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1000-YEAR RECORD OF FIRE-VEGETATION INTERACTIONS IN THE
NORTHEASTERN UNITED STATES: A COMPARISON BETWEEN COASTAL
AND INLAND REGIONS

A Thesis Presented

By

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ABSTRACT

1000-YEAR RECORD OF FIRE-VEGETATION INTERACTIONS IN THE
NORTHEASTERN UNITED STATES: A COMPARISON BETWEEN COASTAL
AND INLAND REGIONS

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Lake sediments preserve a record of vegetation and fire history that can be revealed through pollen and charcoal analyses. This study evaluates spatial and temporal variations in fire occurrence and fire-vegetation interactions for eight ponds in the New England region. Average charcoal values are higher following European settlement at all eight sites, and most modern ignitions result from human activity. Charcoal values prior to settlement suggest that fire occurrence and intensity was greatest near southern coastal sites. Coastal Maine sites show fewer fires and sites away from the coast almost none at all. Modern records show that lightning ignitions are rare in coastal forests. Aboriginal populations were concentrated along the coast, and most presettlement fires were probably the result of human ignitions. Pollen and charcoal analyses from three sites in Acadia National Park

Suggest that fire is also strongly linked to forest succession in coastal Maine forests.

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The Bowl

Chronology

The Bowl is located in Acadia National Park, Mt. Desert Island, Maine. The 55-cm core raised from 12.5m of water by R.B. Davis in 1979 was dated at the University of Maine at Orono by Pb^{210} analysis. An increase in the percentages of agricultural indicators (i.e. Ambrosia, Rumex and Gramineae) at 19-23cm (Fig.8) denotes the time of European settlement (1760-1800 AD) (Patterson et al. 1983). The record of opaque spherules (Fig.9) is reasonably consistent with 20th century industrial activity (Clark and Patterson, in press), although a large peak at 5cm may reflect spherules generated locally during the 1947 Bar Harbor fire. In fact, correlation between opaque spherules/pollen (OS/P) and C/P yields a significant r value of 0.56 ($p = .01$). This suggests that the production of opaque spherules is related to fire activity at this site.

Extrapolation from the settlement horizon and from Pb^{210} analysis dates the bottom of this core at approximately 1450 AD. The analyses indicate pre- and postsettlement sedimentation rates of approximately 1.0 and 1.1mm/yr respectively.

Charcoal

The charcoal record (Fig.8) provides clear evidence of two presettlement fires at 28cm and 38cm (~1600 and 1700 AD) (Patterson et al. 1983). A peak at 49cm may reflect a fire in about 1500 AD. Widespread burning after settlement resulted in increased charcoal values above 20cm.

A charcoal peak at about 19cm corresponds to 1820 AD and may reflect slash burning activity associated with extensive logging on Mt. Desert Island early in the 19th Century (Moore and Taylor 1927). The Bar Harbor fire of 1947, which burned 6,875 ha on Mt. Desert Island, burned the entire watershed of The Bowl and is clearly evident in a charcoal peak at 6cm. This level is dated by Pb^{210} analysis at 1947-48.

A comparison between the point counting and grid methods for estimating charcoal area yields similar average values (Table 3). A significant ($p = .01$) r value of 0.76 suggests that the two methods produce similar results. When only the non-zero values are taken into consideration an even better correlation ($R = 0.86$) exists between the two methods. The point counting method is less accurate with lower charcoal concentrations (Clark 1983), and this could explain the discrepancy.

Pollen

Modern percentages of beech and hemlock are about one half those of 500 years ago. An increase in pine pollen between 1600 to 1800 AD is similar to the trend at Larkum Pond. These gradual changes began well before settlement and may reflect the effects of the cooler and drier climate presumed to be associated with the Little Ice Age.

Birch stands presently occupy much of The Bowl's watershed (Patterson et al. 1983a). Pollen percentages reflect the importance of birch in the modern forest, but also indicate that birch may have been even more abundant prior to settlement.

Charcoal and pollen correlation

A comparison of charcoal/pollen (C/P) and conifer/sprouter (C/S) ratios (Fig.10 and Fig.11A) shows a significant ($p = .01$) positive correlation at lag 0. By calculating absolute pollen influx, Patterson et al. (1983a) shows that following fires decreases in production of pollen by birch is far more important than increases of conifer pollen in causing the C/S peak. They conclude that fire kills birch in the watershed and as a consequence the influence of regional pollen rain, with a greater conifer component, increases (Davis 1967). C/S values remain high

until first gray birch and then paper birch revegetates the burned area.

The correlation of C/P with total birch (Fig.11B) is very nearly the inverse of the C/S graph. This supports Patterson's hypothesis. Low birch percentages are followed by a gradual recovery about 30-40 years following fire (lag 4 and lag 5).

Small birch grains, which probably represent gray birch, are also compared with charcoal (Fig.11C and Fig.12). Only the presettlement levels were used in the comparison because following settlement gray birch expanded its presence throughout the island. This expansion reflects land clearing activities as well as increased fire activity. The negative correlations for lag -5 to lag 0 indicate that gray birch is a relatively unimportant component of the forest prior to fire. The increasing positive correlation from lag 0 to lag 3 reflects colonization of disturbed sites by gray birch, and the declining r values for lags 4 and 5 suggest that the short-lived gray birch gives way to the longer-lived white birch 30 to 40 years after a fire.

If fire is excluded from Acadia's forests, tolerant spruce replaces birch and other deciduous trees. Spruce snags in The Bowl's watershed were 150 years old at the

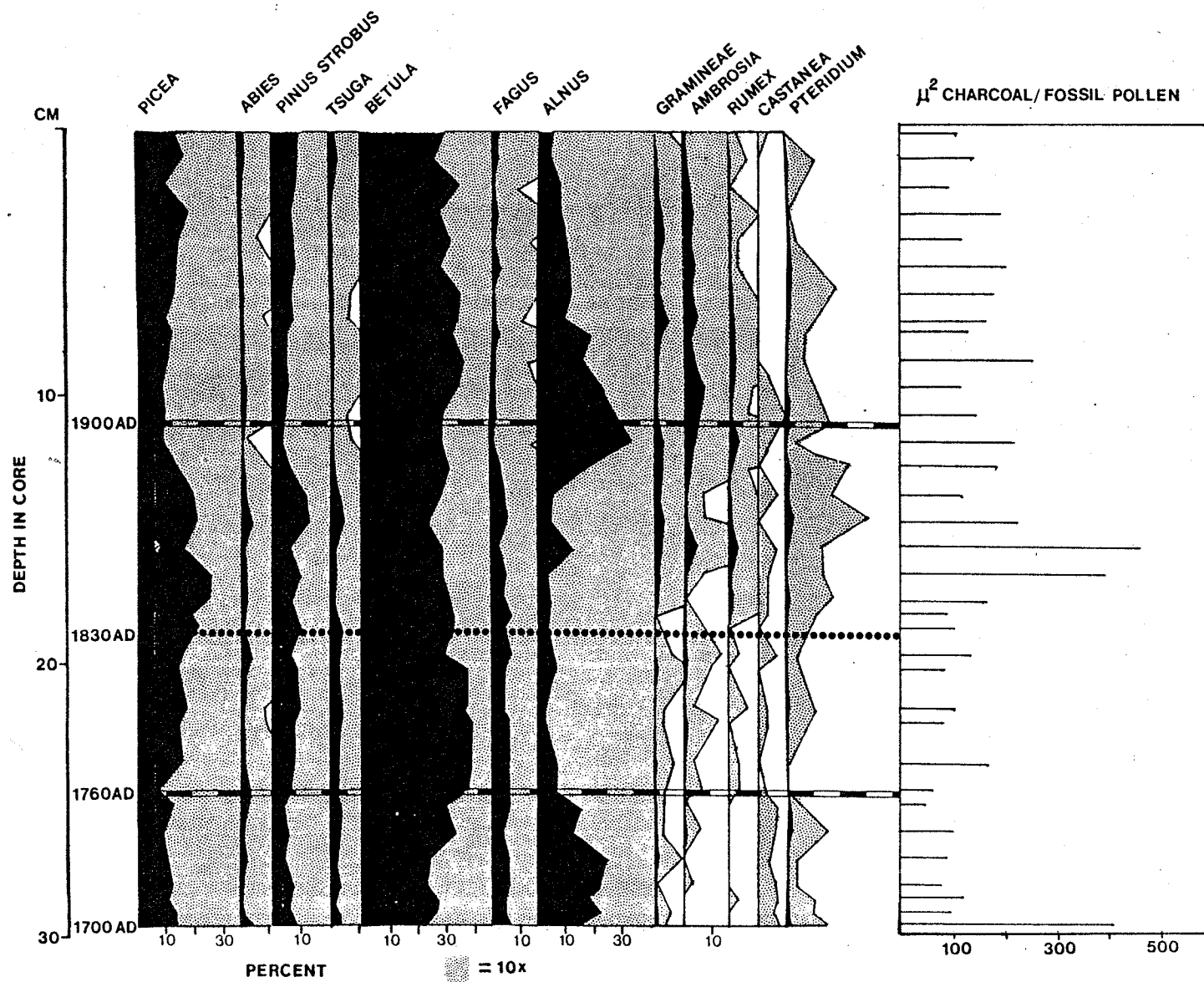
time of the 1947 fire. Their presence indicates that the area had not burned since settlement. This long period without fire may have affected a large buildup of fuel which could have increased the intensity of the 1947 fire. Patterson speculates that presettlement fire regimes may have included more frequent but smaller fires.

Sargent Mtn. Pond

Chronology

Sargent Mtn. Pond is located in Acadia National Park, Mt. Desert Island, Maine. The 30-cm core was dated by Pb²¹⁰ analysis at the University of Maine at Orono. The rise in pollen settlement indicators (Fig.13) is more difficult to interpret than the record from The Bowl, because the small initial increase in percentages is stretched over 6cm. A visual comparison with the record from The Bowl dates 24cm at Sargent Mtn. Pond at 1760 AD.

The opaque spherule curve (Fig.14) is consistent with 20th Century industrial activity. There is no correlation ($r = .08$) between OS/P and C/P at this site. The fact that there is a significant positive correlation at The Bowl suggests that intense fires in the immediate watershed



(eg. the 1947 Bar Harbor fire at The Bowl) may add to the influx of opaque spherules to the sediments.

Extrapolation from a Pb^{210} date of 1830 for 19cm, the settlement horizon as dated by pollen and the opaque spherule curve places the bottom of the core at approximately 1700 AD. Estimated sedimentation rates for pre- and postsettlement sediments are 1.1mm/yr.

Charcoal

The charcoal record for Sargent Mtn. Pond (Fig.13) shows two clear peaks. One (at 30cm) reflects a fire in the presettlement forest in ~1700 AD and the other (at 16-17cm) a postsettlement fire in ~1850 AD. The latter fire may reflect slash-burning associated with logging in the mid 1800's.

The most significant feature in this record is the lack of any peak at the time of the 1947 Bar Harbor fire. The 1947 fire stopped a few hundred meters short of the Sargent Mtn. Pond watershed. The charcoal records from Sargent Mtn. Pond and The Bowl clearly show that charcoal peaks represent fire activity in the immediate watershed.

Pollen

Pollen percentages indicate that birch is just as abundant at Sargent Mtn. Pond as at The Bowl, where birch

stands dominate much of the watershed (Patterson et al. 1983). Spruce percentages are slightly higher at Sargent Mtn. Pond. A sharp decline of hemlock and beech occurs at 12-13cm. It is possible that these species were only minor components of the forest in the early postsettlement period and were further restricted by logging in the mid to late 1800's. The decline is consistent with pollen records from the other two sites in Acadia National Park.

Charcoal and pollen correlation

The results from pollen correlations with charcoal for Sargent Mtn. Pond can clearly be related to post-fire succession. Response in the herb layer is reflected by an increase in Pteridium spores immediately after a fire (Fig.15A). Bracken fern tends to become established as a thicket fern in poor sandy soils and where vegetation has been burned (Verdoorn 1938). Unlike most ferns it is tolerant of fire because its strong underground root system enables it to resprout readily following fire (Small 1964). In addition, it appears to produce abundant spores only following fire (W.A.Patterson III, pers. comm.). The increase in Pteridium spores at this site reflects its ability to recover quickly and take advantage of a disturbed site.

Alder (Alnus spp.) pollen (Fig.15B) increases sharply from 10 to 25 years after fire (lag 2 to lag 4). There is no indication from the correlation curve that an alder population was initially killed by fire. It is possible that alder took advantage of the disturbed area along the edge of the basin several years after fire. Gray birch (Fig.15C) also increases after fire suggesting that both types may be important in early post-fire succession but the high r values for correlation between alder and charcoal indicate that alder is probably more abundant than gray birch.

Correlations of charcoal with total birch (Fig.15D) indicate that birch was destroyed by fire and percentages remain low for four levels following the disturbance but are beginning to recover about 40 years following fire (lag 5).

The spruce correlation curve (Fig.15E) is particularly interesting because it demonstrates relatively high values of spruce pollen for several levels prior to fire. This is consistent with a forest free from fire during a time interval long enough for tolerant spruce trees to begin replacing the birch. The curve also indicates that the spruce was devastated by fire and has not yet begun to recover at lag 5.

Long Pond

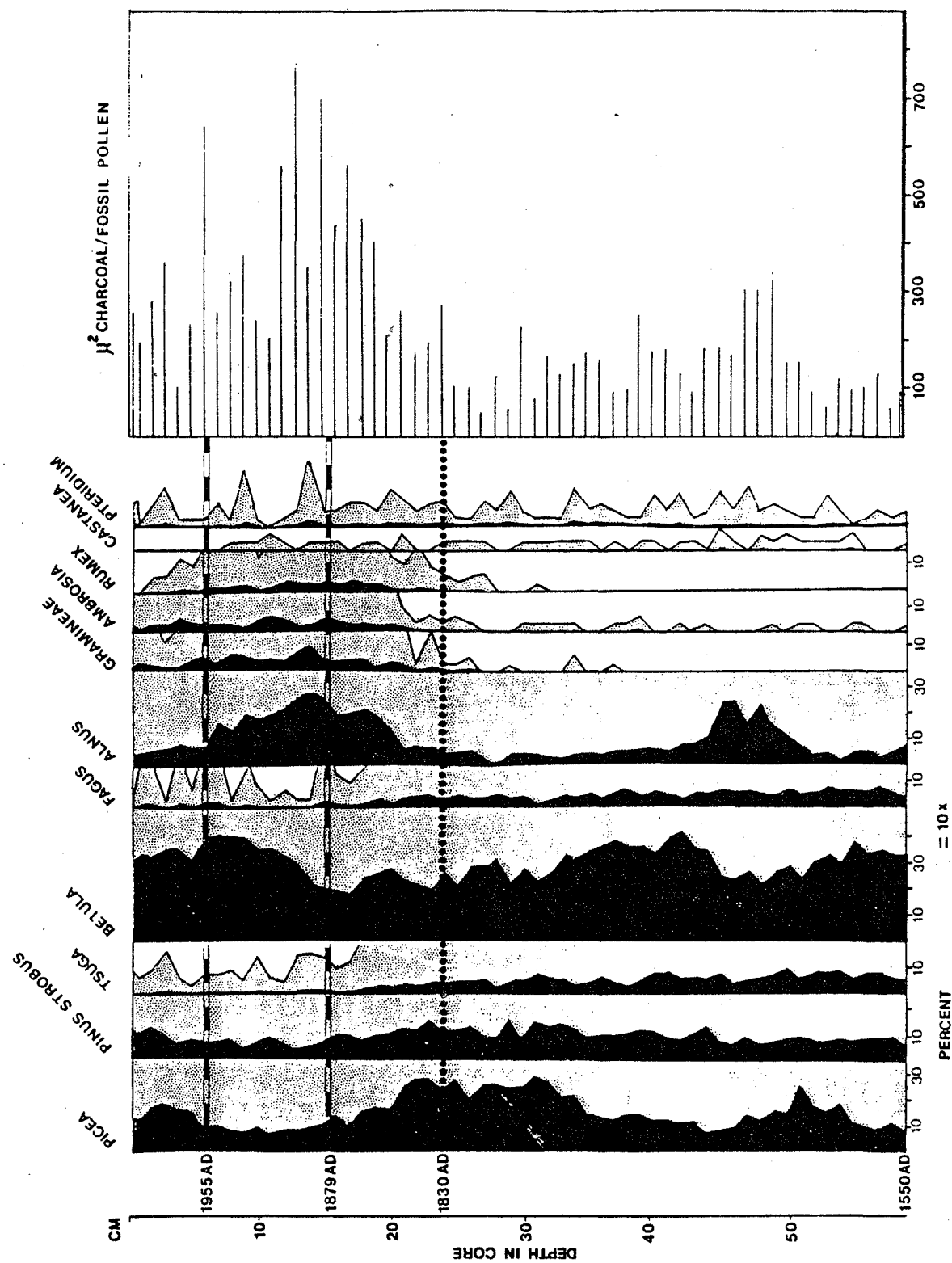
Chronology

Long Pond is located in Acadia National Park, Isle au Haut, Maine. This 60cm core was also dated by Pb^{210} analysis at the University of Maine at Orono. The rise in Ambrosia, Rumex and Gramineae pollen between 27 and 25cm (Fig.16) denotes the time of settlement on Isle au Haut. The first permanent settlement was established in 1792 (C.Schell, pers. comm.). An increase in opaque spherules (Fig.17) above background levels occurs at 16-14cm. Pb^{210} analysis dates 14cm at 1900, which is consistent with the initiation of 20th-Century industrial activity. Although there are only small percentages of chestnut pollen in this record, the decline at about 11cm is consistent with Anderson's (1974) description of the chestnut decline about 1930 in the northeastern portion of its range.

Extrapolation from a Pb^{210} date of 1830 AD for 24cm and the opaque spherule curve places the bottom of the core at approximately 1550 AD. The chronology indicates a postsettlement sedimentation rate of 1.5mm/yr, with 1.4mm/yr prior to settlement.

Charcoal

In 1879 most of Isle au Haut burned (Moore and Taylor



1927). Evidence of this fire can be seen in the abundant charcoal at 16 to 14cm (Fig.16) The 16cm level is dated by Pb^{210} analysis at 1880. A charcoal peak at 6cm is dated by Pb^{210} analysis to the mid 1950's, and may reflect a small fire that burned a portion of the pond's northeast shore (W.A.Patterson, pers. comm.). A presettlement peak at 48cm dates to ~1630 AD.

Pollen

As at the sites discussed earlier a gradual decline of hemlock and beech occurred prior to settlement. A sharper decline following settlement is probably related to land-clearing activities. The decline in white pine pollen above 23cm may reflect the selective cutting of this species from early postsettlement forests (Moore and Taylor 1927).

The pollen diagram suggests that birch is nearly as abundant in the forest around Long Pond as it is at the two sites on Mt. Desert Island. Spruce is more abundant at Long Pond but the percentages of both types vary considerably during the 400-year record. Alder is apparently abundant in the understory. Patterson et al. (1983a) found large clumps of alder scattered through wetland forest types on Isle au Haut. Alder is probably abundant along the shore of Long Pond and in

openings created by disturbance. Alder pollen percentages vary noticeably in the Long Pond record, with large peaks from 50-45cm and 20-10cm.

Charcoal and pollen correlation

The results from pollen correlations with charcoal at Long Pond suggest a post-fire succession similar to Sargent Mtn. Pond. Pteridium (Fig.18A) increases sharply at the time of fire reflecting increased spore production.

Correlations of charcoal with alder (Fig.18B) demonstrate that peaks in alder percentages occur simultaneously with charcoal peaks, whereas gray birch (Fig.18C) does not appear to be affected by fire. These results suggest that alder is the initial post-fire colonizing species in the forest surrounding Long Pond.

Birch (Fig.18D) percentages are low following fire but increase from 15 to 40 years after fire (lag 2 to lag 5) as alder percentages decrease, reflecting the succession from colonizing alder to tree birches.

Correlations of charcoal with spruce (Fig.18E) reveal a decrease in pollen percentages that suggests spruce was killed by fire. The 40 year time interval afforded by five lags is not long enough to detect any recovery of spruce at Long Pond.