bay region is not alone in its losses. The oyster, Dungeness crab, and razor clam fisheries in Washington are cumulatively valued at \$72 million/year for local economies and are important for commerce, recreation, and the culture of local tribes. In 2002-2003, high levels of domoic acid in razor clams along the Pacific Coast resulted in a season long closure of the fishery to protect human consumers from ASP (NOAA NCCOS, 2013). The threat of HAB toxins and population declines due to overharvesting have impacted recreational razor clam harvesting on Washington state beaches. Historically, this recreational fishery was open seven days a week for nine months a year, but this fishery has been reduced to just 15-35 days per year due to a combination of environmental impacts. Similar incidents have occurred around the country, resulting in revenue losses not only for the fishery, but also for local economies due to reduced travel. Blooms of *Karenia brevis* off the Florida coast are estimated to have an economic impact of at least \$15-\$25 million/year (Steidinger et al., 1999). Similar blooms of *Karenia brevis* off the Texas coast have been estimated to cause an economic impact of at least \$9.9 million in one county alone, due to commercial fishery closures, lost tourism, and costs of cleanup (Evans and Jones, 2001).

4.2.8 Human and Child Health

There are several exposure pathways in which human health can be impacted by HAB toxins; one of which is the inhalation of toxins aerosolized by wind and wave action. Aerosolized toxins can cause acute respiratory problems, particularly for asthmatics. In 2001, a HAB off the coast of Tampa, Florida caused a 54% increase in emergency room visits due to respiratory problems (Kirkpatrick et al., 2006). Similarly, in Sarasota County, Florida, the capitalized marginal cost of emergency room

visits for respiratory illness caused by blooms of *Karenia brevis* were estimated to be \$500 thousand to \$4 million dollars per year, depending on bloom severity (Hoagland et al., 2009).

The most well documented pathway for exposure to HAB toxins is through the consumption of contaminated fish or shellfish. Consuming contaminated fish or shellfish can result in a variety of illnesses, some of which are listed below.

- **Ciguatera fish poisoning**—Produces gastrointestinal, neurological, and cardiovascular symptoms. Generally, gastrointestinal symptoms such as diarrhea, vomiting, and abdominal pain occur first, followed by neurological dysfunction including reversal of temperature sensation, muscular aches, dizziness, anxiety, sweating, and a numbness and tingling of the mouth and digits. Paralysis and death have been documented from CFP, but symptoms are usually less severe although debilitating (Miller, 1990). CFP, the most commonly reported HABs illness globally, affects an estimated 25,000 people per year (Wang, 2008), and can be quite common in areas where people regularly consume reef fish, like the Pacific Islands. CFP occurs commonly enough in the U.S. to have prompted public health campaigns (Friedman et al., 2008).
- **Diarrhetic shellfish poisoning**—Produces gastrointestinal symptoms, usually beginning within 30 minutes to a few hours after consumption of contaminated shellfish (Woods Hole Oceanographic Institute, 2012). DSP, which is not fatal, is characterized by incapacitating diarrhea, nausea, vomiting, abdominal cramps, and chills. Recovery occurs within three days, with or without medical treatment.
- **Neurotoxic shellfish poisoning**—Produces an intoxication syndrome nearly identical to that of CFP in which gastrointestinal and neurological symptoms predominate. In addition, formation of toxic aerosols by wave action can produce respiratory asthma-like symptoms.
- **Amnesic shellfish poisoning**—Can be a life-threatening syndrome that is characterized by both gastrointestinal and neurological disorders. Gastroenteritis usually develops within 24 hours of the consumption of contaminated shellfish; symptoms include nausea, vomiting, abdominal cramps, and diarrhea. In severe cases of ASP, neurological symptoms also appear, usually within 48 hours of contaminated shellfish consumption. These symptoms include dizziness, headache, seizures, disorientation, short-term memory loss, respiratory difficulty, and coma.
- **Paralytic shellfish poisoning**—Is a life threatening syndrome. Symptoms are purely neurological and their onset is rapid. The duration of effects generally lasts a few days in non-lethal cases. Symptoms include tingling, numbness and burning of the perioral region, ataxia, giddiness, drowsiness, fever, rash, and staggering. The most severe cases result in respiratory arrest within 24 hours of consumption of the contaminated shellfish. In 1927, PSP from *Alexandrium cantenella* made 102 people sick and killed six, and episodes and toxins causing PSP have continued to be reported ever since (Wang, 2008).

HABs in freshwater reservoirs and other storage locations may provide exposure to toxins when the waters are used recreationally for boating or skiing, etc. However, direct ingestion of the toxin through contaminated drinking water is the primary pathway for exposure in these areas. Conventional water treatment methods may only be partially successful at removing HAB toxins from drinking water supplies. Developing research has illustrated additional pathways for exposure through the consumption of contaminated crops and aerosolization of toxins through spray irrigation. An agricultural operation using irrigation water from a freshwater source that is experiencing or has

experienced a HAB can transfer the toxins to the plant. Some crops are capable of taking up the toxins directly, posing a human health risk (Peuthert et al., 2007).

Human illness from eating contaminated seafood results in lost wages and workdays. Costs of medical treatment and investigation are also an important part of the economic impact caused by such events. Cases of illness and death from contaminated shellfish are probably the most clearly documented among the different types of HAB impacts, since these cases are recorded by public health agencies in individual states as well as at the Federal level. In addition, children are likely more susceptible to the impacts of HABs, given their relatively smaller body weight and high likelihood of being exposed.

It is estimated that the average public health impact due to shellfish poisoning from HABs was approximately \$22 million per year (Anderson and Hoagland, 2000). Effective state monitoring keeps infected fish products off the market, thus lowering the potential effect to human health. These figures represent approximately 45% of the total economic impacts from all causes. Under the No Action Alternative, HABs would continue to impact human health.

4.3 COMPARISON OF ALTERNATIVES

Implementation of the No Action Alternative would not bring the U.S. any closer to controlling HABs. Natural resource managers and event responders would remain limited to prevention measures for curtailing the spatial and temporal scales of HABs, and would have to rely on mitigation measures to reduce the impacts from HABs. The No Action Alternative would inherently result in continued adverse impacts to the environment.

Under the Proposed Action, the field demonstration of HAB control methods would advance research in HAB science. Table 4-1 provides a comparison by listing the direct effects HABs have on the environment, and what impact the Proposed Action would have on those effects. The effects caused by the various control methods are discussed in detail throughout section 4.1, Environmental Consequences, The Proposed Action, and listed in Appendix A. Demonstration phase projects would advance scientific knowledge and bridge the gap between laboratory and field research. As such, the Proposed Action meets the program need and objective.

Table 4-1. Impact of the Proposed Action versus the No Action Alternative on the demonstration environment

Affected Environment	No Action Alternative	Proposed Action
Submerged Aquatic Vegetation	Prevent photosynthesis; suffocate SAV; mortality; epiphyte/SAV toxicity.	The Proposed Action is excluded from use over or within 100 meters of SAV, as such there would be no change in effects from the No Action Alternative.
Water Quality	Increased turbidity; decrease in DO; increase pH; toxins.	Potential localized reduction in the turbidity caused by a HAB; decrease in the magnitude and extent of changes in DO and pH; potential to sequester and/or neutralize toxins.

Wetlands	No direct, indirect, or cumulative effects.	The Proposed Action is excluded from use on and within 100 meters of wetlands, as such there would be no change in effects from the No Action Alternative
Navigable Waters	Spread of HABs in ballast water.	Reduced potential for spread of HABs.
Wildlife	Bioaccumulation and biomagnification of HAB toxins; hypothermia; mortality.	Possible localized reduction in quantity of HAB toxins and potential neutralization of toxins; reduction in mortality for those planktonic organisms which are preyed upon by HABs.
Affected Environment	No Action Alternative	Proposed Action
Coral Reefs	Stressed coral leading to bleaching; mortality.	The Proposed Action is excluded from use over and within 100 meters of coral reefs, as such there would be no change in effects from the No Action Alternative.
Benthic Environment	Hypoxic/anoxic areas.	Potential for localized decrease in magnitude and extent of hypoxic/anoxic areas; decrease in toxin accumulation.
Aquaculture	Mitigate economic losses.	Decrease magnitude of impacts within the facility or surrounding area.
Recreation	Areas closed to recreation; exposure to toxins.	Decrease in length of localized closures; potential neutralization of toxins and decreased risk of exposure.
Human and Child Health	Illness and mortality from inhalation and ingestion of toxins.	Potential for minor reduction in the magnitude, extent and duration for potential exposure to toxins; potential neutralization of toxins.

5.0 MITIGATION AND MONITORING REQUIREMENTS

The purpose of mitigation is to avoid, minimize, or eliminate negative impacts on affected resources, to some degree. Part 1508.20 of the CEQ Regulations for Implementing the Procedural Provisions of NEPA states that mitigation includes: “avoiding the impact altogether by not taking a certain action or parts of an action; minimizing impacts by limiting the degree or magnitude of the action and its implementation; rectifying the impact by repairing, rehabilitating, or restoring the affected environment; reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; and compensating for the impact by replacing or providing substitute resources or environments.”

5.1 GENERAL MITIGATION MEASURES

The particular control method to be applied would be chosen with the particular water body and environmental conditions at the project site in mind. Only the most appropriate method after taking all of these conditions into consideration would be chosen. All field demonstrations of physical and chemical control methods are required to obtain the appropriate Federal, state, and local permits and comply with the conditions listed therein. The conditions and standards set forth by those permits act as mitigation measures; and therefore, supersede the general mitigation measures described in Table 5-1. Any material used for demonstration not naturally originating from the demonstration area/region should be cleaned and/or sterilized before use. Additional project-specific mitigation measures may be imposed as a condition of the grant award including equipment use and placement.

Table 5-1. General mitigation measures.

Potential Impacts	Mitigation Measure
Impacts to Protected Species	<p>Apply all of the above measures, as applicable:</p> <ul style="list-style-type: none"> a) Adhere to local Time of Year Restrictions. b) Use appropriate screening over the intake of water withdrawal devices to avoid organism entrainment. c) Divide the project area into sections for treatment to allow motile organisms a better chance to leave the treatment area and reduce the opportunity for hypoxia development. d) Use only the minimum amount of control necessary to achieve success. e) Use biodegradable chemicals when demonstrating a chemical control method. f) Use mitigation measures detailed in the SEIS-APM (2001), as applicable, to prevent impacts to aquatic resources from the use of copper. <ul style="list-style-type: none"> o Avoid the use of copper in waters where salmon and trout are present. Even at recommended dosage concentrations, copper is toxic to all live stages of these fish. o Avoiding the use of copper in waters with a low calcium carbonate content and low pH. Each of these variables increases the toxicity of copper. g) NOAA developed Sediment Quality Guidelines through its National Status and Trends Program. To mitigate the toxic effects of copper, all projects using this control method must test for background levels of copper in the sediments to ensure that the project does not exceed the established ERL value. This value represents a concentration, below

Potential Impacts	Mitigation Measure
	<p>which effects are rarely observed.</p> <ul style="list-style-type: none"> i) When using whole macroalgae, only use native species. j) Apply any other such measure that would preclude impacts. k) Demonstration projects will not be conducted when marine mammals or sea turtles are visually detected to be present.
Impacts to Water Quality	<p>Apply all of the above measures, as applicable, and:</p> <ul style="list-style-type: none"> a) Use turbidity curtains where necessary to limit the spread of turbid water beyond the project area. b) Practice velocity reduction techniques when depositing dredge spoils in order to precipitate solids and constrain turbidity. c) Develop disposal plans for dredged spoils, harvested cells, and HAB toxins. d) In near-shore tidal environments, only use flocculation on ebb tides to limit the effects on increased turbidity on more sensitive near shore environments. e) Do not perform sediment disturbing activities in or within 100 meters of areas known to contain contaminated sediments. f) Use biosurfactants that biodegrade into non-toxic byproducts. g) Apply any other such measure that would preclude impacts.
Impacts to EFH	<p>Apply all of the above measures, as applicable, and:</p> <ul style="list-style-type: none"> a) In near-shore tidal environments, only use flocculation on ebb tides to limit the effects on increased turbidity on more sensitive near shore environments. b) Monitor turbidity during operations, and cease operations if turbidity exceeds predetermined threshold levels. c) Use turbidity (or silt) curtains where necessary to limit the spread of turbid water beyond the project area to adjacent benthic resources. d) Design intake structures to minimize entrainment or impingement. Use velocity caps that produce horizontal intake/discharge currents and ensure that intake velocities across the intake screen do not exceed .5 feet (.15 meter) per second. Intake of water withdrawal impacts to eggs or minimize entrainment of native fauna e) To the extent possible, conduct research during the time of year when it will have the least impact on sensitive habitats and species critical life stages (e.g. spawning, and egg, embryo, and juvenile development). For more information about species time restrictions contact your regional EFH coordinator(http://www.habitat.noaa.gov/protection/efh/regionalcontacts.html).
Impacts to Human Health	<p>Apply all of the above measures, as applicable, and:</p> <ul style="list-style-type: none"> a) Characterize contaminated soils and develop a mitigation plan for their use, isolation, treatment or disposal. b) Temporarily restrict access to the project area. c) Use deflectors to avoid overspray of chemical controls. d) Apply any other such measure that would preclude impacts.
Impacts to the Benthic Environment	<p>Apply all of the above measures, as applicable, and:</p> <ul style="list-style-type: none"> a) Maintain a shallow angle for the slope of the walls in sediment removal areas to assist in benthos recolonization. b) Use sediments of similar grain size and composition. All sediments used in HAB control methods should be free of toxins and foreign material in accordance with state and federal limits. c) Apply any other such measure that would preclude impacts.

Potential Impacts	Mitigation Measure
Impacts to Aquaculture	Apply all of the above measures, as applicable, and: a) Obtain approval from pertinent stakeholders and regulatory agencies. b) Apply any other such measure that would preclude impacts.

As a means of mitigation, projects occurring in or within 100 meters to several resource areas are excluded from field demonstration of PCMHAB methods. All projects will be required to supply information (e.g., resource location maps and/or other supporting information) that proposed demonstration locations are not within or 100 meters to these excluded resource areas. Note, demonstrations outside of 100 meters of critical resources should be conducted such that tides, currents, winds, and/or waves do not transport PCM method materials to the areas below. Resource areas excluded are:

- Coral Reefs;
- Bird nesting areas;
- Sea turtle nesting beaches while turtles are present;
- Cultural and Historic Resources;
- Wetlands, and;
- SAV beds.

Marine Protected Areas, Wilderness Areas, and Designated Critical Habitat Areas are generally excluded, absent specific approvals and required permits from appropriate Federal, state, and local authorities. All projects will still be required to supply information, such as resource location maps and/or other supporting information.

5.2 MONITORING REQUIREMENTS

- All projects must analyze zooplankton and phytoplankton abundance and density pre- and post-treatment, as well as record details on the spatial extent of the bloom, cell density, and toxin concentration.
- All projects must record water quality and hydrology parameters pre- and post-treatment. Parameters include, but are not limited to temperature, pH, turbidity, DO, total nitrogen, total phosphorus, calcium carbonate, conductivity, current direction and speed, and flow regime.
- All projects must determine the abundance and composition of the benthic community pre- and post-treatment.
- All projects using chemical control methods must test after treatment to ensure desired chemical levels were achieved.
- Those projects which require project-specific mitigation would require monitoring to ensure mitigation is successful.
- Projects demonstrating sediment resuspension in areas of unknown sediment contamination are required to do an initial screening for legacy industrial compounds, metals, and pesticides in consultation with state or local regulatory agencies. These compounds include, but are not limited to, DDT, lindane, PCBs, PAHs, mercury, and lead.

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APPENDIX A—SUMMARY OF THE EFFECTS FROM THE PROPOSED ACTION

PHYSICAL CONTROL METHODS

	Flocculation	Sediment Burial, Resuspension, and Removal	Cell Harvesting	Water Column Mixing
Submerged Aquatic Vegetation	<ul style="list-style-type: none"> • Sedimentation preventing photosynthesis • HAB cell decay leading to hypoxia, anoxia, and hydrogen sulfide toxicity resulting in mortality • Temporary turbidity increase inhibiting photosynthesis 	<ul style="list-style-type: none"> • Uproot and/or burial • Turbidity inhibiting photosynthesis • Temporary turbidity increase inhibiting photosynthesis 		<ul style="list-style-type: none"> • Benthic withdrawal- increased turbidity and change in localized water circulation patterns
Water Quality	<ul style="list-style-type: none"> • Temporary turbidity increase • Nutrient increase/decrease from flocculants and decomposing HAB cells • HAB cell decay leading to hypoxia, anoxia, and hydrogen sulfide toxicity resulting in mortality 	<ul style="list-style-type: none"> • Temporary turbidity increase • Decrease nutrient concentration/transformation at sediment-water interface • Release of contaminants/heavy metals/toxins 	<ul style="list-style-type: none"> • Alter nutrient concentrations by changing phytoplankton community make up temporarily 	<ul style="list-style-type: none"> • Vertical Mixing—isothermal conditions with uniform salinity, nutrients, and dissolved oxygen • Activities with benthic withdrawal activities increase turbidity • Horizontal Mixing—increased DO in surface waters
Wetlands	<ul style="list-style-type: none"> • Indirect through water quality effects 	<ul style="list-style-type: none"> • Indirect through water quality effects 	<ul style="list-style-type: none"> • Indirect through water quality effects 	<ul style="list-style-type: none"> • Indirect through water quality effects
Wildlife	<ul style="list-style-type: none"> • Reduced clearance rates and reduced shell and tissue growth in bivalves • Coughing in fish • Decreased feeding activity of visual foragers • Entrainment of non-target plankton • Indirect through water quality effects 	<ul style="list-style-type: none"> • Attraction of fish to treatment area due to suspended macroinvertebrates • Capture and burial of non-target species resulting in mortality • Loss of prey species and decrease in benthic diversity • Indirect through water quality effects 	<ul style="list-style-type: none"> • Entrain non-target species resulting in mortality 	<ul style="list-style-type: none"> • Vertical Mixing—isothermal conditions resulting in discontinuity in thermal refuge • Vertical Mixing—buoyancy disruption of non-target phytoplankton
Coral Reefs	<ul style="list-style-type: none"> • Sedimentation/turbidity preventing photosynthesis 	<ul style="list-style-type: none"> • Sedimentation/turbidity preventing photosynthesis • Abrasion of coral • Removal or burial of coral 	<ul style="list-style-type: none"> • Removal of zooxanthellae • Removal or damage to coral • Removal of food source 	<ul style="list-style-type: none"> • Activities with benthic withdrawal activities increase turbidity and change in localized water circulation patterns
Benthic Environment	<ul style="list-style-type: none"> • HAB cell decay leading to hypoxia, anoxia, and hydrogen sulfide toxicity resulting in mortality • Bioavailability of sequestered toxins, trophic transport • Indirect through water quality effects • Accumulation of flocked HABs • Burial of sessile organisms 	<ul style="list-style-type: none"> • Resuspension of interred cysts which are more toxic; initiate bloom • Burial of sessile organisms 		<ul style="list-style-type: none"> • Activities with benthic withdrawal activities increase turbidity and change in localized water circulation patterns
Aquaculture	<ul style="list-style-type: none"> • Same as discussed in SAV, wildlife, and benthic environment • Indirectly through water quality 	<ul style="list-style-type: none"> • Resuspension of nutrients, antifouling paint/trace metals, biosolids, and biocides • Same as discussed in SAV, wildlife, and benthic environment • Indirectly through water quality • Temporary turbidity increase 	<ul style="list-style-type: none"> • Removal of beneficial phytoplankton/ food source species • Increased turbidity and potential for sedimentation 	<ul style="list-style-type: none"> • Activities with benthic withdrawal activities have same effect as burial and resuspension
Recreation	<ul style="list-style-type: none"> • Placement of equipment within waterbody 	<ul style="list-style-type: none"> • Placement of equipment within waterbody 	<ul style="list-style-type: none"> • Placement of equipment within waterbody 	<ul style="list-style-type: none"> • Placement of equipment within waterbody
Human Health		<ul style="list-style-type: none"> • Possible resuspension of contaminants into the water column 		<ul style="list-style-type: none"> • Benthic withdrawal- resuspension of trace metals and biocides below aquaculture- health effects

CHEMICAL CONTROL METHODS

	Macroalgal Isolates & Whole Macroalgae	Barley Straw	Copper	Hydrogen Peroxide	Biosurfactants	Isolated Algicidal Compounds	Silica	
Submerged Aquatic Vegetation	<ul style="list-style-type: none"> HAB cell decay leading to hypoxia, anoxia, and hydrogen sulfide toxicity resulting in mortality 	<ul style="list-style-type: none"> HAB cell decay leading to hypoxia, anoxia, and hydrogen sulfide toxicity resulting in mortality 	<ul style="list-style-type: none"> Bioaccumulation in plant and roots HAB cell decay leading to hypoxia, anoxia, and hydrogen sulfide toxicity resulting in mortality 	<ul style="list-style-type: none"> HAB cell decay leading to hypoxia, anoxia, and hydrogen sulfide toxicity resulting in mortality 	<ul style="list-style-type: none"> HAB cell decay leading to hypoxia, anoxia, and hydrogen sulfide toxicity resulting in mortality 	<ul style="list-style-type: none"> HAB cell decay leading to hypoxia, anoxia, and hydrogen sulfide toxicity resulting in mortality 	<ul style="list-style-type: none"> HAB cell decay leading to hypoxia, anoxia, and hydrogen sulfide toxicity resulting in mortality 	
Water Quality	<ul style="list-style-type: none"> Cell lysis- release toxins Increase in nutrients from decomposing or lysed HAB cells HAB cell decay leading to localized/short-term hypoxia/anoxia 	<ul style="list-style-type: none"> Increased turbidity from soluble organic compounds Cell lysis- release toxins Increase in nutrients from decomposing or lysed HAB cells HAB cell decay leading to localized/short-term hypoxia/anoxia 	<ul style="list-style-type: none"> Water soluble heavy metal/toxin Cell lysis- release toxins Increase in nutrients from decomposing or lysed HAB cells HAB cell decay leading to localized/short-term hypoxia/anoxia 	<ul style="list-style-type: none"> Cell lysis- release toxins Increase in nutrients from decomposing or lysed HAB cells HAB cell decay leading to localized/short-term hypoxia/anoxia 	<ul style="list-style-type: none"> Cell lysis- release toxins Increase in nutrients from decomposing or lysed HAB cells HAB cell decay leading to localized/short-term hypoxia/anoxia 	<ul style="list-style-type: none"> Cell lysis- release toxins Increase in nutrients from decomposing or lysed HAB cells HAB cell decay leading to localized/short-term hypoxia/anoxia 	<ul style="list-style-type: none"> Indiscriminate growth of existing diatom community Cell lysis- release toxins Increase in nutrients from decomposing or lysed HAB cells HAB cell decay leading to localized/short-term hypoxia/anoxia 	
Wetlands	<ul style="list-style-type: none"> Indirectly through water quality 	<ul style="list-style-type: none"> Indirectly through water quality 	<ul style="list-style-type: none"> Indirectly through water quality 	<ul style="list-style-type: none"> Indirectly through water quality 	<ul style="list-style-type: none"> Indirectly through water quality 	<ul style="list-style-type: none"> Indirectly through water quality 	<ul style="list-style-type: none"> Indirectly through water quality 	
Navigable Waters	<ul style="list-style-type: none"> Placement of equipment 	<ul style="list-style-type: none"> Placement of equipment 	<ul style="list-style-type: none"> Transport from treatment area Placement of equipment 	<ul style="list-style-type: none"> Placement of equipment 	<ul style="list-style-type: none"> Placement of equipment 	<ul style="list-style-type: none"> Placement of equipment 	<ul style="list-style-type: none"> Placement of equipment 	
Wildlife	<ul style="list-style-type: none"> Kill non-target phytoplankton Release of toxins cause mortality HAB cell decay leading to hypoxia/anoxia resulting in mortality Attract zooplankton, fish and other wildlife as food source and refuge Inhibit growth of non-target phytoplankton 	<ul style="list-style-type: none"> Bales provide habitat for aquatic invertebrates which attract fish and waterfowl Waterfowl may roost on straw masses Release of toxins cause mortality HAB cell decay leading to hypoxia/anoxia resulting in mortality Kill non-target phytoplankton 	<ul style="list-style-type: none"> Toxic to non-target organisms- disruption in hormone activity, reduction in growth rate, respiratory distress Release of toxins cause mortality HAB cell decay leading to hypoxia/anoxia resulting in mortality 	<ul style="list-style-type: none"> Release of toxins cause mortality HAB cell decay leading to hypoxia/anoxia resulting in mortality 	<ul style="list-style-type: none"> Release of toxins cause mortality HAB cell decay leading to hypoxia/anoxia resulting in mortality 			<ul style="list-style-type: none"> Indiscriminate growth of existing diatom community
Coral Reefs	<ul style="list-style-type: none"> Inhibit zooxanthellae 	<ul style="list-style-type: none"> Inhibit zooxanthellae 	<ul style="list-style-type: none"> Inhibit zooxanthellae 	<ul style="list-style-type: none"> Interferes with retake of zooxanthellae 	<ul style="list-style-type: none"> Interferes with retake of zooxanthellae 	<ul style="list-style-type: none"> Interferes with retake of zooxanthellae 	<ul style="list-style-type: none"> Interferes with retake of zooxanthellae 	

	Macroalgal Isolates & Whole Macroalgae	Barley Straw	Copper	Hydrogen Peroxide	Biosurfactants	Isolated Algicidal Compounds	Silica
Benthic Environment	<ul style="list-style-type: none"> HAB cell decay leading to hypoxia/anoxia and hydrogen sulfide toxicity resulting in mortality to benthos Accumulation of toxic HAB cells increased toxins in benthic environment 	<ul style="list-style-type: none"> HAB cell decay leading to hypoxia/anoxia and hydrogen sulfide toxicity resulting in mortality to benthos Accumulation of toxic HAB cells increased toxins in benthic environment 	<ul style="list-style-type: none"> HAB cell decay leading to hypoxia/anoxia and hydrogen sulfide toxicity resulting in mortality to benthos Accumulation of toxic HAB cells increased toxins in benthic environment Aquatic sediments a sink for copper 	<ul style="list-style-type: none"> HAB cell decay leading to hypoxia/anoxia and hydrogen sulfide toxicity resulting in mortality to benthos Accumulation of toxic HAB cells increased toxins in benthic environment 	<ul style="list-style-type: none"> HAB cell decay leading to hypoxia/anoxia and hydrogen sulfide toxicity resulting in mortality to benthos Accumulation of toxic HAB cells increased toxins in benthic environment 	<ul style="list-style-type: none"> HAB cell decay leading to hypoxia/anoxia and hydrogen sulfide toxicity resulting in mortality to benthos Accumulation of toxic HAB cells increased toxins in benthic environment 	<ul style="list-style-type: none"> HAB cell decay leading to hypoxia/anoxia and hydrogen sulfide toxicity resulting in mortality to benthos Accumulation of toxic HAB cells increased toxins in benthic environment
Aquaculture	<ul style="list-style-type: none"> Same as discussed in wildlife, benthic environment, and water quality 	<ul style="list-style-type: none"> Same as discussed in wildlife, benthic environment, and water quality 	<ul style="list-style-type: none"> Toxic and bioaccumulates Same as discussed in wildlife, benthic environment, and water quality 	<ul style="list-style-type: none"> Same as discussed in wildlife, benthic environment, and water quality 	<ul style="list-style-type: none"> Same as discussed in wildlife, benthic environment, and water quality 	<ul style="list-style-type: none"> Bacteria contaminates fish and shellfish harvests Same as discussed in wildlife, benthic environment, and water quality 	<ul style="list-style-type: none"> Same as discussed in wildlife, benthic environment, and water quality
Recreation	<ul style="list-style-type: none"> Recreation temporarily restricted from treatment area 	<ul style="list-style-type: none"> Recreation temporarily restricted from treatment area 	<ul style="list-style-type: none"> Recreation temporarily restricted from treatment area 	<ul style="list-style-type: none"> Recreation temporarily restricted from treatment area 	<ul style="list-style-type: none"> May cause foaming in high energy environments Recreation temporarily restricted from treatment area 	<ul style="list-style-type: none"> Recreation temporarily restricted from treatment area 	<ul style="list-style-type: none"> Recreation temporarily restricted from treatment area
Human Health	<ul style="list-style-type: none"> Lysed cells release toxins causing respiratory distress and poisoning syndromes 	<ul style="list-style-type: none"> Lysed cells release toxins causing respiratory distress and poisoning syndromes 	<ul style="list-style-type: none"> Lysed cells release toxins causing respiratory distress and poisoning syndromes 	<ul style="list-style-type: none"> Lysed cells release toxins causing respiratory distress and poisoning syndromes 	<ul style="list-style-type: none"> Lysed cells release toxins causing respiratory distress and poisoning syndromes 	<ul style="list-style-type: none"> Lysed cells release toxins causing respiratory distress and poisoning syndromes 	<ul style="list-style-type: none"> Lysed cells release toxins causing respiratory distress and poisoning syndromes

APPENDIX B—LIST OF RECIPIENTS

- Department of Agriculture, Natural Resources Conservation Service
- Department of Agriculture, Agriculture Research Service
- Department of Agriculture, Forest Service
- Department of Agriculture, Farm Service Agency
- Department of Agriculture, National Institute of Food and Agriculture
- Department of Agriculture, Animal and Plant Health Inspection Service
- Health and Human Services, National Institutes of Health
- Health and Human Services, Indian Health Service
- Health and Human Services, Centers for Disease Control and Prevention
- Health and Human Services, Federal Drug Administration Center for Veterinary Medicine
- Health and Human Services, Federal Drug Administration Center for Food Safety and Applied Nutrition
- Health and Human Services, Health Resources Service Administration
- National Science Foundation
- Advisory Council on Historic Preservation
- Department of Transportation, Maritime Administration
- National Aeronautics and Space Administration
- Department of Interior, National Park Service
- Department of Interior, Bureau of Indian Affairs
- Department of Interior, US Fish and Wildlife Service
- Department of Interior, Bureau of Land Management
- Department of Interior, Bureau of Ocean and Energy Management
- Department of Interior, US Geological Survey
- Department of Interior, Office of Environmental Affairs
- Department of Interior, Bureau of Safety and Environmental Enforcement
- Department of Interior, Bureau of Reclamation
- Federal Energy Regulatory Commission
- Department of Defense, Department of Army
- Department of Defense, Army Corps of Engineers
- Department of Defense, Department of Navy
- Marine Mammal Commission
- Nuclear Regulatory Commission
- Federal Maritime Commission
- Council on Environmental Quality
- State Department
- Department of Homeland Security, US Coast Guard
- Environmental Protection Agency
- Department of Justice, Environmental and Natural Resources Division
- National Harmful Algal Bloom Research and Management list serve maintained by the U.S. National Office for Harmful Algal Blooms

APPENDIX C—COMMENTS ON DRAFT PCMHAB PEA

Comment	Response
The DEIS references a 2009 paper by colleagues and myself on p. 40, section 4.2.8. At the end of the first paragraph, there is a reference to illness costs due to K. Brevis blooms of \$500 thousand to \$4 million per year. This is incorrect. Those figures represent the estimated range of capitalized costs, i.e., the discounted sum of annual illness costs, assuming that observed costs occur annually in perpetuity. The annual costs are on the order of \$20-140 thousand (2014 dollars).	Changed text to reflect 'capitalized marginal costs'
I have attached a recent paper with colleagues that takes a look at illness costs due to Florida red tides in the broader southwest Florida region. You may wish to reference estimates from that paper in addition to or in lieu of the 2009 paper. Annual illness cost estimates for the southwest FL region range from \$60-700 thousand; capitalized costs range from \$2-24 million.	No Change
Additional HAB control technologies are feasible and should be included in the Final EA. Attached is a white paper that elaborates on our comments and provides further details for these additional HAB control technologies. In the final EA, the water column mixing alternative should be expanded to include all water bodies including all marine coastal areas and open water; not just enclosed or semi-enclosed water bodies.	Changed to 'suitable' to 'often used for'; note: research is not limited to closed or semi-enclosed' water bodies
Additional HAB control technologies are feasible and should be included in the Final EA. Attached is a white paper that elaborates on our comments and provides further details for these additional HAB control technologies. In the final EA, the water column mixing alternative should be expanded to include all techniques and technologies for controlling HABs through the manipulation of water salinity, temperature, and stratification (as identified in the attached paper).	Water column mixing changes salinity, temperature, and stratification and thus are already included in the PEA
Additional HAB control technologies are feasible and should be included in the Final EA. Attached is a white paper that elaborates on our comments and provides further details for these additional HAB control technologies. The final EA should include technologies that manipulate light intensity as a physical control alternative.	No Change. Considered and not included due to practicality and lack of testing on possible environmental effects. Added appropriate text to section 2.3
I have no major criticisms of the document but do wonder how certain strategies came to be listed whereas others were not. I have concerns about the safety or rationale of a few of the methods	Selection of PCM strategies included in the PEA was based on several criteria that included readiness for field demonstration, current use in private algal control, need for environmental

<p>listed (e.g., copper, silica) and wonder why others were removed from the Proposed Action. For example, the PEA states that cysteine pre-treatment is not considered for the proposed action because of lack of field-readiness – but I am not convinced that each of the other methods (e.g., some allelochemicals) has had more lab testing than cysteine. Moreover, I wonder if it should be included given the lag between the draft document and funding period.</p>	<p>assessment, and likelihood of requiring an environmental impact statement. Cysteine treatments were determined to not require an environmental assessment and could be included in future PCMHAB projects. Readiness for field demonstration includes those methods not currently ready, but likely to be in next five years. If other methodologies become 'field-ready' then a supplemental PEA would be created in order to include those techniques</p>
<p>I also require clarification regarding the discussion of shellfish breeding as a mitigation strategy (p. 12). Is this an area that PCM HAB would fund? It is an area I have strong interest in (and potential collaborators).</p>	<p>Yes. Already part of existing HAB research funding program.</p>
<p>Specifically recommend the following techniques be included in the EA as physical control alternative:</p>	
<ul style="list-style-type: none"> • Floating water pumping units in environments with a stratified water column 	<p>No change. Covered as part of the water column mixing sections of the PEA</p>
<ul style="list-style-type: none"> • Floating closed-loop systems that circulate either heated or cooled water (or other fluids) 	<p>No change. Significant environmental concerns with manipulating thermal characteristics</p>
<ul style="list-style-type: none"> • Floating underwater arrays of banks of light connected to boats or work barges (a light shocking technology) 	<p>Light intensity manipulation added to table 2.2</p>
<ul style="list-style-type: none"> • Floating desalinization plants 	<p>No change. Significant environmental concerns and impractical</p>
<p>I sincerely hope you will accept this request and include it in the parameters in your work with HABS. We believe this mitigation approach offers the best options to address the harmful impacts of red tide in a responsible environmental way. (Editor’s Note: this comment is in reference to the previous comments on inclusion of water circulation and light banks)</p>	<p>See responses to above comments</p>
<p>We recommend the document better explain the role of this work with freshwater blooms. Will only marine events be addressed with this proposed work? Will there be similar work done for the Great Lakes? There are high profile HABs in Lake Erie that could be addressed more specifically to give this document some Great Lakes currency.</p>	<p>No change needed. Introductory text states work is in US coastal waters and the Great Lakes. Other freshwater systems are not in the purview of NOAA</p>
<p>Recommend the document better address/explain the technologies that are specific to cyanobacterial</p>	<p>Additional text on cyanobacterial blooms included under appropriate methodologies,</p>

blooms.	Added information on cyanobacterial blooms to pg 1
Page 1, Line 46 – Red tides are only one form of Harmful Algal Blooms; the two terms are not synonymous.	Colloquial term, but added references to brown, green, and mahogany tides
Page 1, Line 47 – Harmful Algal Blooms can result from both marine and freshwater algae.	Deleted 'microscopic marine' on page 1
Page 2, Line 15 – This study on economic effects refers only to marine effects: important to distinguish.	added 'coastal'... waters
Page 2, Line 28 – Climate change is also a major driving factor worth including.	added 'climate change' pg 2
Page 3 – Summary of Key Compliance Requirements: add Executive Order National Ocean Policy, Executive Order on Invasive species, Marine Mammal Protection Act, Wilderness Act.	Added NOP E.O., Invasive Species E.O., MMPA, and Wilderness Act to Section 1. Text regarding wilderness areas addressed in new text in Section 1, Wilderness Act. Additionally added marine mammal & Wilderness area mitigation text to Chapter 5.
Page 6, Section 1.5 – Add section on consultation with DOI before testing methods to avoid potential effects to wildlife refuges, national monuments, national trails (including water trails), and national parks.	No Change. DOI covered in existing text, no need to single out 1 agency and not the others.
Page 7, Physical control methods – Need assurances that non-native species including bacteria and virus are not introduced by offsite materials such as flocculation materials (clay) or other foreign matter.	Clarified text in Chapter 5 Mitigation and Monitoring
Page 9, Native Macroalgae – Need language to assure that there are no indirect long-term effects of changing algal communities by introduction of native macroalgae.	Clarified text in Chapter 5 Mitigation and Monitoring
Page 8, Line 21 – Need to define and quantify ‘clean and free of toxins’ including minimum detection level and what toxins must be tested for; ‘of similar grain size’ needs to be quantified.	Clarified text in Chapter 5 Mitigation and Monitoring
Page 9, Paragraph following Line 12 – Insert language stating for introduction to a water body or area, organisms must be verified to be native to target area.	Clarified text in Chapter 5 Mitigation and Monitoring
Page 17; 3.2.8 – Add state fisheries	State fisheries are already covered, see pg 17
Page 17; 3.3. – Add potential negative effects to wilderness waters/shorelines, “soundscape,” and “dark night skies.”	Added text to Sections 3 & 4 regarding noise and aesthetics & visual resources (includes 'dark night skies')
Page 18; 3.4 Marine Protected areas – Include DOI MPAs (see MPA website with list) including National Parks, Wildlife Refuges, BLM coastal lands and monuments.	Description of DOI managed lands added and referenced.
Page 20, Line 7 – Contact (ie, via aerosolized particle contact with mucous membranes such as eyes) is another route through which HABs can exert negative impacts on human health	Added text regarding mucous members and physical contact. See Section 3.9, pg 20
P 20; 3.10 Child Health. – “While some HAG control measures might adversely impact child health, neither project activities nor potential minor and transitory environmental impacts are in proximity of areas where children congregate; therefore this project does not pose a hazard to child health.” The congregation of	Section 3.10, included examples of areas 'where children' congregate' per language in EPA memo of 8.14.12, Addressing Children's Health through Reviews Conducted Pursuant to the National Environmental Policy Act and Section 309 of the Clean Air Act

children is not needed for impacts to be felt. Please clarify a few points: 1) If the areas will be selected based on where waters are suffering severe ecological harm, how do we know it won't be in an area where children congregate?; 2) How is "where children congregate" defined?; and 3) How far from an area of where children congregate is acceptable? Please define where n congregate is acceptable? Please define where and when these actions can be used.	
P. 23; Submerged Aquatic Vegetation Lines 24-25 – This could be an issue at low tide in shallow waters. Will activities only occur at high tide in these areas?	Since methods are not being conducted over SAV beds (see Chapter 5), the tidal state is irrelevant
Page 23; Protected Species – Provide more information on the potential affected environment including birds and sensitivity of feathers; furred mammals such as sea otters; fish to chemicals ingested etc. This section seems incomplete	Added text in Sections 3, 4, and 5 to specifically address birds and non-marine mammal furred mammals.
Page 24; line 32 – Add federal to list of appropriate agencies for site-specific projects including national parks, wildlife refuges etc.	Changed 'USFWS' to broader 'DOI'
Page 25; Invasive Species – Add hitch hikers to pathways of introduction. Some of the offsite materials could carry hitch hikers including bacteria, fungi, or virus.	See text Chapter 5
Page 26; Line 15 – Fish mortality is not the only measure of negative effects. If the fitness of the fish is reduced and reproduction is affected, then this should be stated.	Added text to include transitory and sublethal fish impacts
Page 26; 4.1.1.3 – Add to cultural resources list water trails, dark night skies, and soundscapes as potential cultural resources to be checked for site specific information.	No change needed here, cited in appropriate section in Affected Environment
Page 27; 4.1.1.4 – MPAs should be defined to include National Parks, Wildlife Refuges, and BLM coastal lands. See MPA Center website for a partial list of MPAs in the nation.	MPA's defined in Section 3.4, include requested organizations
Page 27, Line 32 – Ensure 'free of toxins' is defined elsewhere in document and minimum standards are established for what toxins must be tested for.	See Chapter 5 table, toxins defined in accordance with state and federal limits
Page 30; Protected species – Provide more information on the potential effects on birds and sensitivity of feathers; furred mammals such as sea otters; and fish to chemicals ingested etc. This section seems incomplete.	Added text in Sections 3,4, and 5 to specifically address birds and non-marine mammal furred mammals.
Page 31; Invasive species. – Discussion of potential introduction of bacteria, fungus, or virus from offsite materials should be presented before stating that there is no potential for introduction of non-native species.	See Chapter 5
Page 33; 4.1.2.3 – same as 4.1.1.3	See Chapter 5
Page 33; 4.1.2.4 – same as 4.1.1.4	See Chapter 5
Page 35, Wetlands – HABs can also occur in large estuaries adjacent to wetlands.	No Change, 'Open water' includes large estuaries

Page 35, Line 36 – Appendix with list of species and where they occur would be helpful. Good coverage with references of existing effects of HABs. Add indirect effects of HABs bioaccumulation in California sea lions which flood beaches in hundreds when ill from HABs in southern California. Gulland, F. M. D., Haulena, M., Fauquier, D., Langlois, G., Lander, M. E., Zabka, T., & Duerr, R. (2002). Domoic acid toxicity in Californian sea lions (<i>Zalophus californianus</i>): Clinical signs, treatment and survival. <i>Veterinary Record</i> , 150, 475-480.	List exists, see Appendix E. HAB bioaccumulation already covered in App E
Page 36, Coral Reefs – Corals are additionally stressed by HAB combined with high temperatures that also cause coral bleaching.	Recognized, no change
Page 37, Aquaculture – Question if aquaculture globally is a source for introduction of HABs by hitch hikers?	Not covered by this PEA
Page 38, Fish – Bioaccumulation through food web includes weak fish eaten by marine birds and mammals that are then sickened and die. Perhaps a foodweb section to explain this broad scale effect.	Food web discussion already exists, see Section 4.2.6 Protected Species, Wildlife, and Critical Habitat, pg 37, line 2-15
Page 38, 4.2.4 – same as 4.1.1.4	See Chapter 5
Page 39, Land use – Add national parks.	Changed text to include 'parks
Page 41, Line 38 – This does not consider the decrease in HABs anticipated from prevention measures. Amend appropriately.	There are no current mitigation activities in the coastal environment of which we are aware
Page 42 – All of the no action alternatives assume no impact or effect from concurrent prevention measures and initiatives. Amend and qualify appropriately.	There are no current mitigation activities in the coastal environment of which we are aware
Page 42, Table 4-1. Under Proposed Action for several treatments (coral, SAV, wetlands, MPAs, etc.), a distance of 100 meters seems insufficient as a buffer distance because currents may move water mass in direction of sensitive habitats/species. Ballast water should not be released in bays or nearshore to reduce potential introduction of invasive species. Wildlife – Potential introduction of invasive species	Added text to Chapter 5 such that demonstration projects are not carried out such that wind, waves, currents, tides, etc could transport method materials to the excluded resources
Page 44, Table 5; i) – not use naturalized species in sensitive habitat or MPAs – non-native species should be avoided.	Correct, text changed to clarify
Page 44, Table 5-1. Add mitigation measure of not testing methods in MPAs (including National Parks, Wildlife Refuges, Wilderness, Sanctuaries etc.). Add weather restrictions	Additional mitigation measures for work in MPAs covered by necessary permits. Weather restrictions covered by wind, wave, etc. in transport statement
Page 44, line 6 – 100 m is insufficient buffer if currents move water mass in direction of sensitive species or habitats.	No Change. See above referenced transport statement
Page 46 – How long would monitoring be continued? Provide a series of levels of monitoring – intense in short term and then later at longer time period and simpler sampling.	Monitoring time varies by technique and location; it will be evaluated during the proposal review to ensure there is no significant impact
Page D63 – California sea lion – Correct spelling of	Corrected spelling of domoic acid. Added text

domoic acid (demon-like but not spelled that way!). This is now a regular occurrence not just in 1998. See more recent articles. Also documented in harbor porpoise in central California. Gulland, F. M. D., Haulena, M., Fauquier, D., Langlois, G., Lander, M. E., Zabka, T., & Duerr, R. (2002). Domoic acid toxicity in Californian sea lions (*Zalophus californianus*): Clinical signs, treatment and survival. *Veterinary Record*, 150, 475-480.

Gulland, F. 2000. Domoic acid toxicity in California sea lions (*Zalophus californianus*) stranded along the central California coast, May-October 1998. Report to the National Marine Fisheries Service Working Group on Unusual Marine Mammal Mortality Events. U.S. Dep. Cornmer., NOAA Tech. Memo. NMFS-OPR-17, 45 p.

Greig, D.J., F. Gulland and C. Kreuder. 2005. A Decade of Live California Sea Lion (*Zalophus californianus*) Strandings Along the Central California Coast: Causes and Trends, 1991-2000 *Aquatic Mammals* 2005, 31(1), 11-22, DOI 10.1578/AM.31.1.2005.11

Greig et al. 2005 noted that “Strandings from domoic acid toxicity appear to have increased dramatically over the ten years of this study. Although first documented in marine mammals in 1998 (Scholin et al., 2000), the clinical signs in animals stranded in 1991 and 1992 suggest that sea lions were affected before this date. On the time scale of this study, the severity of the domoic acid events seems to be increasing.”

regarding this is now a regular occurrence. Did not add the harbor porpoise information as App D is a representative, not inclusive, list of HAB impacts on species.

APPENDIX D—SPECIFIC HAB SPECIES AND THEIR DISTRIBUTION

Some of the specific types of the more common HABs and their locations are summarized below.

- ***Pseudo-nitzschia species (spp.)***—Several species of the diatom genus *Pseudo-nitzschia* produce domoic acid, which is known to cause amnesic shellfish poisoning (ASP) in humans when contaminated shellfish is consumed. Species of this genus can be found worldwide, with toxic species having been documented on the northeast coast of Canada, off the coast of North Carolina, in the Gulf of Mexico, and on the Pacific west coast from Alaska to Mexico (Lewitus et al., 2012).
- ***Gambierdiscus toxicus***—This species (Figure 1-1) produces ciguatera toxin and maitotoxin, which are known to cause ciguatera fish poisoning (CFP) in humans through the consumption of contaminated fish. This dinoflagellate is known to occur in tropical and subtropical regions around the world, including the Gulf of Mexico and Caribbean (Bagnis et al., 1980).
- ***Dinophysis spp.***—These dinoflagellates produce okadaic acid, which is believed to cause diarrhetic shellfish poisoning (DSP) in humans through the consumption of contaminated shellfish. These organisms are found worldwide, including the northeast coast of the U.S., the Gulf of Mexico, and the Pacific coast from British Columbia to Mexico (Lewitus et al., 2012; Landsberg, 2002).
- ***Alexandrium spp.***—Some species of the dinoflagellate genus *Alexandrium* produce toxins, including saxitoxin. Saxitoxin is known to cause paralytic shellfish poisoning (PSP) in humans through the consumption of contaminated shellfish. Species of this genus can be found worldwide, with toxic species having been documented on the northeast and west coasts of the U.S. and in the Canadian Maritime Provinces (Moore et al., 2011).
- ***Karenia brevis***—This species of dinoflagellate produces brevetoxins that cause neurotoxic shellfish poisoning (NSP) through the consumption of contaminated shellfish. *Karenia brevis* is also known for blooming in such high densities as to discolor the water and form what are known as red tides. In addition to the ability to cause NSP, brevetoxins can aerosolize from wind and wave action, resulting in respiratory irritation. *Karenia brevis* is known to occur in the Gulf of Mexico and along the southeast coast of the U.S., as far north as North Carolina. (Landsberg, 2002; Erdner et al., 2008; Hoagland et al., 2009).
- ***Cyanobacteria***—The major HAB forming species of cyanobacteria is *Microcystis*, which produces the toxin microcystin. Cyanobacteria are known to produce a variety of other toxins that cause illnesses in both humans and wildlife. Health effects caused in humans include rashes, as well as more serious gastrointestinal and neurological symptoms. Cyanobacteria are also known for extreme bloom sizes and densities which cause various ecological problems. Blooms of cyanobacteria occur in freshwater and low salinity brackish environments, including the Great Lakes and numerous estuaries (Carey et al., 2012; Reardon, 1989; Landsberg, 2002; Erdner et al., 2008; Lopez et al., 2008; Jewett et al., 2008; Pelaez et al., 2010; Paerl et al., 2011; O’Neil et al., 2012).
- ***Brown tide***—Brown tides are caused by blooms of algae that color the water brown. Brown tides have occurred in relatively enclosed waters of southern New England, particularly Long Island, New York, and in Texas. *Aureococcus anophagefferens* is responsible for brown tides in southern New England and a similar species, *Aureoumbra lagunensis*, blooms in Texas bays and lagoons (Anderson et al., 2008; Bricker et al., 2008).

APPENDIX E—EXAMPLES OF SPECIFIC WILDLIFE IMPACTS

A variety of species protected under the ESA, MMPA and MBTA would be directly and indirectly impacted by HABs under the No Action Alternative. The general impacts of HABs discussed in sections 4.2.2, Submerged Aquatic Vegetation; 4.2.1, Water Quality; 4.2.2, Wetlands; 4.2.2, Coral Reefs; and 4.2.2, Benthic Environment can result in degraded water quality and habitat for many protected species. Listed below are a few of the well-documented effects HABs have on protected and ESA species. The species protected under the ESA, MMPA and MBTA need protection for a variety of reasons, including reduced populations, destruction of habitat and accidental bycatch in fishing operations. Combined with threats of overharvesting and habitat degradation from other sources, the No Action Alternative would continue to impact protected species. More information on marine mammal unusual mortality events can be found at <http://www.nmfs.noaa.gov/pr/health/mmume/>.

- **Humpback whale (*Megaptera novaeangliae*)**—Over a five-week period in 1987, 19 endangered humpback whales washed onshore in Cape Cod Bay, Massachusetts (Figure 4-1). Upon examination, it was determined that the whales were healthy immediately prior to their deaths but had consumed mackerel contaminated with saxitoxin, a PSP toxicant from red tides, resulting in mortality (Woods Hole Oceanographic Institution, 2007).



Figure D-1. A humpback whale killed from consuming mackerel contaminated by saxitoxin (photo credit, G. Early from Woods Hole Oceanographic Institute, 2007).

- **North Atlantic right whale (*Eubalaena glacialis*)**—Research indicates PSP toxin, saxitoxin, is a contributing factor preventing the recovery of the endangered North Atlantic right whale. The whale has been protected for over 60 years; however, the species is not recovering and has experienced a significant decline in reproductive success over the last 20 plus years. Numerous whales, as well as the co-occurring zooplankton assemblage, have tested positive for PSP toxins (Doucette et al., 2006).
- **West Indian manatee (*Trichechus manatus*)**—In 1996, 149 West Indian manatees were killed in Florida during a bloom of *Karenia brevis* (formerly *Gymnodinium breve*). It is

believed that mortality resulted from three potential routes for toxin exposure, including inhalation of aerosolized toxins, ingestion of contaminated SAV, and ingestion of contaminated seawater (Bossart et al., 1998; Trainer and Baden, 1999; Landsberg and Steidinger, 1998). Figure 4-2 shows a dead manatee from a similar event in 2006. From January – April 2013, 267 manatees have been killed by or suspected to be killed by a bloom of *Karenia brevis*, which has persisted in the waters of southwest Florida since September 2012 (Florida Fish and Wildlife Conservation Commission, 2013).

- **Shortnose sturgeon (*Acipenser brevirostrum*)**—In 2009, 13 individuals associated with a severe bloom of *Alexandrium* spp. and high saxitoxin levels were found dead in Maine. Evidence of saxitoxin exposure was found in liver and gill tissue as well as in stomach contents. Consumed clams high in saxitoxin suggested that sturgeon exposure occurred through dietary trophic transfer (Fire et al., 2012).



Figure D-2. Scientist Andy Garrett views a manatee dead from algal toxins. Photograph by Rick Loomis (Weiss, 2006).

- **Southern sea otter (*Enhydra lutris nereis*)**—Research shows that freshwater blooms of cyanobacteria are impacting marine species at the land/sea interface. In 2007, 11 Southern sea otters were discovered dead or dying in the Monterey National Marine Sanctuary in California. The otters were suffering from liver failure as a result of the hepatotoxin microcystin, produced from cyanobacteria. Research confirmed the presence of microcystin in local lakes and rivers which tributary to Monterey Bay, as well as in the coastal marine environment. A large portion of the sea otter diet is marine invertebrates such as clams and mussels. These filter feeders are known to bioaccumulate microcystin and are likely the cause of the sea otter mortality (Weiss, 2010).
- **California sea lion (*Zalophus californianus*)**—A bloom of *Pseudo-nitzschia australis* along the California coast in 1998 is believed to have caused the death of 400 California sea lions, as well as many other birds and marine mammals. During the bloom, high concentrations of domoic acid were found in anchovies and sardines, a principal food source for sea lions (Scholin et al., 2000). These events have become a somewhat regular occurrence along the California coast (Bargu et al. 2010).

- **Bottlenose dolphin (*Tursiops truncatus*)**—In the spring of 2004, 107 bottlenose dolphins washed up on the shores of Florida beaches. Though there was not a HAB in the area at that time, upon examination it was found that the dolphins had consumed menhaden, a filter feeding fish, contaminated with brevetoxin. This finding indicates how the effects of HABs can be delayed and last beyond the actual bloom (Flewelling et al., 2005).



Figure D-3. Bottlenose dolphins killed by brevetoxins in a red tide event in Florida (Photo from WHOI, 2004).

- **Seabirds**—In 2007, a widespread seabird mortality event occurred concurrently with a red tide of *Akashiwo sanguinea*, in Monterey Bay, California. In total, 550 birds were stranded or killed during the bloom, including 14 different species of migratory seabirds, such as northern fulmars (*Fulmarus glacialis*), scoters (*Melanitta* spp.), and western grebes (*Aechmophorus occidentalis*). Among other symptoms, the birds were covered in a slimy yellow-green foam which reduced waterproofing on their feathers, resulting in hypothermia. It was determined that the foam was derived from organic matter of the red tide and contained surfactant-like proteins. A similar event occurred in 1997, although the relationship was unknown at the time (Jessup et al., 2009)

APPENDIX F—GLOSSARY

Algicidal	Resulting in algal mortality.
Algistatic	Inhibiting the growth of algae.
Allelochemical	Naturally occurring polyunsaturated fatty acids, phlorotannins, or secondary metabolites (not required for growth or reproduction of the species) produced by an organism that influence the growth, survival, and/or reproduction of another organism. Allelochemicals occur in terrestrial and marine plants and can have both beneficial and harmful effects on other organisms.
Anadromous Fish	Those fish species that migrate from the ocean, upriver to spawn.
Anoxia	Having no dissolved oxygen.
Benthic	Located at the bottom, sediment surface, or sub-surface at the bottom of a waterbody.
Bioaccumulation	When organisms sequester toxins or other substances within their tissues at higher concentrations than occur in the surrounding environment.
Biochemical Oxygen Demand	The amount of dissolved oxygen needed for the microbial decomposition of organic material.
Biodegrade	Decomposed or broken down by the action of living things.
Biomagnification	The magnification of toxins through a food web as lower order organisms are consumed by higher order organisms. Lower order organisms, such as plants, shellfish, and fish, bioaccumulate toxins within their tissues. The higher order organisms that feed upon them ingest accumulated toxins from multiple sources.
Biosurfactant	Surfactants produced from living things such as bacteria and yeast. Surfactants aid in the emulsification and breakdown of hydrocarbons by lowering the surface tension of a liquid.
Chelation/ Chelated	The formation of a bond between an organic compound (chelator) and a heavy metal. This bond inactivates the metal so it is not free to react with other elements or ions. Chelated copper allows the copper ion to remain in an available form in the water column for a longer period of time to achieve algal control.
Demersal	Living and/or feeding at the deepest part of a waterbody.
Demonstration	The minimum level of field application of a control method anticipated to produce a quantifiable reduction in the magnitude (i.e., intensity, duration, size) or toxicity of a HAB.

Dissolved Oxygen	The oxygen dissolved into a liquid.
Epilimnion	The upper most layer in a thermally stratified waterbody. A lack of mixing within a waterbody can result in thermal stratification, with the epilimnion being warmer and typically experiencing higher levels of dissolved oxygen and fewer nutrients than the deeper hypolimnion.
Flocculation	Flocculation is the process of removing suspended particles from a liquid using a flocculant, such as a chemical or other substance. Through repeated collisions and adhesion between the suspended particles and the flocculant, large, rapidly-sinking aggregates (or flocs) are formed and settle out of the water column.
Harmful Algal Bloom	A term used by the scientific community to describe a diverse array of both microscopic and macroscopic algae which produce toxic effects on humans and other organisms, physical impairment of fish and shellfish, nuisance conditions from odors and discoloration of water, or overwhelming effects on ecosystems such as severe oxygen depletion or overgrowth.
Humic	A general term referring to the organic matter which results from the decay of plant material.
Hypolimnion	The bottom layer in a thermally stratified waterbody. A lack of mixing within a waterbody can result in thermal stratification, with the hypolimnion being devoid of oxygen, cooler, and with more nutrients than the epilimnion.
Hypoxia	Dangerously low level of dissolved oxygen.
In situ	In place; to examine something where it occurs.
Isothermal	Equal, constant, or uniform temperature.
Lignin	An organic polymer present in the cell wall of plants.
Lysis/ Lyse	The rupture, destruction, or decomposition of a cell or other substance by a specific action.
Mariculture	Aquaculture in the marine environment.
Mesocosm	Experimental water enclosures in which environmental factors can be realistically manipulated. Mesocosms are designed to provide a limited body of water with near natural conditions.
Photic Zone	The depth of water that is exposed to sufficient sunlight for photosynthesis to occur.
Phytoplankton	Phytoplankton are autotrophic plankton, meaning they are capable of using energy from light or inorganic chemical reactions to produce their own food.

Planktonic/ Plankton	Small or microscopic organisms that float in the water and are subject to movement or drift by wind and water currents. Some organisms spend their entire lives as plankton, while others, such as oysters, only experience a single life stage in planktonic form.
Stratification	A vertical layering of a waterbody where the layers do not mix and over time develop different properties from one another. Stratification can be caused by differences in salinity or temperature. The longer the layers remain stratified, the differences between them become greater, making mixing of the layers more difficult.
Submerged Aquatic Vegetation	Sometimes called seagrass, these are aquatic plants that grow in clear, shallow, sub-tidal regions of bays, rivers, and coastal lagoons. These are typically vascular, rooted plants that can grow to the water's surface. Algae and floating plants are generally not considered to be submerged aquatic vegetation.
Thermotaxis	A behavior in which an organisms moves based upon a temperature gradient.
Turbidity	A measure of the loss in transparency of water due to suspended particles. Sediment and particulate matter increases the turbidity of water, decreasing the amount of light penetrating through the water column.
Zooplankton	Plankton that cannot produce their own food, as phytoplankton can.