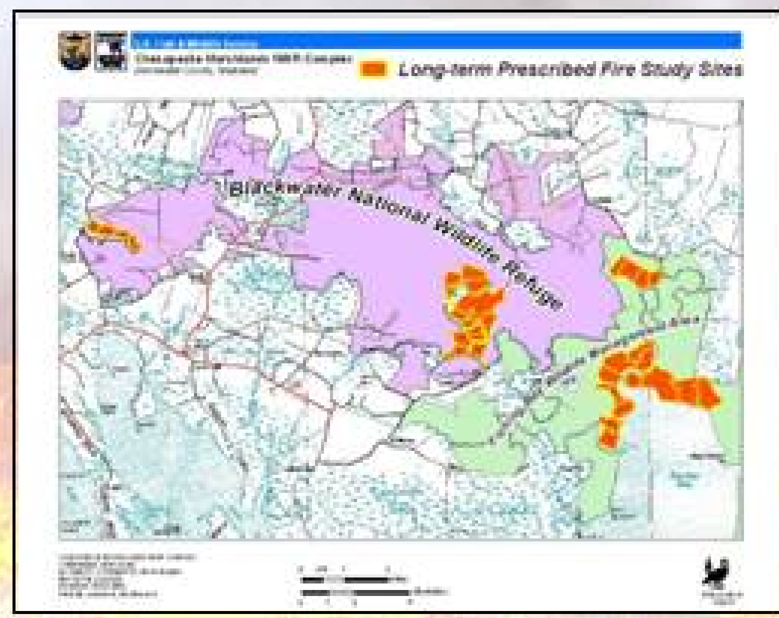
Scientific Review of the Prescribed Fire Program at Blackwater National Wildlife Refuge (Chesapeake Marshlands NWR Complex) and Fishing Bay Wildlife Management Area



2006

Scientific Review of the Prescribed Fire

Program at

Blackwater National Wildlife Refuge

(Chesapeake Marshlands NWR Complex)

and

Fishing Bay Wildlife Management Area

February 22, 2005

Introduction

"*The goal of the wildland fire management program is to plan and make decisions that help accomplish the mission of the National Wildlife Refuge System (U.S. Dept. of Interior 1998; 620 DM1)" and help achieve refuge purposes and objectives.*

When establishing protection priorities, firefighter and public safety is the first priority. Property and natural/cultural resources follow "If it becomes necessary to prioritize between property and natural/cultural resources, we prioritize based on relative values to be protected, commensurate with fire management costs." In addition, the fire program is guided by Departmental Policy (U.S. Dept. of Interior 1998; 620 DM1) which states:

1. every area with burnable vegetation must have an approved Fire Management Plan (FMP) that addresses all potential wildland fire occurrences and includes the full range of wildland fire management actions
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2. fire will be integrated into land, natural, and cultural management plans and activities on a landscape scale, across bureau boundaries, and will be based on the best available science.

3. wildland fire will be used to protect, maintain, and enhance natural and cultural resources.

4. wildland fire management must be cost effective, consider firefighter and public safety, benefits, and values to be protected, and be consistent with natural and cultural resource objectives.

Background

In 1995, staff at the Chesapeake Marshlands NWR Complex (then Blackwater NWR) and Maryland Department of Natural Resources, Wildlife and Heritage Services, collaborated in a comprehensive review of the fire management programs for Blackwater River and Fishing Bay marshes in Dorchester County, Maryland. Controversy regarding management objectives, the strategies/tools to implement them, and new Departmental and Service policies prompted this review. This effort was led by an independent and impartial, interdisciplinary panel of local and national experts in fire and wetlands ecology who were asked to review all relevant biological and cultural information related to prescribed fire in this ecosystem, and to recommend an appropriate fire management regime. The panel was charged to "examine the 48 issues, (Appendix A), related to fire management on federal and state lands within Blackwater NWR and Fishing Bay WMA, and following deliberations, offer findings and suggestions for appropriate fire management alternatives." A list of panel members is attached in Appendix B.

After an intensive 4 day site review and testimonies by state and refuge staff, landowners, and others who expressed an interest in the use of fire in this ecosystem, the panel identified 6 fire management alternatives for these units (Samson et al. 1996)

1. Aggressive Fire Suppression Regime- Fire is excluded from all areas.
2. Appropriate Fire Suppression Regime- The influence of fire is restricted to unscheduled wildfires.
3. Current Annual Marsh Plus Fire Regime- Annual fire frequencies are prescribed for only half the marsh acreage and fire use is expanded into upland communities.
4. Current Annual Marsh Fire Regime- Annual fire frequencies are prescribed in all community types at varying frequencies.
5. Multiple-objective Prescribed Fire Regime- Fire and fire exclusion are prescribed in all community types at varying frequencies.
6. More Frequent Prescribed Fire Regime- Frequent fire frequencies are prescribed in all community types.

When the fire management alternatives were compared with the 2 agencies land management objectives, the recommended alternative was the Multiple Objective Prescribed Fire Regime (MOPFR). This regime supports the refuge's programmatic approach to prescribed fire by allowing the refuge and state to use prescribed fire as a tool to achieve more than one management goal and/or objective at a time.

The prescribed burn program at Blackwater is divided into 3 classifications of treatment objectives:
1) Hazard Fuel Reduction-"The Service will employ prescribed fire whenever it is an appropriate tool for managing Service resources and to protect against unwanted wildland fire, whenever it threatens human life, property and natural/cultural resources." (FMH Chapter 1.1)

2) Retaining Ecological Health- maintain current levels of *Schoenoplectus americanus* and *Spartina patens* to provide habitat for wildlife.

3) Research- " Fire, as an ecological process, will be integrated into resource management plans and activities on a landscape scale, across bureau boundaries and will be based upon the best available science." (FMH Chapter 1.1).

Within a single burn unit, we might burn to reduce hazardous fuels, or to retain the ecological health of the marsh, or as part of our fire research plots or any combination of objectives. This alternative provides for the greatest management flexibility and evaluation of the ecological and programmatic effects of a variety of fire regimes. (Samson et al. 1996)

Even though Pendleton and Stevenson (1983) found that marsh burning did not lead to marsh loss but rather increased marsh production the panel could only find anecdotal evidence that this increase in marsh production had any effect on slowing marsh loss.

The panel also recommended that adaptive management, coupled with active monitoring and long-term research and assessment, be applied to guide changes in management objectives and actions in the future. (Samson et al.) The panel completed the review and in 1996 submitted their recommendations with a final report entitled, "Technical Review of Fire Management Alternatives in the Blackwater National Wildlife Refuge and Adjacent Wetland Management Areas." (Appendix C)

The panel's recommendations were incorporated into the environmental assessment, written in 1998, for Blackwater's Fire Management Plan. The panel recommended 4 fire frequencies. The following 3 rotations and a control were proposed: 1) annual burn, 2) 3-5 year burn, 3) 7-10 year burn and, 4) no burn, or fire exclusion. As noted below, substantial changes to the annual burning program were made as a result of the review and implementation of MOPFR.

COMPARISON TABLES

Pre-1995 review | Post 1995 review

Blackwater NWR and Fishing Bay WMA	Acres treated	Multiple Objective Prescribed Fire Regime BWR & FBWMA	Acres treated
Annual	30,700	Annual	9,300
3-5	300	3-5	6,300
7-10	0	7-10	5,700
No burn	300	No burn	10,000
Total	31,300	Total	31,300

Multiple Objective Prescribed Fire Regime by agency

Blackwater NWR	Acres treated	Fishing Bay WMA	Acres treated
Annual	3600	Annual	5700
3-5	200	3-5	6100
7-10	200	7-10	5500
No burn	5000	No burn	5000
Total	9000	Total	22300

Comparative Analysis of the Pre-1995 and MOPFR Programs

Pre-1995 Program	MOPFR program
-- All or nothing: Annual/no burn	Multiple fire return frequencies in every habitat community.
-- 70/30 planned vs accomplished.	70/30 planned vs accomplished
-- 70/30 burn mosaic	70/30 burn mosaic
-- Not ecosystem based	Ecosystem based

-- Objectives based on furbearers, waterfowl, marsh health	Clearly defined objectives (wildlife/habitat diversity)
-- No Dept/Service policies	Clear Dept./Service policies
-- No clear priorities/mandates	Clear priorities and mandates
-- Separate programs/efforts	Cooperative Agreement
	Cross boundary, landscape effort

The refuge and DNR staff implemented the panel's recommendations in 2000, after complying with the National Environmental Protection Act (NEPA) requirements and finalizing the Fire Management Plan in accordance with national and regional policies.

In 1998, the Fish and Wildlife Service entered into a collaborative agreement with the University of Maryland and the Maryland Cooperative Fish and Wildlife Research Unit to initiate a study entitled "Evaluation of vegetative response to fire exclusion and prescribed fire rotation on Blackwater National Wildlife Refuge and Fishing Bay Wildlife Management Area"(Flores 2003). The study was designed to evaluate the implementation of the panel's recommendation of the 4 fire frequencies.

2003 Panel Review of Fire Management Alternatives

Prompted by a change in personnel and more recent studies on fire effects in marsh ecosystems, 4 of the original 5 members (one was unable to attend due to illness), reconvened on November 13 and 14, 2003, for a symposium at the Horn Point Laboratory of the University of Maryland Center for Environmental Science in Cambridge, Maryland.

The purpose of the 2003 symposium was to review the most current research findings related to the use of prescribed fire in marsh ecosystems. Eleven scientists from federal, state, and private institutions presented their scientific results at the conference (Appendix D). The fire review panel and 40 additional researchers participated in the conference. Each presenter was given 30 minutes to present their research projects, followed by a question and answer period from the panel and the audience. A brief synopsis of each of the 11 research presentations is provided in Appendix E.

At the conclusion of the 2-day conference, the fire review panel met to discuss whether the Multiple Objective Prescribed Fire Regime was still the most effective management alternative. The panel issued a report in April 2004 entitled "Review of fire management programs for Fishing Bay Wildlife Management Area and Blackwater National Wildlife Refuge" (Appendix F).

The 2004 Fire Review Panel Report found the was "no basis" for recommending changes in the management regime, and acknowledged that the research issues are extremely complex. The Panel also expressed disappointment that funding had not been made available to conduct the recommendations the Panel made in 1995. To address the complex issues regarding the dynamics of the marsh ecosystem and the effects of prescribed fire, additional multi-disciplinary research is needed and recommended.

Expansion of Scientific Research Activities

In 2004, the Refuge began a collaborative research project with George Mason University and U.S. Geological Survey wetland scientists. Based on the findings of Flores (2003), 2 additional study areas were added to the long-term fire research monitoring program which increased the number of study areas from 6 to 8 areas. Each of these 8 study areas has 3 treatment sites including an annual burn, a 3-5 year, a 7-10 year, and a control or no burn area.

A second graduate student, Ms. Cheryl Leonard, began conducting a research project entitled "Above- and below-ground vegetative response to prescribed fire rotations at Blackwater National Wildlife Refuge" in 2004. Ms. Leonard is comparing the vegetative response of above-ground and below-ground biomass among the various fire rotations and fire exclusion.

In addition, refuge staff established permanent photographic stations within each of the treatment and control sites within the 8 study areas. Photographs are taken 2-3 times per year to visually document the effects of fire on changes in the above-ground vegetation and in the marsh ecosystem. In 2006, refuge staff will also collect fire behavior and post-burn severity data.

A collaborative research project with the U.S. Geological Survey and the National Aquarium in Baltimore was initiated in 2005. A study entitled "Marsh elevation dynamics at Blackwater National Wildlife Refuge Using Surface Elevation Tables (SETs)" was funded through the Quick Response Program of the U.S. Geological Survey and the U.S. Fish and Wildlife Service. The objectives of this project are to investigate and document changes in elevation at 3-year old and 25-year old restored marshes with high precision and to partition the changes into surface (i.e., erosional and depositional) and below-ground processes. The results of this study will assist scientists in understanding the processes of marsh soil development as restored marshes mature. This information will be used to facilitate the design of future marsh restoration projects at the refuge.

The National Geodetic Survey (NOAA), USGS, and the refuge initiated terrestrial and wetland elevational research in September 2005. This information will be used to determine the effects of elevational change on marsh loss over time.

In addition, a global climate change research project was initiated in 2005 at Blackwater National Wildlife Refuge entitled "Predicting the vulnerability of coastal wetlands to sea level rises and other stressors". This project will address several factors relating to global climate change and the effects on marsh loss and marsh accretion.

Wetland Restoration and the Use of Prescribed Fire

In 2005, the U.S. Army Corps of Engineers (ACE) issued a report entitled "Draft Baltimore Harbor and Channels Dredged Material Management Plan and Tiered Environmental Impact

Statement”. In this report, Blackwater NWR is listed as 1 of 3 options for the placement of clean dredged material from the Port of Baltimore. The Blackwater option has the highest environmental benefits and also the highest cost for wetland restoration.

Blackwater staff are working closely with the ACE and the Port of Baltimore to develop technical working groups in the following disciplines: wetland processes, geology, hydrology, biology, fire effects, and engineering. Scientific experts from over 20 federal, state, and private organizations will be working collaboratively to investigate factors related to restoring the Blackwater watershed over the next 50 years. This large-scale initiative will be the most comprehensive scientific project undertaken to restore the marsh ecosystem at Blackwater refuge. The effects of fire on marsh processes will continue to be closely examined throughout this project.

Literature Cited

Flores, C. 2003. Evaluation of vegetative response to fire exclusion and prescribed fire rotation on Blackwater National Wildlife Refuge and Fishing Bay Wildlife Management Area. Unpublished thesis. University of Maryland Eastern Shore, Princess Anne, Maryland. 326 pp.

Pendleton, E.C. and J.C. Stevenson. 1983. Investigations of marsh losses at Blackwater Refuge, Horn Point Environmental Laboratories, Center for Environmental and Estuarine Studies, University of Maryland, Cambridge, MD. 151p.

Samson, D.A., W.P. Leenhouts., E.C. Soutiere, D. Boesch and F. Cole. 1996. Technical Review of Fire Management Alternatives in the Blackwater National Wildlife Refuge and Adjacent Wetland Management Areas.

U.S. Dept. of the Interior, Departmental Manual 620, Chapter 1.

U.S. Dept. of the Interior, Departmental Manual 620, Chapter 1.

U.S. Fish and Wildlife Service 2004. Fire Management Handbook.

Appendix A: Forty Eight Issues Related to Fire Management on Federal and State Land.

1. Effects of Rx fire on improving/maintaining habitats to achieve purposes/objectives.
2. Effects of Rx fire in maintaining fire maintained ecosystems and perpetuating historical vegetation communities representative of those for which these areas were acquired and established.
3. Effects of Rx fire on maintaining vegetative productivity and vigor (above and below ground).
4. Effects of Rx fire on marsh succession.
5. Effects on marsh loss.
6. Effects on habitat suitability for and abundance of marsh herbivores.
7. Effects on providing browse for wintering waterfowl.
8. Effects on plant biomass and NAPP and contributions to marsh accretion.
9. Effects on structural habitat diversity due to incomplete burns.
10. Effects on trapping and control of herbivores.
11. Effects on socioeconomic/cultural factors.
12. Effects of methods, timing, and frequency of fire.
13. Are past scientific management recommendations used.
14. Effects of mash herbivores on marsh loss and succession.
15. Are the marshes fire-maintained or fire-adapted?
16. Declines of 3-square and resultant effects on biodiversity (landscape context).
17. Effects on overall species diversity and abundance.
18. Effects on T&E species and species of special concern.
19. Effects on non-game species.
20. Effects on waterfowl species.
21. Effects on predator-prey relationships.
22. Effects on residual vegetation.
23. Effects on invertebrates.
24. Effects on spatial reorganization of habitats.
25. Effects on adjacent forest lands.
26. Effects on nutrient recycling.
27. Effects on sediment transport.
28. Effects on air quality.
29. Effects on soils and soil organisms.
30. Effect on water quality.
31. Effects on fishery resources.
32. Effects on specific plant species (3-square, patens, distichlis, and phragmites).
33. Effects on public use.
34. Effects on adjacent landowners.

35. Effects on public health and safety.
36. Use of Rx fire as a presuppression tool and relationship to liability.
37. Need to suppress every wildfire on or threatening refuge or the WMU.
38. Use of LE as alternative management activity to using wildfire presuppression burning to prevent trespass/arson wildfires.
39. Fire will continue to be a major process on these areas with or without Rx fire.
40. Comparison of effects of Rx fire vs wildfire on human environment, public safety, and natural resources (sporadic wildfire vs. scheduled Rx fire).
41. Comparative costs of fire management activities.
42. Appropriate coordination with local fire companies.
43. Impacts on local fire companies/state resources with non-Rx fire.
44. Appropriate monitoring and assessment.
45. Frequency and timing of Rx vs. wildfire.
46. Recognition of and compliance with regulatory factors.
47. Sixty years of prescribed burning has not stopped marsh loss – should we still be burning.
48. Maintenance of literature pertinent to wildland fire and associate effects.

Appendix B: Interdisciplinary Fire Panel Members (1995 and 2003)

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* Mr. Cole was unable to attend the 2003 conference, due to illness.

Appendix C:

Technical Review of Fire Management Alternatives in the Blackwater National Wildlife Refuge and Adjacent Wetland Management Areas

April 11, 1996

Table of Contents

Executive Summary

An independent panel of 5 individuals evaluated the fire management programs of the Dorchester County lands of the Maryland Department of Natural Resources (MDNR) and Blackwater National Wildlife Refuge (BNWR) as they relate to the established objectives of these units. The panel identified 6 possible fire management alternatives of these units:

- Aggressive Fire Suppression Regime - Fire is excluded from all areas.
- Appropriate Fire Suppression Regime - The influence of fire is restricted to unscheduled wildfires.
- Current Annual Marsh Plus Fire Regime - Annual fire frequencies are prescribed for only half the marsh acreage and fire use is expanded into upland communities.
- Current Annual Marsh Fire Regime - Annual fire frequencies are prescribed for only half the marsh acreage.
- Multiple-objective Prescribed Fire Regime - Fire and fire exclusion are prescribed in all community types at varying frequencies.
- More Frequent Prescribed Fire Regime - Frequent fire frequencies are prescribed in all community types.

The panel recommends that the agencies begin comprehensive planning to implement the Multiple-objective Prescribed Fire Regime alternative. This alternative best achieves most of the 23 ecological land management objectives. It provides the greatest management flexibility and a diversity of fire regimes. This diversity and flexibility will allow the MDNR and BNWR to evaluate the ecological and programmatic effects of a variety of fire regimes. This will require an adaptive management approach which includes adequate land-term research, monitoring and evaluation in order to determine whether or not management actions are achieving unit objectives.

The most significant single finding of the panel was that no new or additional evidence to refute the findings of Pendleton and Stevenson (1983) that: "*Annual marsh burning was not directly implicated in marsh losses and....marsh losses on the refuge appear from this study to have proceeded from natural causes, primarily that of rising sea levels.*" Although Pendleton and Stevenson (1983) and others also found that fire "*was found to increase marsh production*," the panel could only find anecdotal evidence that this increase in marsh production had any effect on slowing marsh loss.

Introduction

For many years, fire has been used in wetlands of Maryland's Eastern Shore to facilitate trapping of fur-bearing animals, stimulate the growth of vegetation thought to be beneficial to furbearers or waterfowl, or to reduce the risk to life and property due to uncontrolled fires. Prescribed fire has also long been used in the management of wetlands of the Blackwater National Wildlife Refuge (BNWR) and nearby wildlife management areas operated by the Maryland Department of Natural Resources (MDNR). Prescribed fires have been thought to be beneficial, and even necessary, for favoring the growth of wetland vegetation conducive to wildlife use and to facilitate the trapping of introduced nutria, which overgraze these marshes. At the same time, the tidal wetlands of this area have undergone very rapid deterioration and loss as a result of geologic and hydrodynamic phenomena, human alterations and populations of animal grazers. To meet this challenge of habitat loss, prescribed fires have also sought to promote the growth of wetland vegetation which may enhance the long-term viability of the wetlands.

The effectiveness of fire in achieving multiple management objectives, including sustaining these important wetland ecosystems and enhancing wildlife, have come into question. To help address the role of fire in the stewardship of these public wetlands and adjacent wetlands, the Maryland Department of Natural Resources (MDNR) and the Blackwater National Wildlife Refuge (BNWR) convened an independent panel of experts to examine the issues related to fire management on these lands by reviewing the literature, visiting the environments in question, and obtaining public input on the issues. The Panel was asked to deliberate, offer its findings and suggest appropriate fire management alternatives. The Panel is composed of:

X Edward C. Soutiere, President, Tudor Farms, Cambridge, MD.
X Frank T. Cole, Project Leader/Fire Ecologist, U.S. Fish and Wildlife Service, Tall Timbers Research Station, Tallahassee, FL.
X Donald F. Boesch, Ph.D., President, Center for Environmental and Estuarine Studies, University of Maryland System, Cambridge, MD.
X Douglas A. Samson, Ph.D., Director of Science and Stewardship, The Nature Conservancy of Maryland, Chevy Chase, MD.
X Willard P. Leenhouts, Fire/Wildlife Ecologist, U.S. Fish and Wildlife Service, National Interagency Fire Center, Boise, ID.

This is the final report of the panel. In it, we describe an array of Fire Management Alternatives, from the most limited to the most extensive; evaluate the potential of these Alternatives to meet 23 specific objectives in an Alternative Evaluation Matrix; present the Panel's Findings; and develop Recommendations for the preferred alternative and comprehensive planning.

Fire Management Alternatives

After reviewing the literature, conducting a site visit, obtaining public input on the issues, and discussing the issues, the panel developed 6 fire management alternatives for the Maryland Department of Natural Resources and the U. S. Fish and Wildlife Service. The panel feels that these 6 fire management alternatives represent a broad spectrum of possible alternatives. The panel also feels that it would be irresponsible for any alternative to advocate no fire management action, even suppression. This would risk public safety, be irresponsible ecological stewardship, and be contrary to agency policies. Each alternative is evaluated against 23 land management objectives.

- **Aggressive Fire Suppression Regime**: A fire management plan will be developed to ensure that all wildfires will be controlled at a minimum size irrespective of values at risk or suppression cost, and no prescribed fires will be used. Under this alternative aggressive wildfire suppression will be taken on all fires regardless of the values at risk to ensure that a minimum of public land burns. No prescribed fires will be used on any lands. It is anticipated that there will be less average annual acreage burned compared to the current situation. Fire management costs will significantly increase due to the aggressive wildfire suppression strategy.

- **Appropriate Suppression Fire Regime**: A fire management plan will be developed to ensure that all wildfires will be suppressed according to policies of each land management agency, and no prescribed fires will be used. Under this alternative the current fire management strategy will continue, less any prescribed fires. Wildfire suppression actions will be taken on all lightning and human caused fires appropriate to the values at risk and cost of suppression. It is anticipated that aggressive suppression will be taken where public safety and property are at risk, but less aggressive actions may be used where the fire is causing little human threat or ecological impact (e.g., remote marsh areas). No prescribed fires will be used on any lands. It is anticipated that there will a decrease in the average annual acreage burned from the current situation, but much of the 13,000 acres currently prescribed burned will be burned by wildfires. Fire management costs should significantly increase with the increased wildland fire suppression activities.

- **Current Annual Marsh Fire Regime**: The current fire management plan will continue to ensure that all wildfires will be suppressed according to policies of each land management agency. This is the "no action" alternative because there will be no change in the current fire management plan. Wildfire suppression actions will be taken on all lightning and human caused fires appropriate to the values at risk and cost of suppression. Annual prescribed fires will be applied to approximately 3,000 acres of U.S. Fish and Wildlife Service and 10,000 acres of Maryland Department of Natural Resources marsh lands. Under this alternative the current fire management strategy will continue. This is probably the least costly wildland fire management alternative.

- **Current Annual Marsh Fire Regime Plus Woodland Prescribed Fires**: A fire management plan will be developed to ensure that all wildfires will be suppressed according to policies of each land management agency. Wildfire suppression actions will be taken on all lightning and human caused fires appropriate to the values at risk and cost of suppression. Annual prescribed fires will be applied to approximately 3,000 acres of U.S. Fish and Wildlife Service and 10,000 acres of Maryland Department of Natural Resources marsh lands. The U. S. Fish and Wildlife Service will also begin using prescribed fire on 500 acres of woodlands on approximately a 5-year fire rotation interval. Under this alternative the current fire management strategy will continue, with the addition of woodland prescribed fire by the U. S. Fish and Wildlife Service. Fire management costs should increase proportional to the increased woodland prescribed fires.

- **Multiple-objective Prescribed Fire Regime**: A fire management plan will be developed to ensure that there are significant areas of all vegetative community types representative in varying fire regimes. Under this alternative wildfire suppression and prescribed fire activities will be planned to ensure that all major public land vegetative community types have representative areas of approximately 1-, 5-, and 20-year fire rotation intervals, and total fire exclusion. It is anticipated that there will be little change in the average annual acreage burned compared to the current situation. Fire management costs should significantly increase with the increased wildland fire suppression and prescribed fire activities needed to implement this alternative.

- **More Frequent Prescribed Fire Regime**: A fire management plan will be developed to ensure that frequent fire regimes are maintained in all vegetative community types. Under this alternative wildfire suppression and prescribed fire activities will be planned to ensure that all major public land vegetative community types have representative areas of approximately 1- and 5-year fire rotation intervals. It is anticipated that there will more annual acreage burned compared to the current situation. Fire management costs should significantly increase with the increased prescribed fire activities, but wildland fire suppression cost decreases may mitigate some of the increased prescribed fire costs for this alternative.

Alternative Evaluation Matrix

The 6 alternatives were evaluated against 23 land management objectives provided by MDNR and BNWR. The first 21 land management objectives were provided to the panel by the Maryland Department of Natural Resources and U.S. Fish and Wildlife Service as evaluation criteria of the fire management alternatives. The panel added the objectives 22 and 23 to evaluate the probability an alternative could be implemented.

The probability an alternative could achieve any particular objective is indicated as: ++ Highly probable; + Possible; +- Uncertain; - Unlikely; -- Highly improbable.

Objective	Aggressive Fire Suppression Regime	Appropriate Fire Suppression Regime	Current Annual Marsh Fire Regime	Current Annual Marsh Fire Regime Plus Woodland Rx Fires	Multiple Objective Prescribed Fire Regime	More Frequent Prescribed Fire Regime
1. Provide a level of wildland fire protection that will result in the least cost plus net value change (cost efficient level) commensurate with resource management objectives and constraints.	–	+	++	++	++	+
2. Reduce adverse impacts of all resource mgt. activities and the threats of wildfires associated with trespass and arson fires in the intermingled Federal/State/Private lands and along the WUI.	–	–	++	++	++	++
3. Maintain optimum nesting and brood habitat for State and Federal endangered and threatened species and species of special concern.	–	–	+	++	++	+
4. Provide feeding & resting habitat for mtce. requirements of migratory waterfowl during migration and wintering periods.	–	–	+	+	+	+
5. Promote the control of resident and alien furbearers.	–	–	++	++	+	++
6. Provide nesting and brood habitat for duck production	+-	+	++	++	++	+-
7. Maintain health and vigor of marsh vegetation	-	-	++	++	+	++
8. Maintain current marshland acreage and species mixture. Reduce brush invasion into marshlands.	–	–	+-	+-	+-	+-
9. Control phragmites, an alien species	-	-	-	-	+-	+-
10. Reduce brush species dominance and encourage native herbaceous growth on abandoned cropland areas.	–	+	–	–	+	++
11. Reduce the encroachment of tree species that are not part of the desired community	–	–	–	++	++	+
12. Prepare sites for seeding and planting and dispose of logging slash.	–	–	–	+	++	++
13. Utilize mgt. practices to produce traditional forest habitat values: wood, water, wildlife, rec.	–	–	–	+	++	+
14. Provide compatible public hunting, trapping and outdoor recreational opportunities	–	+-	+	++	++	+
15. Provide opportunities for the public to under-stand & appreciate the need for wildland fire activities	–	–	+	++	++	++
16. Comply with state air quality implementation plans to protect public health	++	++	+	+	+	+
17. Assure no disruption or adverse impact on transportation/utility corridors occurs from wildland fires.	+	+	++	+	++	+
18. Prepare sites for seeding and planting	-	-	-	+	++	++
19. Maintain current ecosystem diversity w/in the landscape context.	-	-	++	+	+	+-
20. Contribute to the recovery and restoration of Chesapeake Bay ecosystem diversity & function	-	-	+	+	++	-
21. Protect valuable resources of international, regional and local significance.	-	+-	+	+	++	-
22. Achievable w/in current funding levels.	-	++	+	+	+	-
23. Achievable under current social/political constraints.	-	++	+	+	+	-

Objective Achievement Rationale

The following is a discussion of the wildland fire use rationale behind the rating given in the Alternative Evaluation Matrix. The rationale provided are generalizations. As with all generalizations, specific exceptions always exist, but on average the generalization applies most often across a broad spectrum of circumstances. See the Findings section of the report for a detailed explanation of these issues.

1. Provide a level of wildland fire protection that will result in the least cost plus net value change (cost efficient level) commensurate with resource management objectives and constraints. A combination of presuppression hazard reduction prescribed fire and appropriate suppression strategies has been shown to be the most efficient level of wildfire protection. Only the alternatives that use prescribed fire can implement a presuppression hazard reduction program. Since most of the wildfires occur in the marshes, the alternatives that implement marsh prescribed fires are rated the highest.
2. Reduce adverse impacts of all resource management activities and the threats of wildfires associated with trespass and arson fires in the intermingled Federal/State/private lands and along the wildland/rural interface. Same logic as 1.
3. Maintain optimum nesting and brood habitat for State and Federal endangered and threatened species and species of special concern. The more habitat diversity, the greater probability of addressing endangered and threatened species needs. The extirpation of the red-cockaded woodpecker demonstrates that uplands require some fire treatment. The alternatives that utilize prescribed fire in both the marsh and uplands rate higher than those that only address the marsh. The More Frequent Prescribed Fire Regime lacks the long rotation and complete exclusion options and is rated lower.
4. Provide feeding and resting habitat for maintenance requirements of migratory waterfowl during migration and wintering periods. Frequent fires in wetlands subsidized vegetation species (i.e., *Scirpus* spp.) that are favored by waterfowl. All alternative that utilize prescribed fire in the marsh achieve this objective, but the panel felt that marsh fire was only one of many factors needed to achieve this objective, and by itself would not assure optimal feeding and resting habitat.
5. Promote the control of resident and alien furbearers. Winter prescribed fire fuel reduction facilitates trapping, which is the most efficient furbearer control technique. The most aggressive marsh prescribed fire programs makes objective achievement greater. Because the Multiple-objective Prescribed Fire Regime sets aside significant marsh acreage in long rotation and fire exclusion zones, this reduces the chances of this alternative achieving this objective.
6. Provide nesting and brood habitat for duck production. Black ducks require dense ground nesting cover which is in ample supply unless fire is completely excluded or applied across all habitat types. Wood ducks require nesting cavities which are provided by artificial nesting cavities or trees with cavities that are facilitated by fire damage. Prescribed fire has been used successfully in the management of

waterfowl habitat (Kirby et al. 1988) and silvicultural treatments (Wright and Bailey 1982). Therefore, the alternative to utilize prescribed fire and maintain a diversity of marsh and upland habitats is rated the highest.

7. Maintain health and vigor of marsh vegetation. Much of the existing marsh vegetation has evolved with periodic fire (Kirby et al. 1988). The *Scirpus* marshes require annual or biennial burning. Attempting to convert water stressed marshes that have adapted to fire may result in complete marsh vegetation loss from the rise in the relative sea level. Alternatives that maintain significant acreage of frequent fire regime vegetation are more likely to achieve this objective.
8. Maintain current marshland acreage and species mixture. Reduce brush invasion into marshlands. Unless the past century of relative sea level rise is reversed which appears unlikely, marsh loss will continue, and achievement of this objective is unlikely. In order to maintain the current marsh condition, all ecological processes must continue as in the past; this includes frequent (annual) marsh burning. Frequent marsh burning, especially growing season burning, also favors herbaceous species over woody species. Only those alternatives that continue the current marsh fire regimes can fully achieve this objective. Because the Multiple-objective Prescribed Fire Regime sets aside significant marsh acreage in long rotation and fire exclusion zones, this reduces the chances of this alternative achieving this objective.
9. Control phragmites, an alien species. Surface fire alone reduces phragmites biomass, but is not an acceptable control technique. Surface fire in combination with herbicides or flooding has been effective. Severe root burns can kill phragmites plants (Cross, D. H. 1983). But fire alone cannot significantly control Phragmites and it is unlikely that any of the alternatives can achieve this objective.
10. Reduce brush species dominance and encourage native herbaceous growth on abandoned cropland areas. Frequent growing season fire favors herbaceous over woody species. The more frequent fires in upland communities, the greater likelihood of brush control.
11. Reduce the encroachment of tree species that are not part of the desired community. Frequent growing season fire favors herbaceous over woody species. Tree control through fire is more successful on small, non-fire adapted tree species (Robbins and Myers 1992). The alternatives that utilize fire in the upland communities and maintain a diversity of fire regimes are most likely to achieve this objective.
12. Prepare sites for seeding and planting, and dispose of logging slash. Fire can be used as an effective site preparation and slash disposal technique, but other alternatives to site preparation and slash disposal are available. The alternatives that utilize fire in the upland communities and maintain a diversity of fire regimes are more likely to achieve this objective. The alternatives that are targeted at specific areas (Multiple-objective) or have the greatest fire frequency are most likely to achieve this objective.
13. Utilize management practices to produce traditional forest habitat values: wood, water, wildlife, recreation. Fire is an ecological process in the forest community

of Maryland. Applied appropriately, traditional forest habitat values can be improved. The alternative that provided the greatest diversity of upland communities has the best probability of achieving this objective.

14. Provide compatible public hunting, trapping, and outdoor recreational opportunities. Fire is an ecological process in Maryland ecosystems. Applied appropriately, wildlife oriented outdoor recreational values can be improved. The alternative that provided the greatest diversity of marsh and upland communities has the best probability of achieving this objective.
15. Provide opportunities for the public to understand and appreciate the need for wildland fire activities. A diversity of wildland fire management options will provide more educational opportunities. The alternative that provided the greatest diversity of marsh and upland communities has the best probability of achieving this objective.
16. Comply with State Air Quality Implementation Plans to protect public health. Prescribed fire emissions are defined as anthropogenic pollution. The more smoke produced, the more likelihood of noncompliance with State Air Quality Implementation Plans. Alternatives that minimize prescribed fire use are most likely to achieve this objective.
17. Assure no disruption or adverse impact on transportation/utility corridors occurs from wildland fires. Transportation/utility corridors can be disrupted by both wildfire and prescribed fire management activities and smoke emissions. The more activity, the more likelihood of disruptions. The alternatives that only burn marsh or optimize the area burned have the greatest probability of achieving this objective.
18. Prepare sites for seeding and planting. Fire can be used as an effective site preparation, but other alternatives to site preparation are available. The alternatives that target the use of prescribed fire in the uplands or frequently use fire in the uplands have the greatest probability of objective achievement.
19. Maintain current ecosystem diversity within the landscape context. In order to maintain the current ecosystem diversity, all ecological processes must continue as in the past, which include frequent (annual) marsh burning and fire exclusion in the uplands. However, ecological processes diversity affords the greatest likelihood of ecosystem diversity. Only those alternatives that continue the current fire regimes can fully achieve this objective. Because the Multiple-objective Prescribed Fire Regime sets aside significant marsh acreage in long rotation and fire exclusion zones, this reduces the chances of this alternative achieving this objective. However, the Multiple-objective Prescribed Fire Regime may provide better ecosystem diversity within the landscape context that the current regime.
20. Contribute to the recovery and restoration of the Chesapeake Bay ecosystem diversity and function. Compared to flooding due to sea level rise, fire is an insignificant ecological process in the Chesapeake Bay. However, ecological processes diversity affords the greatest potential for recovery and restoration of ecosystem diversity and function. Only the Multiple-objective Prescribed Fire Regime provides the diversity and flexibility of fully achieving this objective.

21. Protect valuable resources of international, regional, and local significance. Ecological processes diversity affords the greatest potential for resource protection. The Multiple-objective Prescribed Fire Regime provides the diversity and flexibility of fully achieving this objective.
22. Achievable within current funding levels. Program cost increases are directly proportional to the increase in the amount and complexity of the program. Basically, funding is only available to address the current situation and take appropriate suppression actions. More aggressive suppression or increased prescribed fire activity will require additional funds.
23. Achievable under current social and political constraints. Stakeholder informed consent decreases proportional to the amount of program change. The greatest change in the current program would be aggressive suppression and frequent fire regime prescribed fire activity. There is some stakeholder concern over the current situation. Initiating prescribed fire activities in the uplands will generate concern from local citizens, but this can be mitigated by planning that involves the public and performing professionally.

Recommended Alternative and Justification

The panel recommends that MDNR and BNWR begin comprehensive planning to implement the Multiple-objective Prescribed Fire Regime alternative. This alternative best achieves most of the ecological land management objectives (see Matrix above). It also provides the greatest management flexibility and a diversity of fire regimes. This diversity and flexibility will allow the MDNR and BNWR to evaluate the ecological and programmatic effects of a variety of fire regimes. This will require an adaptive management approach which includes adequate land-term research, monitoring and evaluation in order to determine whether or not management actions are achieving unit objectives. Wildland fire management must be fully integrated into the overall unit management plans of these public lands. Building partnerships and fully engaging local residents and the public in this process will also be critical for obtaining stakeholder informed consent.

The panel recognizes that the implementation cost of the Multiple-objective Prescribed Fire Regime alternative may exceed the current fire management budgets of both the MDNR and BNWR. However, no fire management alternative should be implemented if it does not provide confidence to stakeholders and include a process to validate whether or not management objectives are being achieved. Additional research and monitoring effort is needed to evaluate fire impacts on these marshes and their resident and migratory species, regardless of the fire management alternative adopted. Estimating future program costs under any of the management alternatives, even within a large margin of error, is beyond the scope of the panel, and can best be addressed by the agencies' comprehensive planning process. However, this report provides considerable support and justification for increased allocation of resources to fire management programs on these public lands.

The panel feels that this report should assist the agencies to continue ongoing efforts to jointly develop compatible, ecosystem-based, multiple-scale, interagency land management plans that involve all interested parties and facilitate adaptive management. This process should:

X fully integrate ecological concepts that consider long-term dynamics and cross agency boundaries.

X effectively incorporate current fire-related information, including scientific knowledge, risk assessment, social and economic concerns, and public health considerations.

X identify important research/information needs that relate directly or indirectly to marsh vegetation health and sustainability, and fire impacts on component species and communities.

Findings

Wildfire History

Wildland fire is an ecological process and has been a historic part of Dorchester County. The presettlement fire regime may have been relatively frequent, primarily from anthropogenic ignitions (Pyne 1995). European values and land use changes have significantly impacted the historical fire regime. Agriculture and timber production have removed and fragmented almost all the presettlement upland communities. For centuries wildland fire in the upland communities has been suppressed, and little or no prescribed fire has been used. The open marsh community has been dominated by furbearer management practices (Dozier et. al. 1948). Since early settlement the marshes have been prescribed burned almost annually to improve wildlife food production (*Scirpus olneyi*) and facilitate furbearer harvest (Pendleton and Stevenson 1983). For two centuries the application of fire and fire exclusion has significantly affected the ecological characteristics of Dorchester County. The current ecological composition, structure and species populations reflect these fire regimes.

Causes of Marsh Loss

Marshes in the Blackwater area are changing and being rapidly lost as a result of increased relative sea level rise during this century (Kearney and Stevenson 1991). Changes in the rate of sea level rise in the Chesapeake bay area have three components: (1) decidual scale variation of coastal water level, which results from Gulf Stream flow; (2) increases in global sea level, potentially as a result of global warming: and (3) localized increases in the regional land subsidence rate resulting from groundwater withdrawals. Particularly important in the Blackwater area is the significant decline in aquifer pressures, which result from water withdrawals at Cambridge during the 1950s and 1960s. Models predict that this resulted in 14 cm of compaction at nearby Church Creek, mostly due to compaction of the Nanjemoy formation (Tim Rule, personal communication).

The increased flooding resulting from accelerated sea level outpaces the ability of the marsh to accrete soil, which in the Blackwater area is mainly composed of organic peat, leading to conversion of marsh to open water (Stevenson et al. 1985). This may occur because of insufficient periodic drainage of the soil, which stresses and ultimately kills marsh plants. Also, increased inundation, compounded by marsh breakup, has allowed greater intrusion of saline waters into the upper reaches of the Blackwater wetland system. This has not only increased physiological stress of freshwater or otherwise salt-tolerant plants, but also introduced more sulfate, a significant anion in marine and estuarine waters. The availability of sulfate increased the anaerobic decomposition of organic soils and, under anaerobic conditions in the soil, resulted in higher soil sulfide concentrations and additional physiological stress on plants.

Increased relative sea level has, of course, caused increased flooding of low-lying uplands and their conversion to marshes (Nixon 1982), but the gains in marsh area have been relatively small compared to the losses due to the processes described above. The marshes of the Blackwater have, in fact, resulted from slow submergence of upland areas (Kearney and Stevenson 1991). As a consequence, these marshes lack a well-integrated tidal creek network, are relatively isolated from mineral sediment influx, and are drained by a limited number of long first-order tidal creeks in which ebb velocities are stronger than flood tidal velocities. The effect of this physiography is to make such marshes particularly vulnerable to relative sea level rise.

The marsh soils accrete by upward and lateral extension of below-ground rhizome and root networks (Stevenson et al. 1985). Not all of the above-ground and below-ground organic material produced in a marsh is accumulated in peat. In Louisiana 50 percent is lost in 5 months (White et al. 1978). Emergent macrophyte stem and leaf litter subjected to above-ground inundation treatments increase the rate of decay, and inundation retards decay below-ground. Almost half of the flooded above-ground litter was decomposed within 100 days, but half of the flooded below-ground litter remained after 438 days (Neckless and Neill 1994). Less than a third of the below-ground production is buried, and only about 5 percent of the total *Spartina alterniflora* biomass produced in the Sippewissett Marsh on Cape Cod was accumulated in peat (Valiela et. al. 1976). Blackwater marsh soils are almost entirely composed of plant matter and consist of a thick vegetative mat capping a finely divided, highly organic ooze remnant from organic peat deposition. Ebb-tidal dominance continually erodes these soil materials, which are made even more erodible by marsh die-off and salinity intrusion.

Fire Effects on Marsh Vegetation

Dorchester County marsh wildland fires are surface fires. They consume only dead and living plant components and seldom, if ever, consume organic material in the soil. This is because the soils remain saturated. Exactly what effect fire has had on marsh loss is debatable. Fire directly removes organic matter, which could be used in marsh maintenance. Marsh fires in Dorchester County directly consume 0.46 kg m^{-2} of organic material per fire that would be available for sedimentation (Pendleton and Stevenson 1983). Fire increases primary production (Christensen and Wilbur 1993, Hackney and de la Cruz 1992) and metabolism in wetlands (Johnson and Knapp 1993). Fires every 4-5 years maintain the vigor of marshes (Hackney and de la Cruz 1992). This may explain why total standing *Scirpus olneyi* biomass and live biomass were significantly larger in the burned than unburned plots and live below-ground biomass on burned sites exceeded unburned sites by 3.7 kg m^{-2} (Pendleton and Stevenson 1983). The increase in *Scirpus olneyi* production and deposition, especially in below-ground roots and rhizomes, may be equal to or greater than the potential deposition of organic matter lost due to combustion. Pendleton and Stevenson (1983) concluded: "*Annual marsh burning was not directly implicated in marsh losses and, indeed, was found to increase marsh production. In summary marsh losses on the refuge appear from this study to have proceeded from natural causes, primarily that of rising sea levels.*" This conclusion is supported by observations of moderate to complete deterioration of portions of the Nanticoke estuary

marshes (Kearney et al. 1988) that have experienced an infrequent fire regime (Wade Henry, pers. comm.).
The amount of organic matter consumed by fire (0.46 kg m^{-2}) or the increase in live below-ground biomass by fire (3.7 kg m^{-2}) may be insignificant to the 13.8 kg m^{-2} yr^{-1} of net sediment exported from the marsh (Stevenson et. al. 1985). The effect of fire on marsh loss, whether positive or negative, is probably insignificant to the effects of sea level rise. Although the historic open marsh is being lost, fire can hasten the conversion of the upland fringe to open marsh by killing trees and brush, and selecting for marsh plants adapted to fire (e.g., *Scirpus olneyi*).

In addition to the lack to evidence that fire has contributed significantly to marsh loss, it seems also clear that the effects of burning on the ecological components of the marsh and adjacent estuary are small in comparison to the effects of marsh loss itself. The main threat to the biotic integrity of the wetland ecosystem is the rapid conversion of the marsh to open water as a result of the combination of relative sea level rise, hydrologic alteration and salinity intrusion, rather than fire. Marsh deterioration, in combination with ditching and channelization, is allowing salt water to penetrate farther into the Blackwater marshes. Not only are brackish and fresh marshes being lost, but other biota, including fishes (Leon Fewless, personal communication), is shifting to more salt tolerant forms. With the increased salinity comes increased dissolved sulfate concentrations, which in turn allow sulfate reducing bacteria to degrade the peat in anaerobic marsh soils, resulting in a breakup of the highly organic marsh substrate. The release of soil organic matter also results in depleted oxygen concentrations in adjacent water bodies. While breakup of extensive marshes may in the short term facilitate secondary production of fish and shellfish by increasing the marsh-water interface, as marsh deterioration continues the secondary production which depends on this habitat may be expected to decline precipitously (Brower, et al., 1989).

<u>Grazing Impacts on Marsh Vegetation</u>

Another contributing factor to marsh loss is herbivore grazing - muskrats, nutria, and geese. Nutria create openings in the marsh by concentrating their feeding activities (Hilbricht and Ryszkowski 1961, Wentz 1971). These openings are the nucleus (catalyst) for the interior ponding that is accelerating the BNWR and Nanticoke marsh losses. Grazing damage to marsh substrates in most cases is reversible, except in marshes where periodic anoxic water conditions result in adverse physiological effects in the rhizophere of the remaining plants (Mendelssohn et al. 1981).

Grazers (muskrats, nutria, and geese) may have accelerated marsh loss (Pendleton and Stevenson 1983). Unfortunately, the same plants favored by marsh grazers are stimulated by burning (Chabreck 19__), but burning facilitates furbearer trapping - the primary harvest technique for muskrats and nutria. Under historic conditions plant production, either burned or unburned, and grazing impacts reach some dynamic equilibrium. The Dorchester County marshes have two additional stressors that were not present historically: an acceleration in relative sea level rise and nutria. Relative sea level rise is a stressor to marsh vegetation production, and nutria have increased grazing above historic muskrat levels. Geese also have to a lesser extent increased grazing above historic muskrat levels. There may also be some compensatory effects among the three primary grazers. BNWR (1994) estimates the muskrat population has dropped from 7.9 to 3.0, while the nutria population has increased from 0.7 to 2.5 animals per acre from 1987 to 1993. Exclosure data indicates that total exclusion of grazing could significantly subsidize marsh vegetation (Pendleton and Stevenson 1983). Whether this subsidy offsets the stress of relative sea level rise, or if total exclusion is practical, is unknown.

Total elimination of marsh grazing on either State or Federal lands is contrary to the mandate of those lands, whether recreational (hunting, trapping) or ecological (biological diversity, ecosystem function). The historic components of the marsh (muskrats and geese) must remain part of the future marsh. State law (Nutria Eradication Bill) and Federal mandates encourage the complete extirpation of nutria (a noxious introduction), however. The practicality of complete extirpation of nutria is questionable. An estimated cost of $5 million was provided by a leading nutria expert to extirpate the species from Maryland. The State of Maryland has authorized extirpation of nutria (Nutria Eradication Bill), but failed to appropriate any funds for the activity. Recreational, commercial, and professional harvest of nutria at BNWR has steadily increased for the past 10 years from 65 to over 5,000 per year, but the nutria population has also increased from 100 to 15,000. Both State and Federal land management agencies have been using a rebate program to encourage increased harvest since 1990. This effort has led to a harvest rate of 0.9 animals per acre in 1994 (BNWR 1994). An enhanced harvest effort, as part of the MDNR comprehensive nutria eradication assessment at Tudor Farms, indicated that harvest rates of between 6 - 8 animals per acre are possible. The important - yet unanswered - question is, at what level does harvest mortality become additive to natural mortality? Only at that level is management effective.

At best, the current bounty system is of little ecological value, although it does have some political value: "*While the numbers of nutria which can be removed as part of this program is not adequate to keep nutria populations in check, the refuge program has been praised by the local community and Maryland elected officials because the refuge, at least under this program, is attempting to remove nutria and prevent marsh loss*" (BNWR 1994:2). "*Unfortunately the bounty is well adapted to the needs of the poor informed, politically minded administrator or the table-pounding fireball in the sportsman's club. It is likely to be used, and once it is entrenched, the profits enlist loyal supporters*" (Allen 1962:267).

The MDNR comprehensive nutria eradication assessment currently underway should provide some insight into the level and cost of management activity necessary to manage the nutria population at a level that provides an ecological subsidy to marsh vegetation. Additional insight into the compensatory effect nutria harvest has on other marsh grazers, and whether the ecological subsidy provided is worth the cost, will also be helpful.

Fire Effects on Animal Species

All ecological processes such as fire are both an ecological subsidy and a stressor (Lugo 1993). The effects of fire on any specific ecological component (e.g., endangered species, non-game species, waterfowl species, predator-prey relationships, etc.) are dependent on the evolutionary relationship that ecological component has had with the ecological process. For species adapted to fire, fire is a subsidy; but for those same species, fire exclusion is a stressor. The sustainability of these ecological components is ecologically important. Population levels are more politically and socially important. Maintaining biotic integrity is accomplished through an understanding and management of ecological processes (Samson and Knoff 1993). Hydrology (relative sea level rise) and fire are the two most critical ecological processes influencing the Dorchester County marshes. Unfortunately, only limited fire effects research has been conducted to date on Dorchester County rare marsh animals.

Species such as marsh wrens do not nest in the burned portion of the marsh the first year after a fire, but will in the second. Studies indicate that American bittern, black rail, least bittern, and king rail populations may be subsidized by fire exclusion; common moorhen, clapper rail, and Virginia rail populations may be subsidized by fire; and fire or fire exclusion may have no effects on sora rail populations (Dave Brinker, pers. comm.). The frequent fire regime may have contributed to the extirpation of the Eastern Henslow's sparrow from the Dorchester marshes because "thick vegetation seems a basic requirement of its habitat" (Smith 1968:776). Except for the Eastern Henslow sparrow, no other species has been documented as being extirpated over almost 2 centuries of marsh burning. Possibly significantly altering the 2-century subsidy - stressor relation of fire on the marsh, may significantly alter the biological relationship of the marsh.

Forest fragmentation and fire exclusion of upland habitat of Dorchester County has been significant over the past 50 years (Alan Zentz pres comm.). Not surprisingly, fire adapted species have been significantly impacted (e.g., red-cockaded woodpecker, extirpated in the 1970s, and the Delmarva fox squirrel, Federally listed as endangered).

A discussion of the specific fire effects on other species and ecological communities is beyond the scope of this report. The reader can access much of this information through the Fire Effects Information System (FEIS) (Fisher 1989). The computerized FEIS presents concise, easy-to-understand summaries of technical information. The system has information on about 900 plant species, 90 animal species and 25 plant communities. Hessl and Spackman (1995) provide an up-to-date literature synthesis of the effects of fire on threatened and endangered plants. Kirby et al. (1988) provide a literature synthesis on the effects of fire on wetland ecosystems and fire-wildlife relations. The BNWR is also maintaining a comprehensive library of literature and other information to address this issue.

Fire Effects on Human Communities

The social and economic effects of fire on the human environment adjacent to these public lands must also be considered. People live, work, recreate, and have a personal interest in the public wildlands of Dorchester County. Winter marsh wildfires have been a historical occurrence in Dorchester County for decades, and will continue to be a feature of the regional landscape in the future. Since 1990, 12,345 and 53,470 acres have been burned by wildfires and prescribed fires, respectively. Most wildfires were human-caused (arson) fires in the winter, although wildfires (human- and lightning-caused) occur during all seasons (Gerald Vickers, pers. comm.). Many arson fires set in the marsh in the winter are deliberate attempts to improve furbearer trapping efficiency, but others appear to be simple arson, without motive.

The harmful effects of fire on the human environment are many and varied, and include: direct (fire) and indirect (smoke) health and safety effects, personal property damages, and public use and recreation inconveniences. Citizens and firefighters are far too frequently killed or injured by wildfires. Wildland fire smoke has been attributed to highway accidents, and is a recognized human health risk. Personal property damage from wildfires is millions of dollars annually. Wildfires inconvenience thousands of people using public lands each year.

Public policies are not only to manage fire to achieve land management objectives, but also to protect human life and property. This requires Federal and state agencies to address appropriate suppression actions for wildfires on or near agency lands. Appropriate suppression actions may include pressuppression activities (fuel reduction, education, law enforcement, etc.), as well as suppression strategies (contain, confine, and control). All of these actions are currently being used to some degree in Dorchester County.

Despite the lack of good objective assessments as to the cost effectiveness of any of the presuppression actions, public land managers, fire control specialists, and law enforcement specialists have agreed that pre-season prescribed fire fuel reduction is probably the most cost effective technique for preventing wildfires. Comparative wildfire and prescribed fire costs for Region 5 of the U. S. Fish and Wildlife Service were $909 vs. $15 per acre per incident, respectively (Omi et al. 1995). The relationship between decreasing wildfires by increasing prescribed fire seems intuitively to exist, but analysis of existing data has not been able to demonstrate this link (Omi et al. 1995). Hazard fuel reduction prescribed fires can minimize adverse social effects (smoke and inconvenience) through proper scheduling and prescriptions.

Alternatives to hazard fuel reduction prescribed fires, such as education and law enforcement, are far less effective. The public's values and attitudes concerning wildland fire policy are strong and not easily changed (Manfredo 1993). This is particularly true in an area where wildfires have been a common feature for many generations. The application of fire prevention campaigns such as Smokey Bear can be successful, but it has taken Smokey 50 years of work to achieve today's success. Law enforcement may be even less effective. Arson is one of the most difficult crimes to prove, and penalties for wildland arson crimes have little deterrent effect (Vernon Ricker, pers. comm.).

Land management agencies and their cooperators currently are using a combination of all three suppression strategies to suppress wildfires. The suppression objective "*... is to suppress wildfires at minimum cost consistent with values at risk while minimizing the impacts for the suppression activities*" (U. S. Fish and Wildlife Service 1994:3.2-1). Which strategy is used where and under what conditions is determined through planning and public involvement. Through the sharing of resources, suppression costs can be minimized. The establishment of the Delmarva Fire Management Group has facilitated interagency planning and the sharing of resources (Carowan 1992). The interagency fire program infrastructure currently established in Dorchester County is the model currently being advocated by the wildland fire management community.

Burning under exactly the same conditions, the ecological, social and economic effects of a wildfire or prescribed fire are indistinguishable. But because wildfires are unplanned, unscheduled and more poorly controlled events, the effects may or may not be desirable. However, prescribed fire - a managed event - can be planned and scheduled in order to produce specific effects. Through prescriptions and firing patterns, prescribed fire can be used to develop vertical and horizontal habitat structure and vegetation species composition targeted toward the habitat requirements of specific species. Undesirable effects can also be mitigated through scheduling and prescriptions.

Fire Program Management

A fire program of the MDNR and BNWR is no different than any other management program. It requires a good plan that is followed. The plan, in order to be effective, must be integrated into the general management plan for each agency, address cross boundary interests and have the informed consent of the public. The fire program must evolve with changing conditions and that requires an adaptive management structure where fire objectives are established, management actions taken, and outputs obtained and evaluated to determine if they achieved the objectives. If they do not, either the management action or the objective needs to be modified. Such a program requires sufficient resources (funding and qualified personnel) to do the planning, execute the management action, conduct the appropriate monitoring, and perform the evaluation.

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Appendix D: Presenters and Research Projects

Presenter	Research Topic
Dr. Cecil Frost N.C. Dept. of Agriculture and Consumer Services Plant Industry Division P.O. Box 27647 Raleigh, North Carolina 27611	Pre-settlement vegetation and fire frequency.
Dr. Glenn Guntenspergen Natural Resources Research Institute 5013 Miller Trunk Highway Duluth, Minnesota 55811	Elevation monitoring and wetland loss at Blackwater.
Connie Flores Rocky Mtn. Research Station- Fire Sciences Laboratory 5775 W. U.S. Hwy 10 Missoula, Montana 59808	Evaluation of vegetative response to fire exclusion and prescribed fire.
Dr. Jill Rooth Horn Pt. Laboratory, UMCES Box 775 Cambridge, Maryland 21613	Effects of prescribed fire on marsh elevation change.
Dr. Don Cahoon USGS/ Patuxent Wildlife Research Center 11510 American Holly Dr. Laurel, Maryland 20708	Prescribed marsh burning enhances recovery of sedi-ment elevation from flood-induced peat collapse
Dr. J. Court Stevenson Horn Pt. Laboratory, UMCES Box 775 Cambridge, Maryland 21613	Health and long term stability of natural and restored marshes in Chesapeake Bay
Dr. Steve Gabrey N.W. State University of Louisiana Biology Dept. N.W. State Univ. Natchitoches, Louisiana 71497	Effects of winter burning on plant and bird comm.-unities.
Dr. Pete Marra SERC, P.O. Box 28 647 Contee Whart Edgewater, Maryland 21037	Effects of prescribed burning on secretive marsh birds.

Mike Legare Mattamuskeet NWR 38 Mattamuskeet Rd. Swan Quarter, North Carolina 27885	Marsh bird response during two prescribed burns.
Dr. Curt Larson USGS/ Patuxent Wildlife Research Center 11510 American Holly Dr. Laurel, Maryland 20708	A LIDAR Inundation Model for the Blackwater National Wildlife Refuge.
Dr. Stephen Ailstock Ann Arundel C.C. Biology Dept. 101 College Parkway Arnold, Maryland 21012	Phragmites response to burning.

Appendix E: Summaries of Fire Science Conference on November 13 and 14, 2003.

Author: Dr. Cecil Frost
Title: Pre-settlement vegetation and fire frequency
Summary:

Dr. Frost's expertise is in mapping original fire regimes and pre-settlement vegetation. His talk focused on pre-settlement vegetation and landscape fire ecology. Dr. Frost examined 75 marsh communities from Back Bay, south to the Croatan National Forest in North Carolina, and he mapped pre-settlement fire regimes for several agencies. He studied species diversity as it relates to salinity and fire frequency. Dr. Frost stated that species diversity in marshes increases as salinity decreases and as fire frequency increases.

Dr. Frost stated that fire frequency in marsh habitat was related to fire compartment size on the adjacent uplands and to pathways for fire flow. Most marsh fires are ignited from fires in the adjacent uplands. He used the Venus flytrap to illustrate the relationship between fire compartment size and fire frequency. This plant, which dies out if mean fire frequency drops below four years, is found only in the largest fire compartments. This is an ancient species, long preceding the appearance of Native Americans on the scene, and is one of a number of fire frequency indicator species that help us map presettlement fire regimes. Dr. Frost examined lightning strike density on the Delmarva peninsula and determined that this area receives approximately 4 lightning strikes per square kilometer per year. Dr. Frost stated that it is highly unlikely that an annual fire regime existed in Dorchester County based on lightning ignition.

Author: Dr. Glenn Guntenspurgen
Title: Elevation monitoring and wetland loss at Blackwater
Summary:

Dr. Guntenspergen's presentation focused on elevation monitoring and wetland loss at Blackwater National Wildlife Refuge. He stated that the current rate of sea level rise at rates of 3-4 mm/ year is exceeding the sediment deposit rates of 1-2 mm/ year. He presented a flow chart depicting multiple variables that affect marsh elevation and dynamics, including rising sea level, tidal flooding, sedimentation, vertical accretion, soil volume, compaction/decomposition, changes in ground water, subsidence and plant processes.

Dr. Guntenspergen also displayed the Sediment Elevation Table (SET) that measures both surface and subsurface processes that may affect elevation. Dr. Guntenspurgen and others established this SET at 3 sites throughout Blackwater along an elevation gradient, not taking into consideration fire frequency. He suggested that local processes such as groundwater flux issues may be more of a contributing factor in land subsidence. Blackwater is a rapidly deteriorating system in which marsh surface elevation is not keeping pace with sea-level rise. The marsh is expanding up-slope, but breaking up as well.

Author: Conception Flores
Title: Evaluation of vegetative response to fire exclusion and prescribed fire rotation on Blackwater National Wildlife Refuge and Fishing Bay Wildlife Management Area.
Summary:

In 1998, Ms. Flores initiated a fire evaluation study on Blackwater National Wildlife Refuge (NWR) and Fishing Bay Wildlife Management Area (WMA) to compare the vegetative response of 2 fire rotations and fire exclusion at 6 tidal marsh areas. The 6 marsh areas were divided into 2 treatment sites (annual burn and 3-year burn) and 2 control sites (no burn). To provide an equal basis for comparisons, all sites (N=24) were initially burned in 1998. Ms. Flores collected vegetation data for percent cover, average height, biomass, and stem density at all sites, just after the growing season from September-December 1998-2001. Prescribed burns were conducted on the annual burn treatment areas from January-March 1998-2002. The 3-year treatment sites were burned once from January-March 2001. Ms. Flores conducted a macro-analysis of the overall cover, average height, total biomass, live biomass, litter and stem density data for all species and conducted species specific analysis for: *Distichlis spicata, Juncus roemerianus, Schoenoplectus americanus, Spartina alterniflora,* and *Spartina patens*. She found no significant difference for cover among the 2 treatment and the 2 control sites. However, she did find a difference among the years, with 2001 having the greatest cover and 2000 having the least cover. In 1999, a drought may have negatively affected the vegetation. Ms. Flores found significantly greater live biomass (biomass without litter) in annual burn sites than the other sites. She analyzed litter separately and found significantly less litter among annual burn sites. For stem density, Ms. Flores found that the annual burn sites had significantly higher stem densities than the 3-year treatment or control sites. In addition, 1998 had significantly greater stem densities than the other years. In her macro-analysis (all species), Ms. Flores found that fire had a positive effect (increase) on cover biomass and stem density for *Distichlis spicata, Spartina alterniflora* and *Spartina patens* and a negative effect (decrease) on litter. In her micro-analysis (only sites with ≥ 25% of the dominant species), Ms. Flores found that fire had a positive effect for *Distichlis spicata* and *Spartina alterniflora* biomass and stem density. Fire also increased *Spartina patens* stem densities.

Author: Dr. Jill Rooth
Title: Effects of prescribed fire on marsh elevation change
Summary:

Dr. Rooth stated there are contradictory scientific findings relating the effect of prescribed fire on marsh vegetation. Therefore, it makes it difficult to determine how it would impact marshes under stress from a myriad of negative forcing functions such as sea-level rise. Within Chesapeake Bay, tidal marshes were historically burned for “renewal of vegetation”, to manage unwanted marsh plants (those perceived as not providing wildlife fodder or protection) and to promote trapper access during colder months. Marsh burning removes a considerable amount of accumulated litter that collects on the marsh surface during senescence each fall and winter. Subsequently, a reduction in total organic material near to or on top of the sediment surface reduces overall structural complexity of the wintering marsh community. It is that structural

complexity that can reduce the velocity of the incoming tidal water, consequently causing sediment to deposit on top of the marsh. Mineral sediment deposition is critical to the survival of these highly organic systems that are undergoing rapid subsidence. Other forcing functions that are contributing to wetland loss of the NWR/WMA complex are regional sea-level rise, rodent herbivory, historic groundwater withdrawal, and salinity intrusion.
Study results indicate that over three growing seasons, subsidence prevails at all sites, regardless of the annual burn or no burn treatment. The only significant contribution of accretion to the marshes during monitoring was from Hurricane Isabel in 2003. The fire's removal of organic material both, in terms of lowering organic deposition and marsh surface complexity, appears not to be a factor controlling accretion in those areas annually burned. Rate of elevation change and accretion were more likely to vary with location then paired sites (annual burn versus no burn). This suggests the role of prescribed fire in short-term applications is not playing a decisive factor in the sustainability of marshes. Localized factors such as distance to sediment source and amount of inundation were immediately controlling the elevation of the study marshes. Although cause and effect would predicate that fire would have a role in elevation change there was no consistent evidence to suggest this was occurring.

Author: Dr. Donald Cahoon
Title: Prescribed marsh burning enhances recovery of sediment elevation from flood induced peat collapse.
Summary:

Summary findings of the presentation are excerpted from:

Cahoon, D. R., M. A. Ford, and P. F. Hensel (2004), Ecogeomorphology of *Spartina patens*-Dominated Tidal Marshes: Soil Organic Matter Accumulation, Marsh Elevation Dynamics, and Disturbance, in *The Ecogeomorphology of Tidal Marshes, Coastal Estuarine Stud.*, vol. 59, edited by S. Fagherazzi, M. Marani, and L. K. Blum, pp. 247–266, AGU, Washington, D. C.

"Surface erosion and accretion processes contributed little if any to soil elevation changes during the death and subsequent recovery of the *Spartina patens*-dominated marsh. Instead, marsh elevation was controlled by soil (i.e., subsurface) organic matter accumulation dynamics, which were affected by plant mortality and prescribed burning. Elevation of the underlying marsh peat collapsed as a result of flood-induced mass plant mortality. Following the peat collapse, recovery of elevation was related to increases in the volume of organic material in the root zone, and burning enhanced the volume of organic material and the rate of elevation recovery. How burning affected soil organic matter volume is not clear. Burning of the dead marsh substrate may have increased root production through enhanced plant colonization of the highly disturbed substrate, which is in direct contrast to findings by Gabrey and Afton [2001] and Schmitz [2000] where burning of healthy marshes did not affect belowground production. On the other hand, the effects of burning on soil decomposition processes cannot be overlooked. Burning may have limited the colonization of the substrate by soil fungi by removing the plant canopy."

"From a management perspective, it is important to understand how disturbance affects soil organic matter accumulation and marsh elevation so that appropriate management practices can be developed. We know that lethal stresses on *S. patens* can lead to peat collapse. But we need to better understand the effect of sub-lethal stress from chronic low levels of disturbance (e.g., flooding, grazing, and burning), and the interactive effect of multiple stressors (e.g., sea-level rise and burning), on soil organic matter accumulation and marsh soil elevation change. For individual sub-lethal stresses, such as prescribed burning, we need to understand the extent and intensity of its impact on the relationship between soil organic matter accumulation and soil elevation. For example, does the rapid re-mineralization of plant matter caused by burning act like a fertilizer and enhance soil organic matter? Data from healthy marshes suggests it does not [Gabrey and Afton, 2001; Schmitz, 2000], but our data from an acutely stressed marsh suggests it does. If re-mineralization by burning enhances soil organic matter, will the soil nutrient supply become depleted and limit soil organic matter accumulation if the marsh is burned every year? The typical burning frequency for *S. patens* marshes in Louisiana and Texas is approximately every 3 years [Nyman and Chabreck, 1995], compared to an annual burning frequency at Blackwater National Wildlife Refuge in Chesapeake Bay [Flores, 2003]. What is the fire frequency that will maximize soil organic matter accumulation and marsh soil elevation?"

Author: Dr. J. Court Stevenson
Title: Health and long term stability of natural and restored
Marshes in Chesapeake Bay.
Summary:

The health and long term stability of natural and restored marshes in Chesapeake Bay. Relative sea level is rising in the Chesapeake Bay. This can be balanced by sediment/organic accretion in healthy marshes. Blackwater NWR is a low productivity marsh. Dr. Stevenson adds that marsh burning promotes *S. americanus* which promotes grazing. "Burning should be done on a more limited and experimental basis"
The sediment budget for the Blackwater river has output exceeding input. Dr. Stevenson created cosms for conducting various marsh experiments, including burning. He emphasized that we should not conduct spring burns. (note: The refuge does not conduct spring burns in the marsh) His burning in the cosms showed that *S. americanus* responded with enhanced productivity. Dr. Stevenson also emphasized the need to measure below ground biomass as well as above ground. He determined there was not much difference in nitrogen amounts in the burn vs no burn areas. A big problem with BWR marshes is that they suffer from anoxia. Blackwater embayments go completely anoxic in the water column in the summer. He also added that phragmites can double sediment accretion. Dr. Stevenson also said that the problem with winter fire is that it encourages *S. americanus* at the expense of other non-fire adapted plant species (which can aerate and hold sediment in place).

Author: Dr. Steve Gabrey
Title: Effects of winter burning on plant and bird communities.
Summary:

Burning in Louisiana marshes, managing for snow geese habitat. The goal at Rockefeller NWR was to remove *Spartina patens* and replace with *Schoenoplectus americanus*. The experiment looked at whether or not snow geese prefer burned or unburned marsh.

Dr. Gabrey discovered that burning only plays a part in determining vegetation communities. Salinity and flooding regime were equally as important. *S. patens* perks up 1.5 years after burning, however, there was no change in species or composition. There was a decrease in biomass for the first 2 years.

The study also looked at smaller birds, such as blackbirds and grackles, marsh wrens and sparrows. It was discovered that during the winter period 2 months post burn, blackbirds and grackles liked burned areas and marshwrens and sparrows did not. However, 1 year post burn wrens and sparrows densities were the same as pre-burn. During a post summer burn 6 month survey, densities decreased. One and a half years later though, the densities more than doubled. It appears that the impacts to the wrens and sparrows last about 1 year.

Author: Dr. Pete Marra
Title: Effects of prescribed burning on secretive marsh birds.
Summary:

Effects of prescribed burning on secretive marsh birds. Seaside sparrows and coastal plain swamp sparrows. Does prescribed burning impact non-breeding season bird density? Does prescribed burning impact breeding season bird density? Dr. Marra looked at nest predation rates in natural and artificial nests, reproductive success and annual return rates. Dr. Marra felt it was unfortunate how the sites were selected, as they were not replicate of each other. He looked at annual and no burn sites on Fishing Bay Wildlife Management Area. He asked the question, "does prescribed burning influence wintering bird communities?" There is no evidence of depauperate communities. "This is the time to burn". Dr. Marra also examined whether or not there is an impact from prescribed burning on breeding marsh bird density. He concluded there was not much difference in species richness and diversity.

Dr. Marra also examined the influences that prescribed burning has on reproductive success and annual survival. He studied the seaside sparrow because there are plenty available to study. Some of the causes of failure include predation and flooding. He also asked the question, "does burning influence nest predation?". He found that in 2002 burning had a significant effect on predation of nests. He also reminded everyone of the extreme drought throughout the state in 2002. In 2003, there was no effect on the nests from predation, possibly as a result of an extremely wet year. Dr. Marra found that the greatest number of predators were small mammals, and artificial nests results were similar to natural nests. He felt that before we draw any conclusions, we need more years of data. Based upon what data he has examined, there does not appear to be a difference between burned and unburned areas. The clutch size and fledge rates were equal. The nest predation was higher on burn sites during incubation, but the total number of young fledged was higher on burn sites. He feels that more years on reproductive success and annual survival are needed. Along with small mammal surveys, food sampling and consistent monitoring.

Author: Mike Legare
Title: Marsh bird response during two prescribed burns.
Summary:

Mr. LeGare's presentation was from an operational experience of how prescribed burns are conducted in Florida. Mike's interest is in Black Rails, which has adapted to a fire-dependent species. The three main reasons burns are conducted in Florida are hazard fuel reduction, ecological burning and ecosystem management. Firefighters want to see "clean burns", with no unburned patches of fuel. Mr. LeGare is saying it's important to leave even small, unburned patches that the black rails could hide in. Contrary to popular belief, these birds do not just fly away when the fire approaches. They tend to stay close to the ground and hide and let the fire pass. This struggle between burning for resource value, i.e. birds, etc. conflicts with the firefighters goal to burn quickly, cleanly and operationally safely to manage for smoke issues is where the challenge lies. (note: Blackwater and Fishing Bay prescribed fire goals are to produce a mosaic of burned vs. unburned)

Author: Dr. Curt Larson
Title: A LIDAR Inundation Model for the Blackwater NWR
Summary:

LIDAR sea inundation model for Blackwater. Dr. Larson produced a photo of a map from 1877 that showed the area that is now BWR, mostly forested.
Blackwater has no source of incoming sediment other than adjacent uplands which provide little sediment, thus the refuge is being drowned.

Inundation of a preexisting land surface is the dominant natural process affecting the refuge. Blackwater did not become a marsh until the 20th century. Dr. Larson presented several scenarios projecting sea level rise. In his "business as usual" scenario, the long term trend of sea level rise will continue at a current rate of 3.1 mm/yr. The lidar shows an increase in the area of open water that is relatively constant until about 2050 when open water shows a marked increase. This is due to topographic influences. The intertidal marsh area increases continually in keeping with the open water. It expands after 2050. Sea level overruns the existing landforms after 2050 and high marsh begins a major decline. Dr. Larson also presented a "global warming" scenario. With sea level rise, the rate of inundation will be much more rapid. Much of the refuge will be covered by open water by 2100.

Author: Dr. Stephen Ailstock
Title: Phragmites response to burning
Summary:

Dr. Ailstock examined fire as an element of phragmites control program, and fire as a promoter of phragmites recruitment. Dr. Ailstock manages phragmites for national security. He keeps it in check in areas where line of sight to potential targets is an issue. Dr. Ailstock stated that litter is a very important thing for plants, and that phragmites is a self mulching plant. It creates a lot of micro-climates which encourages diversity. To treat phragmites, we need to combine spraying (rodeo) with burning. Phragmites produces abundant seeds and also spreads through rhizomes. Seeds that land on bare soil do very well. Seeds that land on plants, or water, do not. He asked the question, “are we creating a good host by burning the phragmites?”

Appendix E:

Review of Fire Management Programs for Fishing Bay Wildlife Management Area and Blackwater National Wildlife Refuge

conducted for

U.S. Fish and Wildlife Service and Maryland Department of Natural Resources

by

Dr. Donald F. Boesch, Mr. Willard P. Leenhouts, Dr. Douglas A. Samson, and Dr. Edward C. Soutiere

April 2004

Introduction

In April 1996 a Panel of five scientific experts was convened to review fire management practices at the Blackwater National Wildlife Refuge (BNWR) and adjacent wetland areas managed by the Maryland Department of Natural Resources, particularly the Fishing Bay Wildlife Management Area (FBWMA). These areas are located along the Eastern Shore of the Chesapeake Bay. The Panel's report[1] evaluated existing practices at the Refuge and nearby management areas and specifically considered six possible fire management alternatives. The Panel concluded that the technical basis to support fire management and prescribed burns then practiced was inadequate and recommended the *Multiple-Objective Prescribed Fire Regime* as preferred among the possible management alternatives in order to best achieve the agencies' ecological land management objectives while meeting their social responsibilities. Because of the general lack of technical evidence concerning the efficacy of fire management, the Panel further recommended that adaptive management, coupled with active monitoring and long-term research and assessment, be applied to guide changes in management objectives and actions in the future.

While the agencies indicate they have followed the Multiple-Objective Prescribed Fire Regime "exceptionally well," they felt it was necessary to reconvene the Panel to review whether the results of monitoring and research efforts demonstrate that this management plan is achieving the desired results. Accordingly, four of the original members of the Panel (one member was prevented from attending by illness) reconvened

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[1] *Technical Review of Fire Management Alternatives in the Blackwater National Wildlife Refuge and Adjacent Wetland Management Areas*, April 1996, U.S. Fish and Wildlife Service.

on November 13 and 14, 2003, at the Horn Point Laboratory of the University of Maryland Center for Environmental Science near Cambridge to review new information related to the use of prescribed fire in this and similar ecosystems. The members and institutional affiliations of the Panel members are provided in Appendix 1.

The Panel was asked to prepare a report that either reconfirms, modifies, or replaces the original recommendations and identifies and prioritizes future research needs. The Panel was also given a long list of questions to consider, which were grouped under five technical issues:

A. The current prescribed fire program does/does not consider natural burn cycles in achieving management objectives.
B. The current prescribed fire program is/is not adversely affecting vertical accretion, above and below ground biomass, and species of conservation concern.
C. The current prescribed fire program does/does not consider differing fire frequencies by community type.
D. The multiple-objective prescribed fire management regimes do/do not contribute to invasion of exotic species (nutria, *Phragmites*, etc.).
E. Conversion of marsh to open water will/will not continue irrespective of the use of fire.

The overarching conclusions and recommendations are first presented and the specific consideration of these five technical issues evaluated in greater detail.

Overarching Conclusions and Recommendations

The Panel was specifically asked to make recommendations either to reconfirm, modify, or replace the originally recommended Multiple-Objective Prescribed Fire Regime. After considering the above specific consideration of the five issues, we found that:

a. The current program was designed to address 22 specific management objectives, not to mimic natural burn cycles. To do this would require a very different prescribed fire program[2]. However, marsh vegetation community types and their natural fire regimes should be considered when establishing burning frequencies under the multiple-objective fire regime approach.
b. Based on the existing evidence it cannot be confidently concluded that the prescribed fire programs at BNWR and FBWMA are having either a positive or negative effect on soil accretion or loss and the rate of conversion of marsh to open water. A definitive understanding of the role of fire in marsh soil accretion

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[2] Robbins, L. E. and R. L. Myers. 1992. Seasonal effects of prescribed burning in Florida: a review. Tall Timbers Research, Inc. Misc. Publ. No. 8. 96pp.

will probably require a comprehensive, long-term, well-funded research and assessment commitment.

c. The management agencies have only modestly quantified the effects of the fire management program on species of conservation concern or invasion of exotic species.

Having said that, we have no basis for recommending changes in the management regime at this time. Quite honestly, though, we are less confident in supporting this regime than we were in 1996 because we have learned relatively little over the past eight years other than that the issues are much more complex, questions much more difficult to answer, and management implications much more diverse then originally thought. Consequently, it is impossible to judge whether the multiple, complexly related objectives of the regime are being achieved. We are disappointed that the agencies have failed—or been unable—to obtain sufficient funding and support to implement the Panel's additional recommendation to institute an effective adaptive management program, one which integrates active monitoring, and long-term research and assessment, in order to guide changes in management objectives and actions in the future.

The refuges encompass the most extensive tidal wetlands in the heart of the Chesapeake Bay, the largest estuary in the United States, which is itself the subject of an expensive and internationally prominent restoration and management program. The Panel believes that this justifies a much greater investment in strategic research, monitoring and assessment, which should focus on two priority issues:

1. The effects of fire frequency and other processes subject to management intervention on the sustainability of this valuable wetland ecosystem, particularly plant community dynamics and their effects on marsh accretion in the face of rising sea level.

2. The consequences of fire frequency on species of special conservation concern, including seaside sparrows, wintering waterfowl, forest interior-dwelling species, and the endangered Delmarva fox squirrel.

The Panel believes that research related to plant communities (species composition, community structure, above and below-ground production, detrital exchange, and nutrient cycling) is important only in so far as it helps resolve the central questions of wetland sustainability and habitat suitability for species of special concern. Furthermore, research related to animal populations other than those of special concern is of much lower priority.

Evaluation of Specific Issues

Issue A: ***The current prescribed fire does/does not consider natural burn cycles in achieving management objectives.***

The original charge of the panel in 1995 was to provide fire management recommendations to BNWR and FBWMA to incorporate 22 management objectives, none of which were to mimic natural burn cycles. Implementing a natural fire regime was not one of the six alternatives evaluated by the panel. The multiple-objective prescribed fire regime alternative provided BNWR and FBWMA the opportunity to accomplish many if not most of its 22 management objectives. Burning to reduce hazardous fuel conditions (to protect private property, sensitive species, or both), to promote rare, threatened and endangered species, and to enhance habitat for wildlife species, all represent legitimate and/or mandatory management objectives that may be mutually exclusive of the application of natural burn cycles (or our best approximation thereof), over large portions of the managed landscape. Said differently, even if our knowledge of pre-settlement fire frequencies, seasonality and average magnitude was perfect and complete, mimicking those patterns with prescribed burning would only be appropriate in those portions of the marsh not subject to management for other objectives.

Having acknowledged that, it was observed that the current prescribed fire program at BNWR and FBWMA does not mimic natural burn cycles, for several reasons.

First, "natural" burn cycles—that is, long-term average fire frequencies (or fire-return intervals) for both upland and marsh habitats in southern Dorchester County prior to European colonization (including both wildfires and fires set by Native Americans), are unknown. Frost[3] suggested that pre-settlement fire frequencies in this part of Maryland were 4 to 6 years, based on his review of fire history studies and analysis of fire compartment size, as interpreted from land surface form maps. But the scale of his analysis fails to discriminate between upland and marsh habitats, much less between different vegetative communities in the marsh. Work done by Frost in marshes farther south along the Atlantic (Virginia, North and South Carolina) suggests that pre-settlement fire frequencies for oligohaline and brackish marshes were 1 to 5 and 4 to 6 years, respectively[4]. But no similar analyses have been done for marshes on the Eastern Shore of Maryland, so the effects that local compartment size, prevailing winds, nearby water bodies (e.g., Chesapeake Bay), etc., might have had on natural fire frequencies have not been examined. Further, the history of Native American use of tidal habitats in Dorchester County, and whether or not fire was used to manage marsh communities, is unknown. The limited anecdotal information available on the frequency of "natural" (i.e., lightning-caused) wildfires in Dorchester County marshes today suggests a much longer fire return interval, but because vegetative cover is likely to be significantly different now than in pre-settlement times, such observations are difficult to interpret.

Second, the location of treatment areas where current burn regimes (annual, 3 to 5 years, 7 to10 years and no-burn) are being applied to marsh habitats at BNWR and

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[3] Frost, C.C. 1998. Presettlement fire frequency regimes of the United States: a first approximation. *Tall Timbers Fire Ecology Conference Proceedings* 20: 70-81.
[4] Frost, C.C. 1995. Presettlement fire regimes in southeastern marshes, peatlands and swamps. *Tall Timbers Fire Ecology Conference Proceedings* 19: 39-60.
Frost. C.C. 1996. *Presettlement Vegetation of the Croatan National Forest, North Carolina*. Report to the U.S. Department of Agriculture Forest Service, Croatan Ranger District, New Bern, NC.

FBWMA were apparently selected for reasons of accessibility, logistics (e.g., arrangement of natural fire breaks), and other considerations (e.g., presence/absence of sensitive species), rather than because it was determined that those areas were subjected to particular fire-return intervals pre-settlement. Thus, there is no deliberate correspondence between different marsh community types and prescribed burn frequencies (see also separate discussion of Issue C), and a given marsh community type is subjected to different burn regimes in different areas of BNWR and FBWMA.

Third, even with a management approach that includes multiple burn treatments, this burn regime is unlikely to closely mimic pre-settlement natural cycles, because:

1. The seasonality of burning is likely to be different now than under pre-settlement conditions. Local climate patterns are such that lightning-ignited wildfires were probably most frequent in summer and fall, rather than winter, when most of the current prescribed burning is done. Nothing is known about the seasonality of Native American marsh burning, if it happened at all.
2. Under pre-settlement conditions, we would expect a frequency distribution of return intervals for wildfires started by natural ignition events. That is, while a given section of marsh might have burned on average, say, every six years, some areas would have burned annually and some only once every 15 to 20 years. Applying fire repeatedly to a treatment area at a *set* interval, even when it approximates what we think the *average* pre-settlement fire-return interval might have been, minimizes the temporal variation in the occurrence of fire that likely characterized the region pre-colonization.
3. Similarly, the amount (acreage) of marsh burned during any one fire under pre-settlement conditions likely varied dramatically within and among years and across the local landscape. This variation—from a few acres to thousands of acres, depending on circumstances—is presumed to have had significant effects on the population dynamics of both resident and migratory animal species—at all trophic levels—using the marsh. Ironically, deliberately *not* burning sections of the marsh at all, and/or suppressing any wildfires that might get started in designated "no-burn" zones, likely creates "artificial" conditions relative to what would have prevailed in pre-settlement times, when presumably most or all of the marsh would have burned at some frequency.

Fourth and finally, social and political restrictions (e.g., public safety and human property protection, air quality issues, concerns of nesting season burning killing young animals in nests, etc.) limit many of the extreme and ecologically important prescriptions necessary to mimic natural fires (e.g., a high intensity wind-driven fire during drought conditions which occasionally occurs could not be risked today).

Not being able to implement a natural fire regime does not mean that the knowledge of historic fire regimes is not important. Studies such as those done by Frost and others carried out in southern Dorchester County would improve our understanding of pre-settlement fire regimes in this region. This information will be quite useful in understanding and identifying the fire regimes needed to achieve BNWR and FBWMA management objectives.

Determining a natural fire cycle is fraught with much uncertainty. To begin to empirically demonstrate "natural burn cycles" for Blackwater and Fishing Bay, a large (5-10,000 ac?) area with no prescribed burning would need to be set aside, and the frequency and extent of naturally-ignited fires would need to be recorded over a time period (15-20 yrs?) long enough to allow vegetation communities approximating pre-settlement conditions to become reestablished. Unfortunately, the history of Native American use of the marshes, and how that use may or may not have altered natural burn cycles, may never be known. Thus, even if empirical data on wildfires and natural burn cycles were collected, they will provide an incomplete picture of the burn cycles and patterns that would have structured marsh communities pre-settlement.

The current prescribed burn program at BNWR and FBWMA is using an overall burn regime that represents an approximation of what average natural burn cycles might have been pre-settlement, based on best available knowledge. But the current knowledge base is minimal, especially for southern Dorchester County, and the prescribed burn treatments in use likely differ from pre-settlement cycles in their seasonality, their variation in time and space, and in the degree to which different return intervals correspond to different vegetative community types. Given its significance as one of the dominant ecological processes in these marsh communities, this means that fire is likely affecting native plant and animal populations quite differently now than in pre-settlement times.

To make assessment of this issue even more difficult, this entire question is rendered moot—at least for the area currently occupied by BNWR and FBWMA—if it turns out that marsh communities prior to 1500 covered significantly less area than in the last 200 years. That is, if the vast expanses of tidal marshes in southern Dorchester County have developed with sea level rise and land subsidence only in the last two centuries or less (for which there is some evidence), there were no "natural burn cycles" for marsh communities pre-settlement. Or they were quite different, given that the vegetative landscape mosaic would have been very different. At the same time, however, tidal marsh communities no doubt covered thousands of acres elsewhere around the Chesapeake Bay pre-settlement. So if periodic wildfires are presumed to have been an important natural disturbance process in those communities historically, the question remains relevant, but on a regional rather than site level.

Issue B: ***The current prescribed fire program is/is not adversely affecting vertical accretion, above and below ground biomass, and species of conservation concern.***

When the Panel reviewed fire management alternatives in 1996, it was presented with conflicting evidence and opinions about whether periodic burning negatively or positively affected the longevity of tidal marshes in a rapidly subsiding environment, such as at the BNWR and FBWMA. On one hand, it was argued that fire consumed the vascular plant detritus originating from aboveground production that is essential to soil building in a subsiding wetland that is starved of mineral sediment sources. On the other, it was argued that burning increased belowground production through fertilization and other effects, thereby increasing the volume of roots and rhizomes and related organic detritus in the soil.

Several studies on the effects of burning on Blackwater marshes have been conducted in the intervening years. These have produced mixed and generally inconclusive results with regard to addressing Issue B. One study found that while burning increased stem density and aboveground biomass, it also reduced plant litter on the marsh surface.[5] Another found no consistent differences in soil elevation between matched burned and unburned sites[6]. In some cases burned sites showed more or less elevation change and soil accretion, but this was largely attributable to differences between control and treatment plots, for example whether the site was affected by nutria disturbance. Recent USGS studies of changes in marsh elevation at Blackwater have also not demonstrated any effect of burning on soil volume and sediment elevation similar to those observed in Texas Gulf Coast marshes, where burning enhanced the recovery of sediment elevation from flood-induced peat collapse.[7]

The results of the studies on marsh health and soil accretion did not fully address the Panel's earlier questions regarding the long-term effects of burning on the marsh itself, a key issue for judging the wisdom and sustainability of prescribed burning. The studies thus far have been either modest in scope; limited by designs that did not adequately take into account small-scale variability; very late in coming, or not adequately funded to undertake the comprehensive (expensive) analysis needed to effectively answer this quite difficult and complex issue. We are left with virtually the same uncertainty that existed in 1996 with regard to this most important issue.

The effects of the current prescribed fire program on species of conservation concern are addressed under Issue C.

Issue C: ***The current prescribed fire program does/does not consider differing fire frequencies by community type.***

The current prescribed fire program at BNWR and FBWMA does not specifically adjust fire frequency to individual community types. That is, as discussed under Issue A, there is no deliberate correspondence between different marsh community types and prescribed burn frequencies. Rather, the program is an accommodation to Department of Interior policies, practical on-the-ground limitations imposed by considerations for safety, accessibility, logistics, and resource management objectives, and, finally, by the

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[5] Flores, C. 2003. *Evaluation of Vegetative Responses to Fire Exclusion and Prescribed Fire Rotation on Blackwater National Wildlife Refuge and Fishing Bay Wildlife Management Area.* M.S. Thesis, University of Maryland Eastern Shore, Princess Anne, MD.

[6] Rooth, J.E. 2003. *To Burn or Not to Burn… The Effect of Prescribed Fire on Marsh Elevation Change.* Report to Blackwater National Wildlife Refuge.

[7] Guntenspergen, G. Presentation to the Panel, November 13, 2003. Cahoon, D.R. Presentation to the Panel, November 13, 2003.

recommendations made by the 1996 panel regarding a multiple-objective prescribed fire regime.

As dictated by Department of Interior policies, fire protection and management priorities require BNWR to protect life and health first, property and natural/cultural resources second. Should it become necessary to prioritize between property and natural/cultural resources, the refuge must prioritize based on relative values to be protected, commensurate with fire management costs. It was because BNWR integrated prescribed fire into its management plans on a landscape scale, and not on a community scale, that the 1996 panel recommended the multiple-objective regime with the goal of meeting the needs of the varied plant and animal communities. Before 1996 approximately 30,700 of the 31,300 acres of marshlands within the BNWR and FBWMA were burned annually. The current prescribed burn rotations are as follows: 9,300 acres annual, of which 5,600 are for hazardous fuel reduction; 6,300 acres, 3-5 years; 5.700 acres, 7-10 years; and 10,000 acres, no burning.

As discussed under Issue A, the available evidence suggests that the plant and animal communities dominating the Maryland Eastern Shore developed under a natural fire regime of fires on a frequency of 4 to 6 years, although the burn frequency for tidal marshes is less well known. Studies on the effects of fire on bird species found that different species utilize different habitat niches. For example, fewer black rails and seaside sparrows but more grackles and Eastern meadowlarks use areas that are annually burned[8]. Since there is a special concern for black rails and seaside sparrows on the refuge, which seem to do best under fire frequencies of 3 to 5 years, burning on that frequency, which is more in line with the natural fire regime, would favor the species of special concern over those more adapted to annual fire regime habitats.

BNWR has had as a goal of their fire program the promotion of the three-square bulrush (*Schoenoplectus americanus*) community. Study results are mixed. Some studies found that burning increased above ground live-stem density and live-biomass, but recent studies at Blackwater found no such effect[9]. Salinity and elevation appear to be the dominant factors determining the presence or absence of three-square bulrush. Burning can potentially give three-square bulrush an early start during the growing season, permitting it to out compete smooth and meadow marshhay cordgrass, but burning alone will not maintain the species and should not be substituted for necessary water levels and salinities in the management of this species or any other coastal species[10].

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[8] Kirby, R. E. 1988. Fire in North American wetland ecosystems and fire – wildlife relations: an annotated bibliography. U.S. Fish and Wildl. Serv., Biol. Rep. 88(1),. 146 pp.

[9] Flores, C. 2003. op. cit.

[10] Chabreck, R.H.. 1976. Management of wetlands for wildlife habitat improvement. Pages 226-233 *in* M. Wiley, ed. Estuarine precesses. Vol. I. Uses, stresses, and adaptation to the estuary. Academic Press, New York.

Nyman, J. A. and R. H. Chabreck. 1995. Fire in coastal marshes: history and recent concerns. Pages 34-141 *in* S. I. Cerulean and R. T. Engstrum, eds. Fire in wetlands: a management perspective. Proc. Of the Tall Timbers Fire Ecol. Conf. No. 19. Tall Timbers Research Station,Tallahassee, FL.

The experimental study plots set up to determine the effects of fire frequency on plant and animal communities on BNWR had significant shortcomings. The plant communities differ too greatly between the Blackwater River plots and the Fishing Bay plot to effectively serve as paired plots in a research design. If feasible, the Refuge should lay out a second set of plots to be paired with each site.

Issue D: ***The multiple-objective prescribed fire management regime does/does not contribute to invasion of exotic species (nutria, Phragmites, etc.).***

As discussed under Issue A, fire is an important part of the ecology of Maryland's Eastern Shore. And while Native Americans and early European settlers burned the marshes to improve wildlife food production and facilitate furbearer harvest, fire has been excluded from almost all upland plant communities. However, marsh burning continues as planned prescribed fire and/or unplanned and unwanted arson fires.

Fire is a classic disturbance agent. It changes ecosystems, community, and population structure, either by selectively favoring certain species or creating conditions for new species to invade. It usually favors early successional species, but can sometimes accelerate succession in favor of late successional species. It usually increases mineral elements and temporarily reduces total site nitrogen while at the same time increasing available nitrogen. The physical environment is also altered. Such effects are specific to the fire, fire regime, ecosystem and individual plant and animal species.[11] Since many exotic species are adapted to disturbance, the risk of creating a favorable environment for an exotic invader and exacerbating the impact of an existing exotic species increases as the disturbance regime becomes more frequent and/or severe (irrespective of whether the disturbance is a planned prescribed fire or a unplanned and unwanted arson fire).

At Blackwater National Wildlife Refuge (NWR) two exotic species are of greatest interest: nutria, *Myocastor coypus,* and the common reed, *Phragmites australis*. However, other invasive species are also of concern, especially if fire is reintroduced into the upland plant communities (e.g., multiflora rose, *Rosa multiflora*; common buckthorn, *Rhamnus cathartica*; Asian honeysuckles, *Lonicera* spp.; Japanese barberry, *Berberis thunbergii*; Scotch broom, *Cytisus scoparius*, and Japanese stiltgrass, *Microstegium vimineum*).

Nutria. Willner et al.[12] found that three-square bulrush, *Schoenoplectus americanus,* roots were a preferred nutria food, comprising nearly 80 percent of its diet. While they found that *Schoenoplectus* increased in cover following burning and was out competed by other species without periodic fire, more recent studies have yielded no evidence that fire at the BNWR is maintaining or increasing the coverage of three-square bulrush (as discussed under Issue C, above). If frequent fire did increase *Schoenoplectus* cover, using fire to increase a preferred food source of a desired species such as muskrat, could

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[11] Agee, J. K. 1993. *Fire Ecology of Pacific Northwest Forest*. Island Press. Washington, DC. 491p.
[12] Willner, G. R., J. A. Chapman, D. Pursley. 1979. Reproduction, physiological responses, food habits, and abundance of nutria on Maryland marshes. *Wildl. Monographs*. 65:1-43.

have the unintended effect of increasing populations of destructive nutria as well. Greater nutria populations increase nutria feeding and marsh disturbance and possibly marsh deterioration. In the 1996 Panel review, the destructive effects of nutria feeding activities on the marshes were a major concern. It was suggested that these effects overwhelmed any effects of fire management. By 2003 nutria populations have been considerably reduced, in large part as a result of aggressive eradication efforts. This experience indicates that burning is at most a secondary consideration with regard to management of this invasive rodent, and that direct population controls will be required in any case.

Phragmites Most fires favor *Phragmites*. Fire removes the standing dead canes and accumulated litter, allowing the soil to warm up rapidly in the spring, which results in earlier shoot emergence. Stands burned during the spring (before shoot emergence or during early growth stages), late summer or fall (plants green or dormant), or winter recover quickly; preburn stem density and biomass are attained within one growing season. Although plants burned during the summer usually initiate new top-growth within a few days, stem density is greatly reduced, and stems regrow to only about half of normal height before killing frosts occur. Furthermore, early to midsummer burning during the peak of plant growth (when carbohydrate reserves are lowest) reduces stem density and aboveground biomass for two to four growing seasons.[13] In addition to rhizomatous growth and reproduction, *Phragmites* reproduces successfully by seed especially if the seed falls on moist, bare mineral soil (i.e., a burned marsh where litter is removed). Since burning under high litter moisture content or a flooded marsh can reduce or eliminate litter consumption, prescribed fires may be preferable to wildfires in preventing or retarding *Phragmites* invasion or expansion.

Other species. Among invasive plant species, root total non-structural carbohydrate (TNC) level of a plant is a key indicator of their potential proliferation.[14] Both cutting and burning treatments impact root TNC levels, but growing season treatments had the greatest multiple-year impact. Multiple treatments (cutting and burning) appear to prevent recovery of root TNC to pre-treatment levels for at least two years. The implications are that the timing of disturbances may be even more important than the type of activity (cutting versus burning). To have the greatest success at reducing woody stems, a treatment should be conducted during periods of low below-ground carbohydrate storage (such as immediately after spring flushing and growth) and should be followed with a second growing season treatment before root TNC levels are replenished. The timing of prescribed fire and/or mechanical treatments should be planned appropriately to take advantage of this physiological phenomena.

The multiple-objective prescribed fire management regime, in conjunction with specific management prescriptions (e.g., litter moisture levels) provides the greatest

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[13] Uchytil, Ronald J. 1992. *Phragmites australis*. In: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (2003, October). Fire Effects Information System, [Online]. Available: http://www.fs.fed.us/database/feis/.
[14] Richburg, J. A. and W. A. Patterson III. 2001. Fire and invasive plants in the Northeastern United States. http://www.fs.fed.us/ne/durham/4155/fire/dibble1_jfsp.html#top

flexibility to tailor a fire (disturbance) regime that can address the particular exotic species issue(s) of interest. The U.S. Fish and Wildlife Service requires every National Wildlife Refuge develop a Habitat Management Plan (HMP). It is the HMP where exotic species' concerns are identified, management conflicts reconciled, habitat goals and objectives identified, and habitat management strategies developed, including the appropriate disturbance regime (location, timing, frequency, and intensity parameters). The HMP integrates fire management into overall refuge management and should be developed as soon as possible.

Issue E: ***Conversion of marsh to open water will/will not continue irrespective of the use of fire.***

There is every reason to believe that the trend of conversion of marsh to open water at BNWR and FBWMA will continue irrespective of the use of fire, but the important question is whether or not this conversion will be accelerated by the continuation of the Multiple-Objective Prescribed Fire Regime. That is a much more difficult question to answer.

Stevenson et al.[15] reviewed the health and long-term stability of the marshes of the Chesapeake Bay, finding that marshes around the bay have been negatively affected by the imbalance between relative sea-level rise and marsh soil accretion. They further noted that even more dramatic losses of marshes have been observed around the BNWR, and attributed these changes to more rapid land subsidence due to groundwater withdrawals[16], reductions of ground water inflows, hydrological modifications and the destructive effects of nutria. Furthermore, the eustatic component of local sea level rise is highly likely to accelerate during the 21st century due to global warming[17], putting greater pressure on tidal wetlands of the BNWR and FBWMA. This was well demonstrated by the NOAA inundation model for the BNWR[18] based on LIDAR elevation surveys. This model does not, however, simulate marsh responses, including soil accretion and marsh losses and gains.

The extensive tidal marshes of the Blackwater and Fishing Bay areas are geologically recent and dynamic environments, built after flooding of low-lying fastlands during a period of relatively stable sea level. They cannot be preserved forever and will experience losses due to inundation and shoreline erosion, as well as gains due to transgression across low-lying fastland. The management plans for BNWR and FBWMA should acknowledge that and seek to minimize wetland losses and maximize gains in this dynamic ecosystem. Although the consequences of fire management in this regime are

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[15] Stevenson, J.C., J.E. Rooth, M.S. Kearney, and K.L. Sundberg. 2001. The health and long-term stability of natural and restored marshes in Chesapeake Bay.
[16] The effects of subsidence induced by groundwater withdrawals was disputed by Curt Larson (NOAA) who presented evidence to the Panel that relative sea-level rise rates were similar at Solomons and Cambridge.
[17] Wood, R.J., D.F. Boesch, and V.S. Kennedy. 2002. Future consequences of climate change for the Chesapeake Bay ecosystem and its fisheries. *American Fisheries Society Symposium* 32:171-184.
[18] Larson, C. Presentation to the Panel, November 13, 2003.

relatively small in comparison to other factors, they should be factored into this dynamic management regime designed to maximize wetland longevity while accommodating transition. At this point, there is no evidence that prescribed fire is enhancing the health and longevity of the marshes and only speculation that it may be having a negative effect.