FIRE AND VEGETATION IN PEAT-BASED MARSHES OF THE COASTAL PLAIN: EXAMPLES FROM THE OKEFENOKEE AND GREAT DISMAL SWAMPS

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INTRODUCTION

Although the majority of the world's peat-based habitats are found in north temperate or boreal areas (Gore 1983), some of these ecologically important communities are in the Coastal Plain of the Southeastern United States (Hofstetter 1983). The Southeastern peat deposits support a mosaic of related habitats (cf. Hamilton 1984) ranging from densely wooded swamp forests to open, grassy habitats. In some areas the latter are shallow marshes (Figure 1), locally termed "prairies" (Okefenokee Swamp, Wright and Wright 1932 and Cypert 1961); in other areas, sites with scattered woody species are called "light swamps" or "lights" (Great Dismal Swamp, Kearney 1901 and Dean 1969). Recently, the peat-based, shallow marshes have become a topic of both fire and management concern.

Peat, substrate formed by partial decomposition of plant material in water, burns readily at sufficiently low moisture content (< 30%, Craighead 1974). Peat-based habitats can support both surface and ground fires, depending on environmental conditions; fire may not only remove above ground vegetation but may also decrease the depth of the peat substrate. Many authors have assumed that ground fires are associated with formation and/or maintenance of open, shallow marshes within Coastal Plain swamps (e.g. Cypert 1961, 1972, 1973; Hamilton 1984), although some have viewed fire solely as a human disturbance with negative impact on the timber of these habitats (e.g. Whitehead 1972, Dean 1969).

Historically, open areas within forested swamp complexes have received little attention, perhaps because the nonforested areas constitute only a small proportion (< 20%) of the total area of the ecosystem (cf. Cypert 1973). Most early descriptions of Coastal Plain peat areas focused on the valuable timber present (reviewed in Hopkins 1947 and Dean 1969). This lack of attention to nonforested areas biased initial assessment of wildlife diversity (Rose et al. 1990). Recent accounts now suggest that open areas are disproportionally utilized by some vertebrates (Rose et al. 1990) and, therefore, are important in maintaining species diversity. Cypert (1973) believed that loss of these areas would cause local extinction of many species, especially wading birds. Two of the more prominent Coastal Plain peat-based ecosystems are in the

Figure 1. A typical Okefenokee prairie (shallow marsh) dotted with small tree islands.

Okefenokee National Wildlife Refuge (NWR) of Georgia and the Great Dismal Swamp NWR of North Carolina and Virginia. Both refuges have a history of human intervention and there has been concern that open, shallow marsh habitat has declined, as a result, in part, of fire suppression (cf. Cypert 1973). In this paper, we review information on land use, community composition, past vegetation patterns and fire history in the two swamps. Then we assess the potential importance of open, nonforested areas to overall biotic diversity of the refuges, consider the costs and benefits of possible fire plans and evaluate the accompanying management challenges.

SITES

The Great Dismal Swamp once covered more than 5,700 km^2 but is now restricted to less than 2,000 km^2 (estimates reviewed by Oaks and Whitehead 1979) and only 10% of that is contained in the NWR. Drainage canals, logging and farming, all initiated more than 250 years ago, account for much of the area decline; today, road construction, draining and development continue to degrade some areas. The last remnants of old-growth timber were removed in the 1930s and much of the current vegetation is categorized as "second- or third-growth forests and dense brushlands" (Levy and Walker 1979). The Great Dismal currently is dominated by dense, woody vegetation

(Rose et al. 1990). Levy and Walker (1979) reviewed the numerous plant community types recognized in the swamp; they are all categorized by woody species.

Only two small natural open areas exist, excluding small, managed wildlife plots (Great Dismal Swamp NWR 1988). Today, less than 0.05% of this refuge is nonforested. In conjunction with remote sensing applications at the swamp, Carter (1979) discussed a small marsh with the water table just below the surface. She listed four characteristic plants: *Typha* spp. (cattail), *Sagittaria* spp. (arrowhead), *Orontium aquaticum* (goldenclub) and *Carex* spp. (sedge). These species, now relatively rare in the Great Dismal, were present in well-defined zones that persisted 4,000-8,000 years ago (Whitehead 1972).

Not only has this community type apparently declined over geologic time but remaining remnants have declined in historic time, as a result of human activity. There are land use records (reviewed in Carter 1979) that suggest that the current marsh of about 25 hectares was approximately 5 times larger 200 years ago and was used by George Washington to grow rice. It seems possible that 200 years ago there were additional scattered marshes in the Great Dismal.

The original size of the Okefenokee was estimated at 2,000-2,800 km^2 (McQueen and Mizell 1926). Today, the area remains relatively stable, with 1600 km^2 in the NWR (Eadie 1984). However, nearly all of the original cypress (more than 500,000,000 m^3 of timber) was removed before 1930 (Izlar 1984). In addition, this swamp's hydrology may have been altered by a canal dug in the 1890s (Izlar 1984) and a sill constructed in 1960 (Finn and Rykiel 1979).

In the Okefenokee, more than 22 shallow peat-based marshes (prairies) with patches of open water, a few cm to a meter deep, occupy approximately 240 km^2; they range in size from almost 30 to less than 0.2 km^2 (Cypert 1973). McCaffrey and Hamilton (1984) distinguished two types: 1) "herbaceous prairie" dominated by emergent vegetation, and 2) "aquatic macrophyte prairie" vegetated primarily by rooted and/or floating dicots in the water-lily family (Table 1). In the latter type, herbaceous emergents are also common. Almost twenty years ago Cypert (1973) estimated that these habitats constituted less than 20 percent of an area otherwise dominated by woody species; today there are concerns that the prairies have declined in acreage. Various combinations of scrub-shrub wetland species (Table 2) seem to be encroaching, perhaps, in part, as an aftermath to logging (e.g. Hamilton 1984).

There are two types of forested areas in the swamp: 1) wetlands, characterized by cypress (*Taxodium distichum*) and/or black gum (*Nyssa sylvatica*), and 2) uplands supporting pine (*Pinus elliottii* and *P. palustris*). The pine habitats, scattered across the swamp and surrounding the outer perimeter, are of special interest because they are also fire communities. Unlike peat fires however, fires in frequently burned pine areas are relatively easy to contain and/or suppress. Upland pine habitats therefore could serve as buffer zones. Unfortunately, there are numerous NWR boundary areas that cut across peat habitat; the upland pines are outside the perimeter of the NWR and, as such, are outside the realm of public land management.

Table 1. Characteristic plant species of shallow marshes or "prairies" in the Okefenokee Swamp of south Georgia. Based on information from McCaffrey and Hamilton (1984).

SCIENTIFIC NAME	COMMON NAME
HERBACEOUS PRAIRIE	
Andropogon virginicus	broom sedge
Carex spp.	sedge
Decodon virginia	water loosestrife
Eriocaulon compressum	pipewort
Lachnanthes caroliniana	red root
Nymphaea odorata	water-lily
Orontium aquaticum	neverwet
Panicum spp.	panic grass
Peltandra sagittaefolia	arrow-arum
Sarracenia spp.	pitcher plant
Woodwardia virginica	chain fern
Xyris smalliana	hardhead
AQUATIC MACROPHYTHE PRAIRIE	
Ericaulon compressum	pipewort
Nuphar luteum ssp. macrophyllum	spatter-dock
Nymphaea odorata	water-lily
Nymphoides aquatica	floating-heart
Orontium aquaticum	neverwet
Peltandra virginica	
Pontederia cordata	pickerel-weed
Utricularia spp.	bladderwort
Xyris smalliana	hardhead

Table 2. Characteristic plant species of "scrub-shrub" wetlands in the Okefenokee Swamp of south Georgia. Based on information in McCaffrey and Hamilton (1984).

SCIENTIFIC NAME	COMMON NAME
Cephalanthus occidentalis	button bush
Clethra alnifolia	sweet pepper bush
Cyrilla racemiflora	titi
Ilex spp.	
Lyonia lucida	fetterbush
Smilax laurifolia	green briar
Vaccinium spp.	blueberry

ECOLOGICAL IMPORTANCE OF NONFORESTED AREAS

Although open, nonforested areas are a small portion of each refuge, they have important implications for maintaining wildlife diversity plus supporting many aquatic plant species. For the Okefenokee Swamp, Cypert (1973) listed at least 19 species of wading birds that he believed to be dependent upon shallow marshes (Table 3); in addition, he speculated that the round-tailed muskrat (*Neofiber alleni exoristus*) would disappear without shallow marshes and that the American alligator (*Alligator mississippiensis*) and waterfowl in general would decline.

There is little information on animal species associated with the small marsh area of the Great Dismal Swamp. Murray (1969) commented on the dirth of water birds throughout the swamp; he noted that many of those present (e.g. several heron species) were relegated to feeding along the artificial canals. Rose et al. (1990) found that 5 of the 12 resident mammals species were found only in nonforested habitats. They also discovered that two species of shrews, previously listed as rare, (*Sorex longirostris fisherii* and *Synaptomys cooperi helaletes*) were relatively common in nonforested areas.

PEAT DEPOSITS AND VEGETATION PAST HISTORY

The swamps of the Coastal Plain are very young in origin, probably less than 10,000 years old, and have been inhabited by humans for at least the

Table 3. Partial list of bird species associated with or dependent up shallow marshes in the Okefenokee Swamp. Based on Cypert (1973).

SCIENTIFIC NAME	COMMON NAME
Ardea herodias	Great Blue Heron
Butorides lentiginosus	American Bittern
Butorides striatus	Green Heron
Casmerodius albus	Great Egret
Egretta thula	Snowy Egret
Eudocimus albus	White Ibis
Florida caerulea	Little Blue Heron
Gallinula chloropus	Common Gallinule
Hydranassa tricolor	Louisiana Heron
Ixobrychus exilis	Least Bittern
Nyctanassa violacea	Yellow-crowned Night Heron
Nycticorax nycticorax	Black-crowned Night Heron
Pandion haliaetus	Osprey
Plegadis falcinellus	Glossy Ibis
Porphyrula martinica	Purple Gallinule
Rallus elegans	King Rail
Rallus limicola	Virginia Rail
Rallus longirostris	Clapper Rail

last 4,000 years (e.g. Trowell 1984). The oldest peat deposits in the Okefenokee NWR are 6,000-7,000 years old, although some areas are of more recent origin (i.e. peat in Sapling Prairie of 1,875 ± 60 years, Cohen et al. 1984). Peat depth ranges up to 4m; accumulation rates have been estimated at 0.03-0.10 cm/year in the Okefenokee (Cohen et al. 1984).

In the Great Dismal, swamp formation began 11-12,000 years ago with the oldest peat approximately 9,000 years old and up to 5m deep (Whitehead and Oaks 1979). The estimated accumulation rate is 0.05 cm/year (Whitehead and Oaks 1979). Extensive human alteration of hydrology, begun over 100 years ago, has been blamed for promoting oxidation and the subsequent loss of a meter or more of peat from parts of the Great Dismal; Whitehead and Oaks (1979) estimated that this peat took 3,000 year to accumulate.

Peat serves not only as the habitat substrate but also as a record of past vegetation. That record can be explored in two ways; 1) the composition of the vegetation that created the peat can be determined and 2) the relative amounts of pollen representing surrounding plant communities can be examined.

Variation in the composition of peat indicates that the two swamps experienced different patterns of vegetational history. Unfortunately, only anecdotal discussion of this evidence exists for the Great Dismal. Whitehead and Oaks (1979) commented that the older peat of that site suggests an expansive primeval, open marshy habitat and postulated that "...the development of a forested swamp took much time and progressed through a series of marshy phases." This scenario is supported only by limited data and it is not known whether such change was uniform over the entire swamp.

Peat types are much better quantified for the Okefenokee. Cohen et al. (1984) analyzed cores representing many areas in the swamp; site-to-site differences in past patterns of vegetation were evident among cores. For example, some sites exhibited a continuous peat core based on *Nymphaea* whereas cores from other sites contained up to five different peat types, indicating five different dominant plant communities over the centuries. Many cores also exhibited large, distinct bands of charcoal (0.25-1.5 cm thick), indicating past fire.

One core, from a currently forested site on a peat island (Cohen et al. 1984), revealed evidence of a minimum of 10 periods of intensive and/or frequent fire (e.g. large bands of charcoal) over an estimated 9,000 years; conservatively, this suggests major peat fires once every few hundred years. Conversely, other cores contained no large bands of charcoal. Charcoal particles, however, were found through out the peat stratigraphy of the swamp. Of special interest is the observation that all cores ended in a large charcoal band, suggesting that the entire area experienced one or more tremendous catastrophic fires approximately 10,000+ years ago.

The study of pollen stratigraphy has historically received more attention from researchers than has peat composition. This approach provides regional information on vegetation patterns. Pollen from the Great Dismal peats corroborates the long-term shift from expansive marsh to a forested swamp (e.g.

Whitehead 1972) indicated by studies of peat types. Rich (1984) examined the oldest pollen samples from the Okefenokee and concluded that, initially, the lower areas of that swamp began as open marsh with the higher ridges occupied by dry prairie. Research on subsequent Okefenokee pollen samples by Fearn and Cohen (1984) documented extensive vegetational change, including a substantial increase in *Taxodium* and a decline in *Quercus*.

Examination of both peat type and relative amounts of pollen in the peat suggests no distinct vegetation equilibrium. Shifts in vegetation type, while perhaps recently influenced by humans, were occurring before the arrival of Europeans. Some argument can be made for native peoples influencing habitats (cf. Robbins and Myers 1989) by altering fire frequency and/or seasonality (see below), but natural forces may be foremost in promoting vegetation changes.

FIRE

Some workers have suggested that fire suppression has altered the landscape of southeastern peat-based habitats (cf. Cypert 1972; Rose et al. 1990). Occasional fires may be necessary for the perpetuation of prairies (Cypert 1961, 1973; Hamilton 1984; Whitehead 1972) and other open areas (Dean 1969). This implies that peat in the marshes must be removed periodically; if accumulation exceeds oxidation rates, then open marshes would eventually disappear. This has important implications for management. Indigenous peoples may have shifted local fire regimes but they had no ability to suppress fire during drought conditions.

Fire is accepted as an important natural component in most Coastal Plain ecosystems (e.g. Christensen 1981, 1988), and is a common management tool; its impact is well-known, at least at a general level in some systems (e.g. longleaf pine-wiregrass, Abrahmson and Hartnett 1990). There is, however, little documentation of the importance of fire in shallow peat-based marshes. Cypert (1961) noted that when peat was relatively shallow, roots of woody species often penetrated the underlying sand; he recorded sufficient root survival in such areas after the 1954-1955 Okefenokee fires to allow many species to resprout. Hamilton (1984), using aerial photographs from 1953 and 1977, was able to document the formation of a "small herbaceous prairie" as the result of a catastrophic peat fire.

Unlike the relatively low-intensity surface fires associated with longleaf pine, peat burns in a more catastrophic fashion. By definition, peat fires are ground fires and consequently are difficult to contain and suppress (cf. Pyne 1984), especially because they occur under drought conditions. However, Cypert (1961, 1973) suggested that the peat fires which land managers have for so long attempted to prevent, are actually necessary for the maintenance of some marshes. Without periodic catastrophic burns, Cypert (1973) believed that these habitats would decline as the result of encroachment by woody plants. Almost thirty years after Cypert (1961) first voiced concern over the decline of wet prairies associated with peat in southeastern Georgia, these concerns have reappeared (Okefenokee NWR 1988). In Virginia and North Carolina, sites known to have historically supported shallow marshes, few areas of open water exist and presumed encroachment of woody plants is almost total (Whitehead 1972). While there is little information on the extent of open marshes in the Great Dismal before the mid-1900s, currently the refuge is interested in their value to wildlife (Great Dismal NWR 1988).

Shallow marshes may result from deep peat fires (cf. Cypert 1961, 1973; Hamilton 1984; Whitehead 1972), although widespread documentation is lacking. Duever and Riopelle (1984) suggest that, between fires in the Okefenokee, woody species naturally begin to invade exposed peat islands scattered over the marsh. Human activities such as draining, logging, farming and road construction, coupled with active fire suppression, undoubtedly shifted the amount and types of fuel as well as alternating fire frequency and perhaps seasonality.

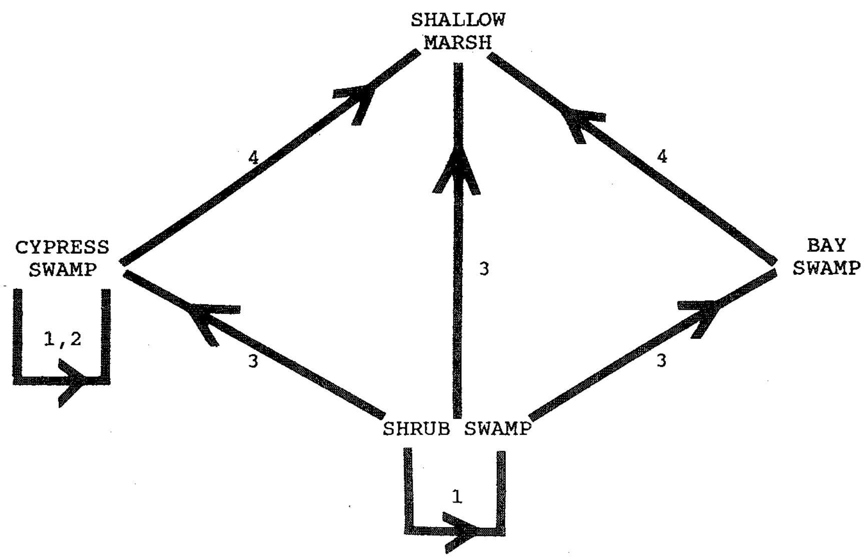
It is this proposed change in fire regime that has been blamed, at least in part, for encroachment of woody vegetation in shallow marshes of the Okefenokee (Cypert 1961, 1973). However, this is supposition and corroborative evidence has not been collected. An additional consideration must be the impact of past logging; in the Okefenokee, there are no longer enough large cypress trees to serve as a seed source for recolonization after a fire. This alone could disrupt a habitat's ability to respond to peat burns (see Hamilton 1984).

Hamilton (1984) presented a model relating fire severity to initial and resultant plant community types. When the artificial influence of logging was removed, the model projected the importance of intense burns (Figure 2). This scenario suggests that relatively severe fires are necessary to shift any of three basic Okefenokee forest vegetation states to open marsh.

No time frame is indicated in the model, therefore there is no prediction of natural fire frequency. An unstated assumption is that reversion to a previous vegetation state occurs in the absence of fire, although there is no estimation of the length of time required. From an ecological perspective, this model is of interest, even without a temporal component. From a management perspective, the lack of a time frame is problematic. If, in reality, the temporal perspective is on the order of centuries, then no current land management philosophy incorporates this pattern of fire history. If it is on the order of many decades, then prescribed fire or an alternative activity must be addressed by management.

Based on observations of plots established after the Okefenokee fires of 1954 and 1955, Cypert (1973) commented that, although peat was destroyed by fire in 1954 and 1955, this loss was not sufficient to create extensive new prairie habitat. He believed that the last period of prairie initiation followed catastrophic fires in 1844. Trowell (1987) outlined conditions that he thought were most likely to promote peat-consuming fires. He expected these fires to be associated with unusually dry, windy spring weather following a harsh winter, during which above ground woody vegetation had been killed by

Figure 2. Effects of fire in the Okefenokee. Modified from Hamilton 1984.



1 = LIGHT FIRE
2 = MODERATE FIRE
3 = SEVERE FIRE
4 = VERY SEVERE FIRE OR FREQUENT FIRES

freezes. This would literally create brush piles and, therefore, good burning conditions. Dead woody vegetation creates "hot spots" during fires in other habitats (sandhill, R. Myers pers. comm.; longleaf pine, Hermann pers. obs.).

If catastrophic peat fires are vital to the perpetuation of marshes in swamps, then they occur in a time frame of many decades to a few centuries. Human activity in the Great Dismal has occurred over a long enough period that marsh formation and/or maintenance may well have been influenced by commercial development. If droughts severe enough to permit extensive peat fires occur every 50-100 years, then areas in the Great Dismal may have missed 1-4 catastrophic fires; however, the impact of this is unclear. Logging has interrupted the natural pattern of vegetation response to fires and undoubtedly, alteration of hydrology has played a part in the decline of wetlands.

In the Okefenokee, hydrologic changes have occurred over a much shorter time and fire suppression has been attempted for only a few decades. It is unlikely that all open areas have been substantially influenced and that the area covered by marshes has decline significantly, as the result of fire suppression. However, the impact of alterations in moisture regime is unclear, especially if the loss of the huge quantity of transpiring old-growth cypress is considered.

In any comparison between the Great Dismal and the Okefenokee, an additional factor must be explored. Although both swamps are in the fire-dominated Coastal Plain, the Great Dismal is approximately 800 km north of the Okefenokee. The likelihood of fire ignition by lightning may very well be different across such a distance. In addition, there is evidence that the Okefenokee Swamp may actually create its own weather patterns (Paul and Waters 1978).

MANAGEMENT CONSIDERATIONS

There are at least three basic problems that must be addressed and quantified before open marsh, peat-based habitats can be effectively managed. 1) Can a loss of habitat actually be documented? To date, all concerns have been based on personal observations and intuition. 2) If a loss has occurred, what are the ecological implications? Again, to date, concerns have been based on intuition. 3) If habitat loss occurs can it be attributed to human activities?

The third question is one that land stewards often ask, believing that if changes result from human intervention, a different course of management will be required than if the shift is natural. If the answer to question 3 is yes, restoration activities may be appropriate; rarely will a habitat heal itself after severe human intervention. If the answer to 3 is no, a philosophical question must be considered. Is the goal of management to mimic nature or is it to produce and/or perpetuate an ecologically important habitat state?

For the Okefenokee, examination of aerial photographs and relocation of Cypert's plots (Cypert 1961, 1973) may provide an answer to question 1. Species lists for specific sites in the swamp reported by Wright and Wright (1932) also may provide a useful comparison with modern observations. Analysis of additional peat cores should be useful in creating a vegetation map over time for sites of interest. Population studies and long-term monitoring on a variety of species are required to answer question 2. Given the extent of human activities in this swamp, the answer to question 3 perhaps seems obvious. However, the relatively short time since human intrusion might limit the impact of this factor. Depending upon land stewardship philosophy, the answer to question 3 may have little impact on management decisions.

For the Great Dismal, historic records provide few answers to the questions proposed above. So little open marsh habitat remains that ecological importance may be difficult to quantify. One approach is to increase marsh area, through management, and then study subsequent wildlife use (see below).

In the past, one approach to managing a peat-based habitat has been to keep the fuel wet so that ground fire is impossible. This is the reason for sill construction in the Okefenokee during the 1960s, although it seems doubtful that this structure could influence the entire swamp during a severe drought, the most probable time for peat fires. More recently, this same approach has been considered for an area of the Mattamuskeet NWR, near the Great Dismal. J. Wiggington (USFWS, pers. comm.) described a "plumbing system" to keep the water table high. During normal to wet years, there is little danger of peat fire and elevated water levels may enhance peat accumulation. During severe drought years, no control system can keep an area flooded if no water is available. In addition, artificial elevation of water levels may enhance peat formation and eventually result in increased fuel available to fire during extreme droughts.

Serious consideration must be given to the question of whether management should attempt to mimic natural processes or whether the goal should be a desired habitat state that is reached by any means deemed appropriate. Since the habitats under consideration have been altered to some extent by human activities, it is not certain that, even if reintroduction of natural processes were possible, the components of the habitat would respond in a natural fashion. For example, Harmon (1984) demonstrated that reintroduction of a pre-suppression fire regime to the Great Smokey Mountains National Park was not sufficient to restore undisturbed forest structure.

There is, however, always a strong reason for understanding natural processes, even if they are not employed in management. The information learned through such inquiry will be invaluable in understanding what habitat states are desired and in the development of management plans.

RESEARCH AND LONG-TERM MONITORING

A review of the ecology and management concerns associated with marshes and swamp forests reveals how little we know about these habitats. Pollen profiles outline the species basis of regional plant communities but there is still much that can be learned from the composition of the peat deposits themselves. Detailed descriptions of peat composition from numerous sites are needed to provide vegetation maps of the swamp at different points in time. The work of Cohen (1974) and Cohen et al. (1984) provide examples of the information that can be gained through this type of study. Understanding the natural history of the Great Dismal would be increased dramatically by similar studies.

Additional information relating to the patterns of vegetational change are needed. Cypert (1961, 1973) initiated such studies by establishing transects for monitoring vegetation after the severe fires of 1954 and 1955. Unfortunately, like many fire studies, no preburn data were available. Although Cypert envisioned the transects as a long-term research project, monitoring ceased when he retired. This illustrates the importance of agency commitment to obtaining such information; interest of individual managers and researchers will not sustain monitoring over the length of time necessary to provide answers to important conservation questions.

The chance for monitoring the impact of peat fires is obviously limited; these types of burns are rare. Unlike other habitats, there have been no agency sponsored projects focused on vegetation recovery after peat fires in swamps or marshes, consequently all possible opportunities to study them should be utilized. The steps taken by Yellowstone National Park to research the impacts of the severe fires of 1988, could be used as a model procedure for studying peat fires. In Yellowstone, using projected direction of fire movement, plots were established and preburn data recorded ahead of the wildfire. This could be done for some targeted peat fires on public lands. Unfortunately, while much of the financing for fire research resides with National Parks and Forests, much of the peat-based swamps needing study are on USFWS property along the East Coast.

Hydrological monitoring in marshes and swamps has been needed for many years. If such monitoring had been in place when the sill in the Okefenokee was constructed, documentation of impacts were and indication of corrective measures would be available to land managers. Hydrological monitoring would also provide the baseline data necessary for the construction of models to predict the outcome of fire, peat accumulation and water table fluctuation.

PRESCRIBED PEAT FIRE

During 1986 and 87, The Great Dismal Swamp NWR addressed the problem of lack of shallow open wetlands in the refuge. Through careful planning the refuge prescribed small (> 150 hectares) peat fires. The areas used no longer supported standing water and were accessible to equipment. A small bulldozer with wide pads and a KG blade was used to clear a 50-foot-wide strip and a fire lane was plowed in the center of this area. Sites were chosen such that the water table was never more than 0.5 m below the surface and in many places the plowed line contacted mineral soil. Plots were subjected to a variety of preburn treatments including vegetation 1) left standing, 2) pushed with a KG blade, 3) pushed and piled, or 4) chopped.

In addition to the above activities, Hermann (1988) suggested the use of soaking hoses in the lanes, in an attempt to extend containment lines as saturated zones below the surface. If a deep fire lane is used and a water source convenient, it may be possible to flood a trench (see Parker et al. 1947) and use this saturated area as a fire line. Hermann (1988) also recommended moving additional dead woody vegetation on to the burn site to mimic the scenario suggested by Trowell (1987) and enhance the formation of hot spots; R. Myers (TNC, pers. comm.) has employed similar methods when burning sand pine.

The burns on the piled sites were especially successful and peat levels were lowered 15-30 cm; in one instance the depth was lowered by 45 cm. A. Carter (USFWS) evaluated the outcome of these experimental burns. Personnel costs were high for the amount of land burned, as a result of prolonged mop-up activities. While containment created few problems, smoke management was an ever present concern. Some of the fires were followed by a period of drought and the depressions created were covered with dog fennel (*Eupatorium* sp.). Other depressions, although wet, remained devoid of vegetation and, initially, were not particularly good waterfowl habitat. Within 3-4 years changes were observed. Some of the deeper burns had open water and supported no vegetation. Others, however, began to show improved conditions for waterfowl. The depressions have remained wet and now contain cattail, willow and graminoids. Dog fennel has disappeared and an increase in waterfowl use has been observed. It is expected that these areas will continue to change with time.

The experience in the Great Dismal suggests that it might be useful to examine the potential of a soil seed bank. Work from the Okefenokee demonstrated that, at least in some sites, there was an appropriate and sufficiently deeply buried bank of viable seeds to revegetate a burned site under appropriate moisture conditions. Gunter et al. (1984) examined seeds from peat cores taken from a marsh and a forested site in the Okefenokee. Seeds were viable down to approximately 50 cm. Interestingly, the species composition of the seeds from both sites reflected herbaceous marsh vegetation; woody species were poorly represented. This type of study has yet to be pursued in the Great Dismal. Under ideal conditions, a land manger would sample a site for buried seeds in order to anticipate what vegetation might repopulate a prescribed peat-fire area. The possibility of seed dispersal from nearby areas should also be considered, as should seeding selected sites artificially.

Of special interest is the possibility that a series of light to moderate burns might produce results similar to one severe fire. Hamilton (1984) implied this (Figure 2), as have many land managers. Moderate fires might keep encroachment of woody species at bay but, it is not likely to be sufficient to remove them; most of the woody species can resprout from root stock. To kill hardwood species, a fire may need to burn deep into the substrate. A moderate fire may only prune stems. Unless another fire occurs in a relatively short period, pruned plants will resprout, grow and produce more above ground stems than existed before the moderate fire. Use of light to moderate fires should be explored on an experimental basis, with thought given to what fire frequency would be needed to meet management objectives. However, unless extreme droughts occur often, frequent fires may not be possible.

SUMMARY

The lack of knowledge of the dynamics of shallow marsh habitats in forested swamps should be of concern to both land managers and conservationists. Not only is there little understanding of how to manage these habitats, there is no quantified description of desired habitat states. Immediate attention should be given to acquiring this basic knowledge.

It may not be appropriate for managers to attempt to mimic exactly how these habitats functioned before human intervention. The landscape of the Coastal Plain has been so altered, that we may no longer be able to expect nature to care for itself. If the apparent trend in the Great Dismal of the entire swamp becoming heavily forested is natural, we are still left with the need to provide critical wildlife habitat. One value derived from understanding the past ecology of shallow marshes is a set of management goals based on past vegetation types and, perhaps, indications of how to achieve them.

Exploration of the vegetation record contained in peat deposits must be expanded. There are additional techniques, such as phytolith analysis (the study of morphologically distinct silica bodies found in plants), that may prove useful in this reconstruction effort (Andrejko and Cohen 1984; Piperno 1988). Ecological research must be done in close cooperation with fire management efforts. Although expensive, continued application of experimental peat burns should be encouraged. Success of these burns could be enhanced if action were taken to better preserve design. For example, the Okefenokee Swamp would have an increased likelihood of peat fire containment, in both prescribed and suppression situations, if some of the refuges boundaries did not cross peat but rather uplands. If pine uplands formed all refuge boundaries, they could be used to create wide effective low fuel or no fuel (black line) zones.

For management to obtain the greatest amount of information possible, some fires should be done within the framework of a well-developed research plan, complete with quantified preburn evaluation of sites. In addition, this work would benefit from concurrent studies of peat composition and seed bank status. Management of shallow peat-based marshes is difficult; it will require the cooperation of land managers and researchers.

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