Fire in Coastal Marshes: History and Recent Concerns

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ABSTRACT

Fire is a traditional management tool in coastal marshes and is an important part of this ecosystem. This paper reviews the role of fire in coastal marshes of the southeastern United States and explores future concerns.

Fire prevents some tidal fresh marshes from being invaded by woody species and increases the production of preferred wildlife food plants in some brackish and intermediate marshes. These goals are best achieved by burning during fall or winter during a moderate, steady wind when water is on the marsh surface. Spring and summer burning interfere with plant growth and harm newly born wildlife. Some fires are apparently set year round in the mistaken belief that all fire benefits the marsh.

Organic matter produced in marshes is an important part of estuarine trophic cycles, but how burning affects organic matter export to estuaries is unknown. Burning generally increases plant production, but that will not benefit estuarine food chains if the extra production is merely burned the next year. A cautious approach would be to burn often enough to maintain high plant production and create desired plant communities, but infrequently enough to allow litter build-up that could be exported by storm tides.

It is not known how burning affects vertical accretion, which is the gradual formation of new soil on the marsh surface in response to subsidence and sea-level rise. Vegetation eventually drowns without accretion. Accretion depends on peat accumulation in Gulf Coast marshes, although mineral matter may be more important elsewhere. Burning might reduce vertical accretion if peat production is reduced. However, burning might enhance accretion if burning increases root production. Burning frequency will likely determine whether the effect is positive or negative, but this has not been studied.

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INTRODUCTION

Marsh burning is a long-standing cultural practice along the coast of the Atlantic Ocean and Gulf of Mexico. Some burning improves habitat quality for wildlife, but much burning is apparently done because of tradition or with poorly planned objectives. Such unrestricted burning might be detrimental to marsh functions and long term marsh sustainability.

The observations of Lynch (1941), Smith (1942), Uhler (1944), and O'Neil (1949) have guided marsh managers in the use of fire for many years. But those observations were made under pristine conditions and when sea-level rise was possibly slower (Titus 1986; Peltier and Tushingham 1989). Therefore, many earlier conclusions about burning may not apply today. Likewise, emerging issues require a reassessment of the role of fire in coastal marshes. The need for reassessment originates primarily from changing environmental conditions, and rapid increases in human population and development in the coastal zone. Fifty years ago, human density was relatively low and only hunters and trappers were generally interested in the marshes. Today, human density in the coastal zone is 60% greater (NOAA 1990), and many people who do not use marshes directly are interested in their management. This widespread interest results from the realization that coastal marshes provide benefits to society at large, as well as to those who use marshes directly. Unfortunately, many coastal marshes have been lost in areas such as Delaware (Phillips 1986), Virginia (Kearney and Stevenson 1991), North Carolina (Hackney and Cleary 1987; Gammill and Hosier 1992), Texas (Morton and Paine 1990), and Louisiana (Gagliano et al. 1981; Britsch and Kemp 1991). The remaining marshes are threatened not only by natural processes, but by high human density, associated pollution, and increased pressure from transportation and flood control needs.

The purpose of this paper is to review the traditional role of fire in coastal marshes of the southeastern United

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States and to explore the most likely future concerns. The text by Kozlowski and Ahlgren (1974) provides a detailed description of the role of fire in many ecosystems, and papers related to fire in many specific wetland types can be found in an excellent bibliography by Kirby et al. (1988).

TRADITIONAL ROLE OF BURNING

Fire has always been an important part of coastal marsh ecosystems. Spontaneous combustion has been observed in dry peat soils (Viosca 1931), and lightning frequently starts fires in the Florida Everglades (Robertson 1953 cited in Loveless 1959) and Louisiana coastal marshes (Lynch 1941; O'Neil 1949). Burning was a common management tool of Native Americans in general (Stewart 1963; Komarek 1975), and coastal marshes were burned periodically to make travel easier and to prevent catastrophic fires (Le Page du Pratz 1758). Curiously, early European settlers considered fire to be detrimental. Coastal marshes were not periodically burned until early this century when people realized that periodic burning prevented fuel accumulations that otherwise resulted in wild fires (Arthur 1931:262–265; O'Neil 1949:93–107). Hoffpauer (1968) stated that intentional marsh burning on the Gulf Coast was an unforgivable sin prior to 1910, but was fairly common by 1926. By the 1930's, wildlife managers began to realize that periodic burning not only prevented wild fires, but could also improve habitat quality for wildlife by promoting the growth of preferred food plants (Arthur 1931:262–265; Griffith 1940; Lynch 1941; Smith 1942; Uhler 1944; O'Neil 1949:93–107).

TYPES OF MARSH FIRES

Marsh fires, whether prescribed or not, can be classified as peat burns, root burns, and cover burns (Lynch 1941; Smith 1942; Uhler 1944; O'Neil 1949:93–107). Water and soil conditions primarily control the kind of fire that occurs, and water levels following burning influence the regrowth of vegetation.

Peat burns actually burn and remove peat soils. They are not a management tool (Uhler 1944) and are uncommon, but they have been reported in coastal marshes and the Everglades (Lynch 1941; Uhler 1944; Loveless 1959; Hoffpauer 1968). Peat burns occur when the marsh is drained and the soil is dry. Peat fires burned away 10–30 cm of soil and caused ponds to form in the Florida Everglades (Loveless 1959). In southwest Louisiana and southeast Texas, peat burns covered many square miles in 1924 (Lynch 1941) and were still revegetating in the 1940's (O'Neil 1949:42). Hoffpauer (1968) noted peat burns from 1946 that were still ponds in 1968. Peat burns are probably more rare now than in the past because today's well channelized marshes probably flood with marine water rather than dry out during drought years.

Burns that damage plant roots without consuming soil are classified as root burns. Marshes that have not burned for several years may produce plant roots that migrate up into the litter accumulation (Lynch 1941). If this litter accumulation burns, then plant roots also burn. Roots may also be damaged if the marsh surface is dry and fuel is abundant enough to cause very hot fires that kill roots several centimeters below the soil surface (Lynch 1941). Marsh managers have attempted to use root burns to totally remove undesired plants such as *Phragmites* and *Typha* so that vegetation more valuable to wildlife could become established (Ward 1942; Uhler 1944). However, the effective use of fire to eliminate a particular species from a coastal marsh plant community has not been documented, and root burns are not normally used as a management tool.

Cover burns result when there are several centimeters of water above the marsh surface. This type of burn removes existing biomass accumulations without damaging plant roots, and has been a valuable, widely used type of burn (Arthur 1931:262–265; Griffith 1940; Lynch 1941; Uhler 1944). Vegetation can quickly recover from cover burns because the root systems are not damaged.

An important factor determining plant growth following cover burns is water level (Hoffpauer 1968). If either rain or tide water stands on the marsh following a burn and covers the stubble for a sufficient length of time, then the roots begin to die and the marsh may not revegetate or may revegetate very slowly.

Periodic cover burns, every 1 to 5 years, have been valuable tools for marsh managers because they promote the growth of preferred wildlife food plants such as *Scirpus olneyi* that begin growing sooner in the spring than dominants such as *Spartina patens* (Chabreck 1981). Cover burns to promote *Scirpus olneyi* should occur in fall or winter because spring cover burns produce marshes dominated by *Spartina patens* (Chabreck 1981). Cover burns can also prevent the invasion of tidal fresh marshes by woody species (Chabreck et al. 1989). Marsh meiofauna and insect populations quickly recover from marsh fires that are presumably cover burns (Matta and Clouse 1972; Ivester and Harp 1978). Well-managed burning programs limit cover burns to fall and winter because spring and summer burning can destroy nests or kill young wildlife.

Cover burns have been used in *Juncus roemerianus* stands on the Atlantic coast because geese will not eat the mature stems, but will feed on the tender green shoots (Griffith 1940). On the Gulf coast, the removal of dense cover may be more important in attracting Snow Geese (*Chen caerulescens*)) to recently burned marshes than food availability (Chabreck 1988). The habit of the species to remain in large flocks indicates that predator avoidance may be an important strategy for survivability. On the other hand, Canada Geese (*Branta canadensis*) are not attracted to burned marsh (Hoffpauer 1968). A related, but short term effect of cover removal by burning is the attraction of raptors such as White-tailed Hawks (*Buteo albicaudatus*) that feed on rats, rabbits, and insects flushed out by the fire (Stevenson and Meitzen 1946; Tewes 1984).

Preventing wild fires may seem to be a great benefit of controlled burning programs. Wild fires cause the greatest damage when they occur during drought, before flooding, or when wildlife are nesting or have young incapable of escaping fire. However, dry soil conditions are not as likely today as they were before marshes were well channelized and when sea-level rise may have been slower. Furthermore, most summer fires are caused by lightning associated with thunderstorms; thus, the associated rain generally helps localize resulting wild fires. And although undesirable, any wildlife mortality caused by wild fires probably would not be a serious threat to wildlife populations. Thus, damage by wildfires may not be serious, widespread or long lasting in many marshes.

NUTRIENT CONTENT OF WILDLIFE FOODS

It has long been known that burning upland vegetation increases nutrient content of the regrowth (Greene 1935). Continuing work in wetlands and other grassland systems supports those earlier conclusions. Singh (1993) found that fire increased N and P content of vegetation and soil in a dry tropical savannah. Smith et al. (1984) found that burning increased crude protein content, but not digestibility, of *Distichlis spicata, Scirpus acutus,* and *Typha* spp. Digestible energy and crude protein of *Spartina spartinae* increased for 30–60 days following burning (McAtee et al. 1979a). Burning also enhanced the nutrient content of the upper two cm of sediments in *Juncus roemerianus* and *Spartina cynosuroides* marshes (Faulkner and de la Cruz 1982).

Marsh wildlife probably benefit from the enhanced nutrient status and production of regrowth, but no direct studies have been done to date. Cattle, elk, and grasshoppers prefer regrowth to unburned vegetation (McAtee et al. 1979b; Stein et al. 1992), and cattle gained or maintained weight on burned *Spartina spartinae* pastures, but maintained or lost weight on unburned pasture (Angell et al. 1986). Cattle on burned longleaf pinelands gained roughly 30% more weight than those grazing on unburned pinelands over an 11 year study (Greene 1935).

DANGERS OF MARSH BURNING

Promoting plant growth in mineral soil marshes may be more complicated than in organic soil marshes because sandy soils may not always retain enough soil water during the following growing season (McAtee et al. 1979b). Thus optimum conditions for burning marshes with sandy soils are unknown.

Either of the dry burns (peat or root) can kill earth bound wildlife if ponds and smaller water holes are not available to provide refuge. Lynch (1941) reported that most wildlife other than rabbits found shelter from an experimental dry burn in southwest Louisiana. However, even cover burns can kill wildlife if they occur when young wildlife are present. Thus marshes should not be burned in spring or summer. We are under the impression that some marsh users seem aware of the beneficial effects of marsh burning, but incorrectly believe that all burning is beneficial. This might account for some marsh burning that occasionally occurs throughout the spring and summer. This concern is not new (Arthur 1931; Hoffpauer 1968) but is still relevant.

Burning vast areas of marshes may be detrimental because burned marshes provide little cover, and cover can sometimes be as limiting as food to wildlife. Burned marshes are not attractive for nesting to birds such as Black-crowned Night Herons (*Nycticorax nycticorax*) and Snowy Egrets (*Egretta thula*) that nest only in areas with significant dead standing stems of *Scirpus acutus* (Bray 1984). Nutria (*Myocastor coypus*) avoid burned marshes presumably because cover is inadequate (Kinler et al. 1987). Also, American alligators (*Alligator mississippiensis*) may be unable to find sufficient nest material in marshes burned in late winter. Thus, different portions of marshes should be burned each year rather than simultaneously burning the entire marsh every few years. This would ensure that there are always areas in various stages of the burning/regrowth/litter accumulation cycle. Furthermore, the portion that is burned in any given year should be divided into units that are interspersed throughout the marsh. Strips, roughly 1 kilometer wide, may be the ideal unit. However, the distribution of the bayous, ditches, and broken marsh areas that serve as fire breaks is likely to dictate the size and shape of burn units.

FUTURE CONCERNS

Plant Production and Organic Matter Export

The effect of marsh burning on organic matter export must be examined because marshes export organic matter to adjacent estuaries (Knox 1986:17–18; Craft et al. 1989), and detritus from marsh grass can be an important food to juvenile fish (Deegan et al. 1990). Unfortunately, there are few studies of the effects of burning on plant production in coastal marshes. McAtee et al. (1979b) found that burning essentially doubled the live standing crop of *Spartina spartinae* compared to pretreatment levels. Hackney and de la Cruz (1981) also concluded that burning increased production in *Spartina cynosuroides* and *Juncus roemerianus* communities. These increases result primarily from the removal of large standing crops of living, but shaded tissue (Vogl 1974). Such self shading can be extremely important at limiting production in marsh grasses (Turitzin and Drake 1981). Increased production following burning may be partially related to increased nutrient availability following marsh burning (Hoffpauer 1968; Vogl 1974; Faulkner and de la Cruz 1982).

The conclusion that burning coastal marshes increases plant production is supported by studies from other fire-dominated grasslands such as prairies and savannahs (Vogl 1974; Komarek 1975). Recent studies showed that 56 years of annual burning was not detrimental to production, species composition, or cover in a tallgrass prairie (Towne and Owensby 1984), and burning increased above and below-ground biomass of a dry tropical savannah (Singh 1993). Increased below-ground production in tallgrass prairie carries over to higher trophic levels such that energy no longer limits the belowground decomposer communities (Steastedt 1987).

Despite the fact that burning seems to increase plant production and that fire is a natural part of these ecosystems, it is not known if burned marshes export or accumulate the same amount of organic matter as unburned marshes. The increase in production following burning may be exported by storm tides or may merely serve as fuel for the next fire. Marshes that burn as soon as fuel availability is sufficient to carry a flame will probably not export or accumulate significant amounts of plant biomass. However, when burning is infrequent, plant litter may build up and be exported to the adjacent estuary by storm tides. Thus, marsh mangers may have to accept occasional wildfires to maintain possible organic matter accumulation and export.

Denitrification

Denitrification is the conversion of nitrates (NO_3^-), to the gases N_2 and N_2O. Ideal conditions necessary for denitrification exist in wetland soils. There is increasing interest in the effect that wetlands have on nitrate levels of adjacent water bodies because nitrates are common water pollutants that promote eutrophication in marine ecosystems (Ryther and Dunstan 1971). This is not a physical process; some species of soil bacteria respire nitrate when oxygen is unavailable. Burning is not likely to affect denitrification in most marshes because nitrate availability generally limits denitrification rates. When nitrate is not limiting however, the size and activity of denitrifying bacterial populations are controlled by the amount of soil organic matter (Burford and Bremmer 1975; Reddy et al. 1982). Marsh burning might affect denitrification rates by affecting belowground plant production, but this has not been documented. The most relevant studies to date were conducted in prairies and found that burning increased root production and increased energy available to the belowground decomposer communities (Kucera 1970 cited in Vogl 1974; Steastedt 1987). Studies are therefore needed to determine if burning increases denitrification in marshes with very high loading rates of nitrates or with very low levels of soil organic matter. Such marshes are likely to be rare however.

Marsh Vertical Accretion

Marsh vertical accretion refers to the formation of new soil on the marsh surface and is a gradual process (Mitsch and Gosselink 1984:178–181). The effect of marsh burning on marsh vertical accretion is not known. Adequate accretion is important because it keeps marsh plants from drowning as sea-level rises and the land sinks. Sea-level has been rising at varying rates since the end of the last ice age, and is expected to rise faster because of global warming (Titus 1986). The need for vertical accretion varies greatly from marsh to marsh because subsidence varies from marsh to marsh. Penland and Ramsey (1990) estimated that relative sea-level rise, which is the combined effect of global sea-level rise and subsidence, averaged 1.04 cm/yr on the Louisiana coast, 0.63 cm/yr on the Texas coast, and 0.17 cm/yr on the west Florida coast. Relative sea-level rise on the Atlantic coast ranges from 0.16 cm/yr at Key West to 0.24 cm/yr at Charleston (Stevenson et al. 1986).

Organic matter is a major component of marsh soils along the Louisiana coast and comprises 41% of the top 10 cm of soil of the inactive Deltaic Plain in southeastern Louisiana. Freshwater marsh soil of this region consists of 65% organic matter. The primary source of this organic matter is debris from previous crops of plants produced by the marsh (Chabreck 1970). Vertical accretion of marsh is directly dependent on organic matter accumulation, primarily from root production, in this region (Hatton et al. 1983; Nyman et al. 1993a) as well as in New England coastal marshes (McCaffrey and Thomson 1980; Bricker-Urso et al. 1989).

Marsh burning might therefore affect marsh vertical accretion because accretion is directly related to peat accumulation in Louisiana and New England marshes (McCaffrey and Thomson 1980; Hatton et al. 1983; DeLaune et al. 1987; Bricker-Urso 1990; Nyman et al. 1993a). Burning would not likely affect many Atlantic coast marshes in the southeast because they accrete primarily mineral soil that they receive from tidal and storm sedimentation (Stevenson et al. 1988). No studies have investigated the effects of burning on peat accumulation. We are unaware of any studies that related burning to root production in coastal marshes, and only two studies in other grassland systems have addressed this problem. The studies in other grasslands found that burning stimulated belowground production (Kucera 1970 cited in Vogl 1974; Steastedt 1987). Whether the effects of marsh burning are positive or negative probably depends on burning frequency. This question is especially important in rapidly subsiding areas such as southeast Louisiana. It may also become important elsewhere if the rate of sea-level rise increases as predicted (Titus 1986). Marsh managers may therefore have to suspend periodic burning programs and accept occasional summer wild fires if it is found that burning reduces vertical accretion. On the other hand, periodic burning may be recommended for all rapidly submerging marshes if it is found that burning promotes vertical accretion

Another danger is the direct loss of elevation resulting from fires that occur when the marsh is dry. Not only can a marsh fire destroy the aboveground growth of the current year, but several years of accumulated plant debris on the soil surface or even soil itself can be lost. Even small losses in elevation might greatly affect vegetation because slight differences in elevation greatly affect flooding frequency in tidal marshes (Reed and Cahoon 1992). Fortunately, peat burns are rare and unlikely in today's well channelized marshes with possibly increased sea-level rise rates.

CONCLUSIONS AND RECOMMENDATIONS

It might be advisable for marsh managers to reconsider the practice of periodically burning marshes to improve wildlife habitat quality. Maintaining peak muskrat (*Ondatra zibethicus*) populations was desirable 40–50 years ago (O'Neil 1949:94) because one pelt was worth a days wages. But today it would take 40–50 pelts to meet minimum wages for one day, assuming that a buyer can be found. Peak muskrat and nutria populations may therefore increase herbivory effects (e.g. Fuller et al. 1985; Shaffer et al. 1992; Nyman et al. 1993b) rather than harvest income. Marshes in coastal Louisiana are also burned for Snow Geese but many geese have been short-stopped (Bellrose 1980:118). Furthermore, geese that do winter in Louisiana have largely abandoned the marshes and now winter primarily in the adjacent rice field region to the north (Bateman et al. 1988; Bellrose 1980:118). Therefore, few Louisiana marsh managers can attract Snow Geese with burning. Likewise, few Snow Geese winter on the southeast Atlantic coast (Gordon et al. 1989). Thus, periodic burning to improve habitat quality for wildlife is not as important as it once was. Some factors to consider follow:

1. Most coastal marshes are subsiding, sea-levels are rising, and organic matter production by plants is a major source of material for marsh building. Although it is obvious that peat burns can destroy many years of accumulated material, it is not known how periodic burning affects marsh vertical accretion. Periodic cover burns might promote vertical accretion by increasing above and below ground plant production, or may inhibit vertical accretion by preventing litter accumulation. Managers should proceed with caution until the effects of burning on vertical accretion are determined.
2. Burning in tidal salt marsh should be avoided because plant debris from this habitat is an important contribution to estuarine food webs.
3. Brackish marsh burning can currently be justified only where peat burns are likely, where stands of *Scirpus olneyi* are to be maintained as food for muskrats or Snow Geese, or where uncontrolled fires regularly damage vegetation, destroy nests, or kill young wildlife.
4. Freshwater marshes should be burned only where woody shrubs are present that must be burned for control.
5. Burning should be done where the area to be burned can be controlled.
6. Burning should be done only during the fall and winter. This avoids destroying nests and young of wildlife. Marshes dominated by *Spartina patens* rather than *Scirpus olneyi* may result if burning is delayed until spring in some brackish marshes.
7. Burning should be done only when water levels in the marsh are at or several centimeters above the marsh surface. Never attempt to burn during drought conditions.
8. Entire marshes should not be burned simultaneously. Instead, various units should be burned each year so that different units are always in every stage of the burn-regrowth-litter accumulation cycle.
9. Despite the dangers of periodically burning coastal marshes, unmanaged burning and fire suppression are not without danger. Unmanaged burning and fire suppression might lead to peat burns, root burns, fires prior to flooding, or fires when wildlife are nesting or have young that cannot escape fires. It is also possible that peat production is lower in unburned marshes than in burned marshes, which may reduce vertical accretion. Thus, marsh managers are annually faced with a dilemma that has long lasting consequences.

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