# RECENT ENVIRONMENT CHANGE ON HOWTH HEAD, COUNTY DUBLIN

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## ABSTRACT

The study site on Howth Head is a small hollow peat bog on the boundary between lowland dry heath and wooded demesne. Fine resolution pollen, sediment and macrofossil analysis were carried out on the sediment. Results suggest that bog formation started in the 15th century, probably as a consequence of changes in hydrology due to quarrying activity. Changes in sedimentation rates are attributable to either impeded drainage caused by local field boundary changes or increased precipitation during the `Little Ice Age´.

The main control on the heath vegetation from the 15th century up to the 1940's was grazing. Greatest floristic diversity, largely represented by herbaceous taxa, was recorded during this time. Fire became an increasingly important factor on the heath after the removal of grazing. Increased fire frequency has resulted in a decline in species diversity and the dominance of *Pteridium aquilinum* and *Calluna vulgaris*. Scrub vegetation on drift soils in Howth demesne were replaced by mixed woodland in *c*. 1830. Documentary sources support the findings in this study.

A record of atmospheric deposition is indicated by spheroidal carbonaceous particles (SCP) and sulphide particles in the sediment. This aspect of the study requires further investigation.

Dedicated to my mother
Christina Cooney
and my late father
Patrick Cooney

"To speak the air, the sky, to speak
the freshness of the hill to tell,
Who roaming bare Ben Etar's peak
and Aideen's briary dell
and gazing on the cromlech vast
and the mountain and the sea
shall catch communion with the past"

(Aideen's Grave)
Sir Samuel Ferguson

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Last and by no means least I thank Eleanor Jennings for assistance and encouragement at almost every stage of this project.

## Abbreviations

| | |
|---|---|
| SCP | Spheroidal Carbonaceous Particles |
| LPAZ | Local Pollen Assemblage Zones |
| BOF | Bog of the Frogs |
| SEM | Scanning Electron Micrograph |
| LOI | Loss On Ignition |

## Chapter 1

# INTRODUCTION

## 1.1 Howth Head

### 1.1.1. *General background*

Howth Head (53° 23'N, 6°, 4'W) on the northern shore of Dublin Bay rises to its highest point on Black Linn at 172 meters. The promontory that forms the headland is connected to the mainland by a Post-glacial tombolo of sand and gravel, moulded by wave action. It would appear that prior to the formation of this land connection Howth was an island, at least at high tide. In fact Ptolemy's map (150 A.D.) of the world shows Howth as an island called Edri Deserta, or in Greek, Edra Heremos, both names meaning the desert of Edar (Culliton 1962). Figure 1.1 shows the main areas of Howth mentioned in the text.

### 1.1.2. *Historical background and human associations*

Archaeological field monuments within a *c.*2 km radius of the study site provide evidence to suggest that Howth Head has been a site of human occupation since the Neolithic period. These monuments include a midden site at Sutton (early Neolithic), a destroyed cairn (mid Neolithic) on Shelmartin and a portal tomb known as \`Aideen's Grave´ (late Neolithic) in the present day woods of Howth demesne (McBrierty 1981). Since the Neolithic every period in Irish history has been recorded on the headland either as field monuments, place names or in literature.

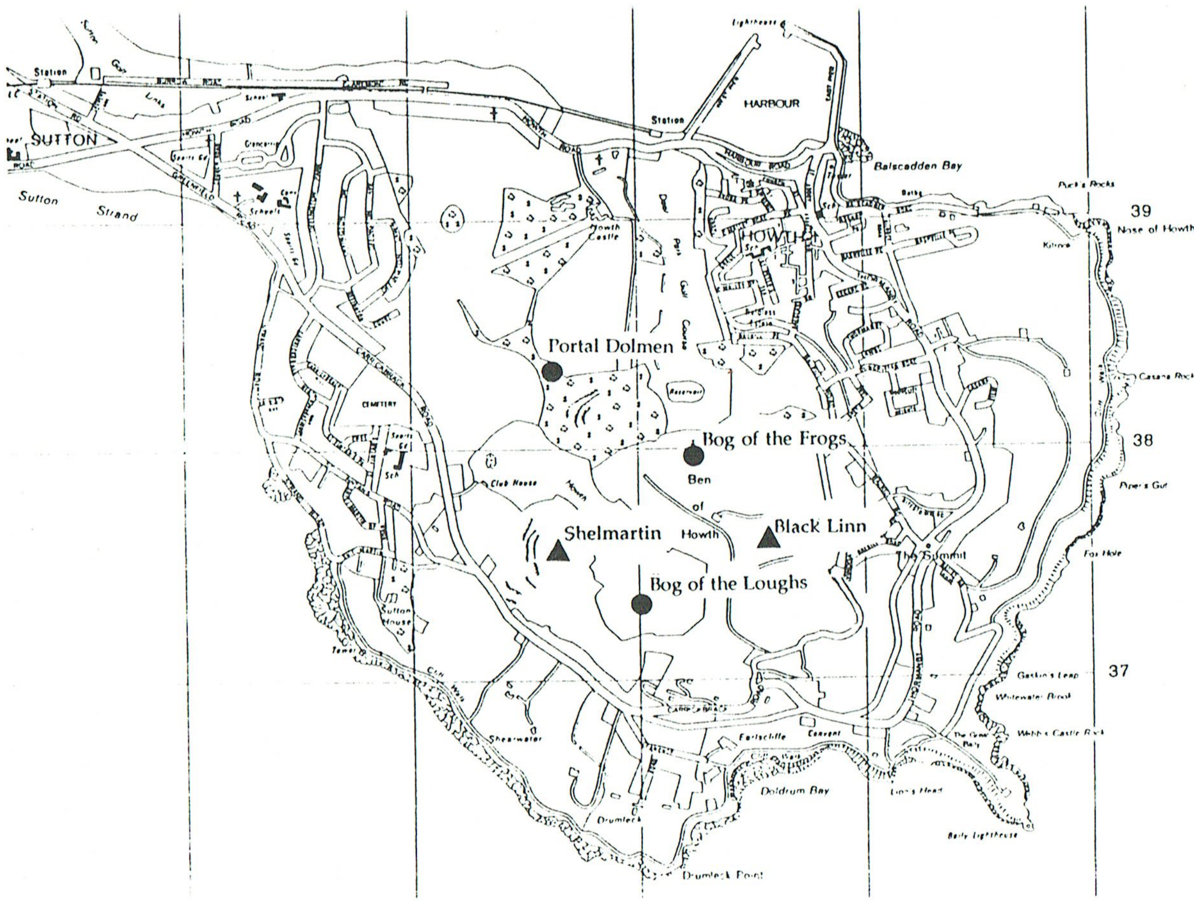



**Figure 1.1 :** Howth Head with main features mentioned in text.

Many of the descriptive local place names record distinctive natural features, including the vegetation. This type of evidence can assist in the interpretation of the vegetation history of the area. For example the sea inlet on the east of the headland is known as Lough Leven, an old Gaelic name for `the Lough of the Elms´. There are no Elms (*Ulmus* ) at this location today. Also the present day `Deer Park´ is evidence that deer were kept on Howth estate from the early 19th century to early in this century (Lewis 1980, McBrierty 1981). (Nomenclature of vascular plants follows Webb 1977.)

For up to 800 years the owners of Howth castle have probably had the greatest single influence on land use practices over much of the headland. This includes the land in the vicinity of the study site. Howth Castle (1564), now much renovated, is considered to be on the site of an original fortification constructed by Sir Almericus Tristram who conquered the headland in 1177. Sir Almericus was the 1st Lord of Howth.

### 1.1.3. *Climate*

The Dublin region, including Howth Head, comes under the influence of westerly atmospheric circulation of mid-latitudes. This, with its associated frontal systems and depressions, brings fairly frequent changes of airmass type and hence meteorological conditions. A wind rose for the Dublin region is presented in Figures 1.2. The annual rainfall patterns for Howth Head and Phoenix Park are presented in Figure 1.3.

Rainfall data indicates that the Dublin region is one of the driest in Ireland with 800mm $yr^{-1}$ between 1941 and 1970 (Meteorological Service 1983). Annual rainfall values taken from three recording stations on Howth (Howth Castle, Danesfort and Howth Corporation) between 1951 and 1980 indicate that Howth Head receives slightly less rain than the regional average with 730mm per year. This makes Howth not only one of the driest areas in

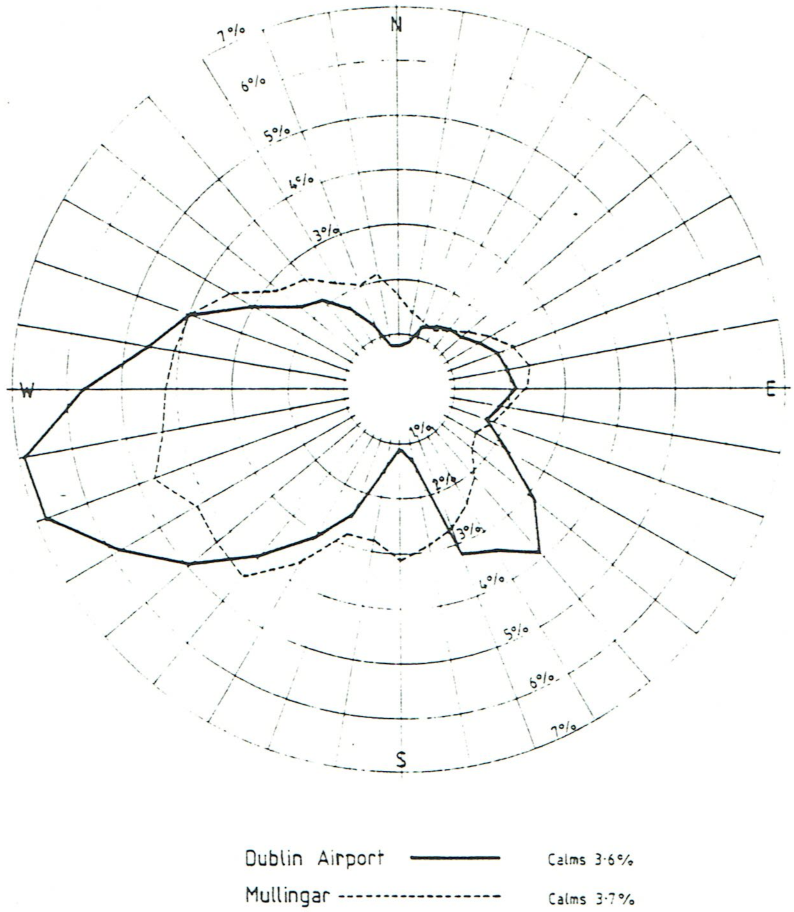



**Figure 1.2** : Wind rose for the Dublin region (Meterological Service 1983). Howth Head lies to the northeast of Dublin City and downwind of airbourne pollutants.

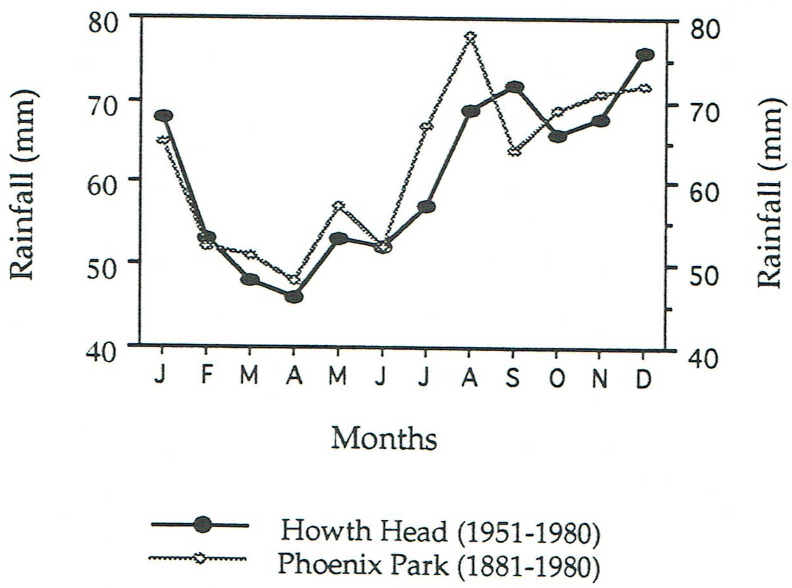



**Figure 1.3** : Average monthly rainfall pattern for Howth Head and Phoenix Park Note that Howth is drier for most of the summer months. Local fog formation in these months may be an important source of moisture for wetland communities.

Dublin but also in Ireland. Some of this shortfall in precipitation is made up for by frequent hill fogs which usually have their base at about 120m.

The proximity of the sea also insures that any snow cover that occurs is usually of short duration. Between 1961 and 1980 Howth Head had on average 13.8 days snow or sleet days compared to Dublin Airport with 21 days. Mean annual percentage wind speed and direction records at Dublin Airport between 1968 and 1980 show that 18% of winds in the Dublin region are from the Southwest and 27% from the West (Meteorological Service 1983).

Annual mean daily air temperature at Howth from 1951-1980 was between 9.5°C and 10.0°C. Mean daily air temperature in January was between 4.5°C and 5.0°C and 15.0°C for July.

### 1.1.4. *Geology, topography and soils*

Most of the southern side of the headland is Cambrian quartzite, sandstones and mudrocks. These are particularly evident on higher ground and are of similar age to those on Bray Head (100m) to the south of Dublin Bay (Whittow 1974). On the upper slopes the overlying infertile peaty soil is well drained and gives rise to characteristic lowland dry heath. Soil depth decreases with increasing altitude. These thin soils ensure a quick water run-off into the 14 small streams on the headland (Sweeney 1991).

Carboniferous limestones occur on the northern side of Howth Head, where they are generally covered by glacial drift and rarely outcrop except along the seashore (Wyse Jackson *et al.* 1993). Thin drift deposits in hollows on the mid slopes are possibly of local origin and unrelated to the Irish Sea ice drift found elsewhere on the headland. Although relatively small in area, these deposits appear to be of sufficient depth (*c.*50cm) and mineral composition to support mature trees and plant communities typical of lowland basic soils. Leaching of minerals from the upper slopes, particularly after a fire event when the soil is exposed to the elements, enables a flush vegetation to exist in these hollows.

### 1.1.5. *Present day vegetation*

Most of the lower ground on Howth is either residential or has been modified for recreational and amenity purposes. These include two golf courses and a woodland in Howth demesne on the northern side. A large Rhododendron garden was planted on the north facing rock outcrops of the demesne about 1850 with almost yearly additions until 1909 (McBrierty 1981). In addition to the common variety of *Rhododendron ponticum* more exotic species have been introduced from different sources. These include *Rhododendron thomsoni* from Trinity College gardens in 1880. In all there are considered to be about 2,000 species, subspecies and hybrids in the gardens (McBrierty 1981). On the more fertile soils on the lower ground farming activity has been reduced. Grazing is now confined to Howth demesne and at least one other area on the western side.

The mid-slopes of Howth are dominated by *Pteridium* and in recent times by the invasion by *Betula* woodland, particularly on the northern slopes of Dun Hill. Approximately 300 acres of heath on the higher ground is leased by An Taisce (The National Trust). It is generally understood that a dominance of *Calluna vulgaris* defines heath (Gimingham 1961). The acid soil conditions found on the upper slopes are therefore suitable for the development of heath communities. The vegetation of the upper slopes is dominated by *Calluna vulgaris*, *Ulex gallii* and *Erica cinerea.* This is probably best classified as a *Calluna vulgaris-Ulex gallii* lowland dry heath (Meleady 1993). Lowland dry heath is generally confined to the east of Ireland and is relatively species poor (Tansley 1939). Fire was a regular event on the heathland until relatively recently. There is no grazing on the heath at present.

Howth Head with an excess of 500 species of vascular plants has attracted Irish botanists for several centuries (Hart 1887; Jeffrey 1981). The earliest work on Irish botany by Threlkeld in 1726 mentions a number of species of particular interest that occurred at Howth (Hart 1887). The first account of the flora was published by Hart in 1887. Colgans *Flora of the County of Dublin* (1904) includes the important and unusual species on the headland. Despite losses of habitat due to urbanisation and drainage in recent years the area still remains a rich hunting ground for professional and amateur botanists.

### 1.1.6. *Bog of the Frogs*

The study site is located in the ancient townland of Lismore and is known locally as `Bog of the Frogs´. It is a small hollow peat bog and covers an area of *c.* 300m$^2$. The bog is situated on the north facing slope close to the 110m contour line on the boundary of heathland and planted mixed woodland of Howth Castle demesne (Plate 1.1). The vegetation immediately surrounding the bog is composed of *Calluna vulgaris, Ulex gallii, Vaccinium myrtillus, Pteridium aquilinum* and the occasional *Betula pubescens.* Typical peatland species differentiate the bog itself from the surrounding vegetation. In summer *Dactylorhiza maculata, Pinguicula vulgaris , Narthecium ossifragum, Molinia caerulea, Potentilla erecta* and *Sphagnum spp.* are particularly notable. This is the only site on the headland for *Drosera rotundifolia*. *Rhododendron* invasion from the woodland is beginning to encroach on the bog. Plate 1.2 shows the bog vegetation in early September.

Approximately 62 hectares of hillside forms the water catchment for a small local stream known as `Bloody Stream´ (Sweeney 1991). This stream has its origin on Black Linn (172m) and flows northwards past Loughoreen Hill but by-passes the bog. Water from this stream does not enter the bog.

**Plate 1.1** : General view of heath above the study site in early September.

**Plate 1.2** : `Bog of the Frogs´ in early September. *Rhododendron ponticum* from Howth demesne is encroaching onto the bog. Note the orange/red spikes of *Narthecium ossifragum* and the pink flowers of *Calluna vulgaris*.

**Plate 1.3** : View from the quarry spoil heap looking towards the bog (out of view). The bog is situated immediately to the right of the dark green Rhododendrons (January 1994).

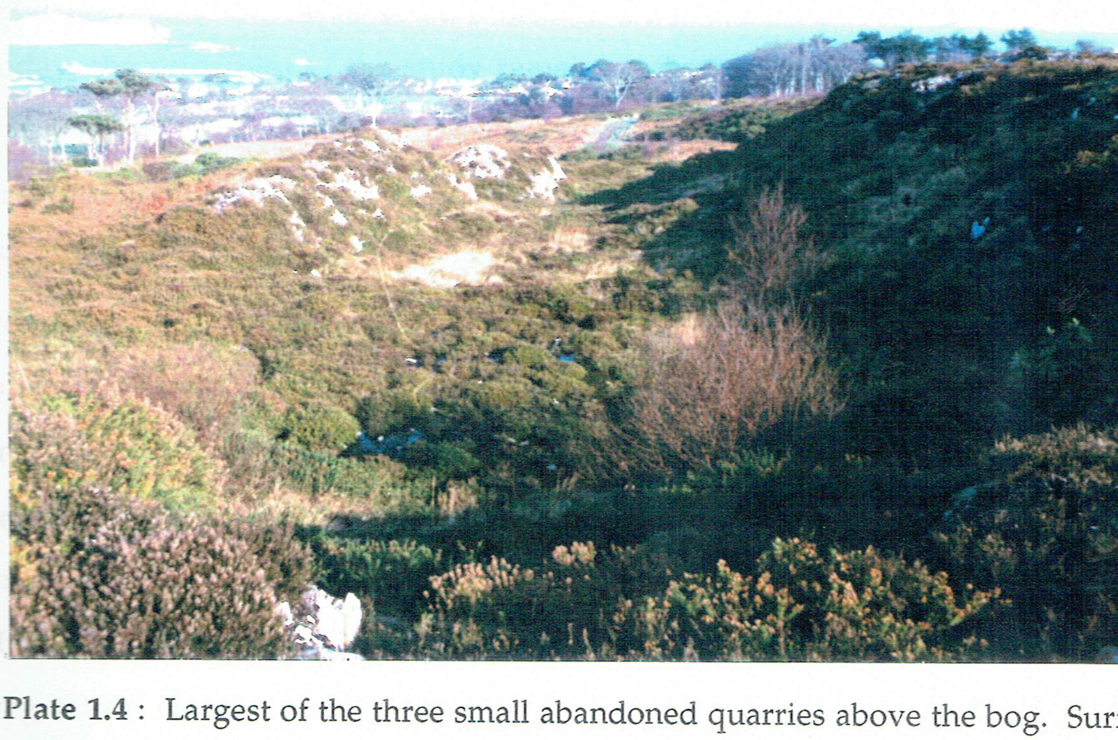


**Plate 1.4** : Largest of the three small abandoned quarries above the bog. Surface water can be seen on the quarry floor in the centre foreground.

Apart from the heath vegetation the area above the bog also includes a long abandoned quarry and a spring (Plates 1.3 and 1.4). The shape of the spring, dug into the hillside, suggests that it was enlarged at some time in the past. Originally this may have been a smaller spring which may have been enlarged to cater for increased water demands in quarrying. The stream flows underground for *c.* 20m before reappearing immediately above the bog. It then seeps into the bog and re-emerges as a small rivulet which passes through a gap in a field boundary before joining with the main stream in the area, `Bloody Stream´.

## 1.2 Palynology and Peat Bogs

### 1.2.1. *Palynology*

The discovery of pollen grains surviving in peat and the realisation of their potential in the study of past vegetation's was due to Swedish state geologist Lennart von Post in 1916 (Faegri & Iversen 1990). Although much modified today, the principles of the study remain unchanged. Palynology has a wide variety of applications including the study of the history of plant species and communities, climate change and the impact of man on the environment. Fossil pollen in sediments is used as an index of vegetation and changes in vegetation. Therefore a change in vegetation should result in a change in pollen types recorded and their abundance. The study of pollen is important in the reconstruction of past vegetation and environments. The relative frequency of pollen found at different levels in a sediment profile can be expressed as percentages of the total. The variation in the percentages of the different taxa through a section of peat gives a quantitative assessment of vegetation changes that have occurred during the formation of the deposit. Anthropogenic influences on former vegetations can also be inferred from sediment studies. The presence of charcoal is used to indicate fire events while specific changes in vegetation can be used to assess the impact of grazing.

### 1.2.2. *Sites for palynological studies*

There are three important factors for the selection of sites for a palynological investigation. A site has to (i) be able to collect pollen, (ii) preserve the pollen it collects i.e.. acidic and anaerobic environment and (iii) have a stratified sediment preferably with a constant accumulation rate over time.

Sites for the successful preservation of pollen have special requirements. The best preservation occurs in anaerobic and acidic environments. Pollen can be identified commonly to genus level and the resulting pollen count is proportional to the vegetation that produced it (Birks & Birks 1980). Stratified sediments are best, as they have good preservation and a temporal sequence of events. Pollen abundance is not directly proportional to vegetation and a number of factors relating to this must be taken into consideration. These include differential pollen production, dispersal and preservation.

The successful preservation of pollen in sediments is due to an inert organic compound known as sporopollenin. This compound is found in the walls of spores and pollen and is sufficiently resistant to withstand acetolysis but can be degraded by strong oxidants such as $H_2O_2$ or $CrO_3$. The amount of sporopollenin present will therefore determine the preservation potential of different pollen types (Traverse 1988). The absence of taxa in profiles may reflect the susceptibility of some pollen types to corrosion and degradation may account for the absence of a specific taxa.

Peat bogs are particularly well suited as sites for palynological investigations. The waterlogged sediments give rise to anaerobic conditions. The acid nature of bog ground water permits the growth of bog mosses, or

*Sphagnum* species. *Sphagnum* absorbs cations in rainfall and releases hydrogen ions to the waters which further reduces the pH of the soil water and creates conditions unsuitable for the majority of micro-organisms. This further increases the rate of plant accumulation. An increase in the growth of peat occurs when the rate of plant production exceeds the rate of plant decomposition (O'Connell 1987). Provided there are no erosion events peat bogs generally provide a good stratigraphy.

In areas where there is a long history of human settlement, like Howth Head, there is increased likelihood that the development of small bogs may have been influenced by human activity.

### 1.2.3. *Pollen source area*

All pollen transported from the site of production to a site of deposition is known as the pollen rain. This pollen rain falls onto the surface of the site and is incorporated into the surface sediments. The potential distance travelled by a pollen grain is considerable. However, most pollen falls near the producing plant despite being very small and having a low specific gravity. From many studies it is generally considered that up to 95% of all pollen produced settles within one kilometre of the source plant (Traverse 1988).

Before interpreting the pollen record from the site it is essential to estimate the pollen source area. Jacobson and Bradshaw (1981) devised a model for describing the relationship between basin size and pollen source area (Figure 1.4). This model excludes sites with inflowing streams and describes five mechanisms for transporting pollen into site. These include local gravity component ($C_g$), trunk space component ($C_t$), canopy component ($C_c$), rain component ($C_r$) and water (inwash) component ($C_w$).

This model predicts that the $C_t$, $C_c$ and $C_r$ components probably contribute small amounts at the Howth site because of its open nature and small size. The $C_g$ and $C_w$ components are probably the most important mechanisms. In the model $C_w$ refers to surface water only and not to inflowing streams. As the bog does not conform with the sites used in this model it is important to consider the effect of the inflowing stream from the quarry and wind strength and direction.

The open nature and location of the site suggest that the prevailing west to southwest winds would transport a higher than predicted percentage of extralocal and possibly regional pollen into the site. The Jacobson and Bradshaw model only serves as a guide for estimating the pollen source area for basins without inflowing streams. The spring which rises immediately uphill of the bog must also be considered when estimating the pollen source area. Additional pollen will be transported by the stream and increase the representation of streamside communities (Jacobson & Bradshaw 1981). The extent to which these two factors increase the pollen source area is unquantified.

This Jacobson and Bradshaw model attempts to predict the potential of sites to record local, extralocal and regional pollen. Local pollen refers to pollen from within 20m radius of the basin, extralocal from 20 to several hundred meters and regional from greater distances.

From pollen evidence (Chapter 3) it would appear unlikely that the study site on Howth Head was ever a fully closed woodland canopy site in the strictest sense. Despite this, it is still possible to use the closed canopy model as a guide to the pollen source area. The model predicts up to 80% of all pollen is derived from within a 20m radius. The remaining 20% is mainly from extralocal sources with very small amounts of region pollen. Figure 1.5 presents the pollen source area predicted by the closed canopy model and the general soil types in the area. A possible pollen source area is also shown after wind strength and direction and the inflowing stream have been considered.

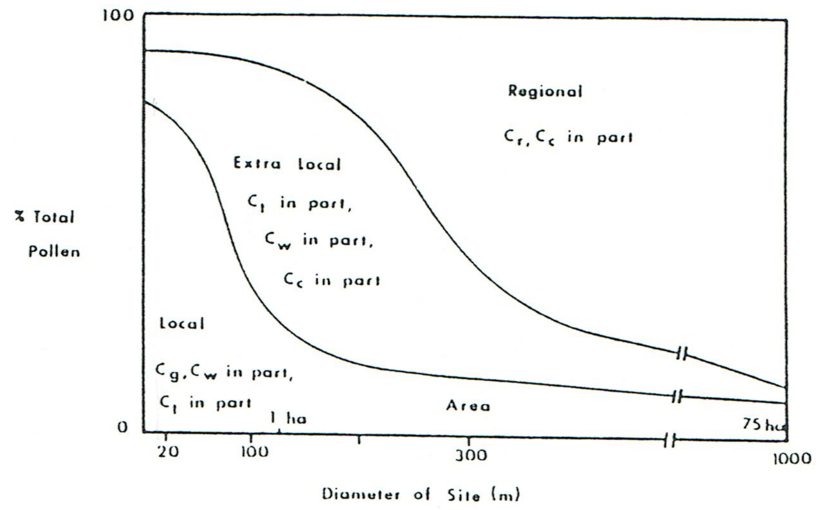



**Figure 1.4 :** Jacobson and Bradshaw (1981) model for pollen source area.

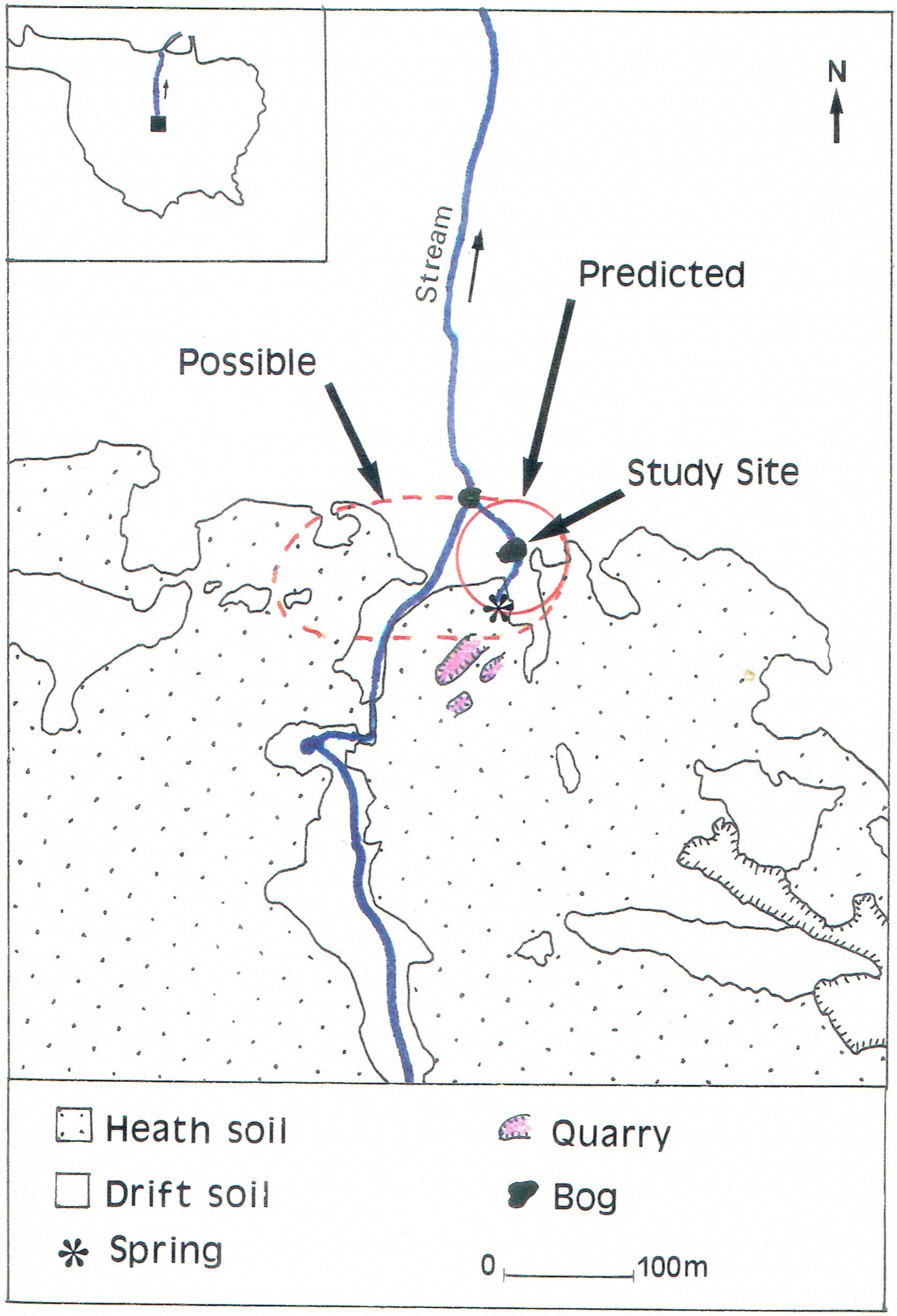



**Figure 1.5** : Predicted and possible pollen source areas for the bog redrawn from colour aerial photographs taken in summer 1990. The predicted pollen source area according to the Jacobson & Bradshaw model (1981) and possible pollen source areas are shown.

## 1.3 Atmospheric Deposition Record

### 1.3.1. *Spheroidal Carbonaceous Particles*

The majority of the particulates emitted during the combustion of oil and coal combustion are Spheroidal Carbonaceous Particles (SCP). McCrone and Delly (1973) have shown that these carbonaceous particles form when fuel droplets or particles are incompletely burnt and volatile components vaporise, leaving a spherical skeleton of non-volatile elemental carbon. Elemental carbon is chemically resistant and therefore preserves well in sediments. Unlike other pollutant indicators (e.g. sulphur) they are not affected by diagenesis. It has been demonstrated in USA, Sweden and Great Britain that SCP profiles in sediments show historic trends in the use of fossil fuels (Wik & Renberg 1991a). Some published sources refer loosely to SCP's as `soot´ (Renberg & Wik 1985a).

SCP's have been studied in a wide variety of contexts including stack effluents, the atmosphere, precipitation and lake sediments (see Wik & Renberg 1987). Forest soil and lake sediment samples contaminated with concentrations of SCP's have been shown to have a geographical distribution pattern consistent with regional air pollution conditions (Renberg & Wik 1985b; Wik & Renberg 1987). Therefore the study of the deposition of these particles can be used as a tool in geographic surveys of atmospheric deposition.

Where the history of fossil fuel consumption is known the concentrations of SCP's in sediments can be used as an indirect dating method. Wik and Renberg (1987) have shown that particulate emissions from oil-fired and coal-fired power plants are carriers of sulphur, heavy metals and polycyclic aromatic hydrocarbons. Concentration depth profiles of these chemicals in dated lake-core sediments have been used to establish the history of atmospheric pollutants. For example Rippey (1990) has shown that atmospheric contamination by these chemicals began early in the last century in Scotland and late last century in southern Scandinavia. Generally there is an absence of `soot´ contamination in pre-*c.* 1930 sediments however after this date concentrations increase up to the 1980s (Flower *et al.* 1988; Battarbee *et al.* 1989).

The concentration of SCP's in sediments, particularly lake sediments, act as markers for acidification. Lakes in the most polluted areas of Sweden have particle concentrations several hundred times greater than the least polluted areas (Wik & Renberg 1991b). There is also evidence from Scotland that atmospheric contamination is indicated by increasing concentrations of SCP's (Jones *et al.* 1993). Lochs studied have shown clear acidification, beginning in the mid to late nineteenth century. Jones *et al.* (1993) concluded that there was a broad correlation between SCP concentrations and sulphur deposition. Where SCP concentrations and sulphur deposition were lowest, lochs were less acidified. Furthermore lake core sediments in Galloway (south west Scotland) indicate that since the mid Post-glacial the increase in acidity is a very recent event associated with acid deposition after A. D. 1800 (Jones *et al.* 1989). The cause of this acidification is still a matter for debate. Recent afforestation of upland areas was considered to be partly responsible however Flower *et al.* (1987) has shown that acidification began prior to afforestation in south-west Scotland.

The majority of studies of SCP's are on lake sediments however ombrotrophic peatlands also retain a record of atmospheric deposition (Clymo *et al.* 1990). Unlike lake sediments, peat deposits are not complicated by processes in the catchment or by mineral particle influx from the catchment. Nonetheless there are difficulties connected with the studies of SCP's in peat deposits. These are uptake by plants, decay of the peat, chemical change in the peat and flow of water within the peat. Establishing a timescale (essential for calculating fluxes) and retention efficiency are important considerations. Depth scale in peat may be misleading due to decay and compression of the peat. Clymo *et al.* (1990) concluded that the preservation of atmospheric deposition is spatially biased in peats, but that the bias in hollows may be uniform so they may, if presented with care, be a useful supplement to the record in lake sediments.

Schultz (1993) has developed experimental collection techniques for modern carbon particle deposition. Microscopic examination has revealed two typically shaped black carbon particles, irregular fluffy soot agglomerations and to a lesser extent spherical particles. A third carbon fraction was identified, however its association with highways implicates traffic as the prevailing source. All three black carbon particles can be microscopically discriminated by particle size and morphology (Schultz 1993). Owing to the distance from study site to the nearest main highway (*c.* 1km) it is unlikely that any carbonaceous particles associated with traffic will be found in the sediment.

SCP's can also play a highly unusual role in the deterioration of urban buildings constructed of calcareous stone. SCP's catalyse the reaction between airborne $SO_2$ and the wet stone surface, leading to the formation of a superficial deterioration crust containing gypsum and carbonaceous particles (Wik & Renberg 1987).

## 1.4 Aims

(1) The principal objective of this palynological investigation is to reconstruct local vegetation history and recent land use changes on Howth Head. The hillside study site, an open small hollow peat bog, is situated on the boundary between two main vegetation types on the headland; these are mixed woodland and *Calluna vulgaris-Ulex gallii* lowland dry heath. Its location suggests that fossil pollen preserved in the sediment would show whether woodland or heath communities were formerly more extensive than their present day distributions suggest.

(2) Although there is extensive literature relating SCP concentration with atmospheric pollution in Northern Europe since the industrial revolution no published literature in an Irish context has been found to date. It is hoped that the study of SCP's in the sediment profile at Howth will contribute in some small way towards the reconstruction of past atmospheric conditions in the Dublin region.

# Chapter 2

# METHODS and MATERIALS

## 2.1 Fieldwork

### 2.1.1. *Monolith collection*

In September 1993 a 72cm monolith was extracted from the study site using a Wardinaar monolith corer (Plates 2.1 and 2.2). Two depth transects were made across the site at right angles to investigate basin morphology. Full details are listed in Appendix 1. The coring site was chosen at the deepest point (Figure 2.1). A full depth of sediment was not extracted, therefore an over-lapping core of the base 8cm was taken using a Dachnoskii corer. To prevent contamination and desiccation the monolith was immediately wrapped in polythene film and aluminium foil. The cores were labelled with site location, date, core depth and stratigraphic top and base. The monolith and core were stored in a cold room at 4°C to inhibit microbial activity.

Three additional sites were also investigated; a small bog beside Howth Golf course, an area known locally as Birch Grove and a second small hollow near `Bog of the Frogs´. These sites appeared to have potential, however for a number of reasons each was abandoned for this project.

Golf course : examination of *c*.10cm of sediment extracted indicated the surface portion was composed of *Sphagnum*. However there were indications that the area was partially drained or disturbed in recent years.

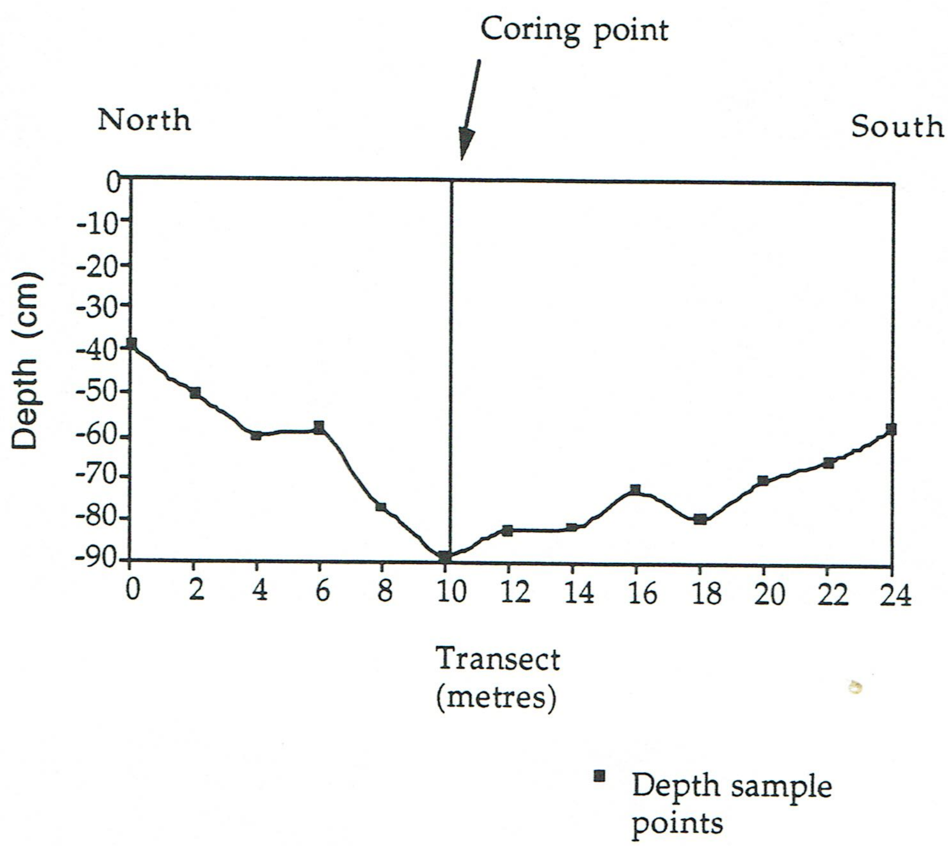



**Figure 2.1** : Cross section `Bog of the Frogs´ view east.

**Plate 2.1** : Wardinaar corer used to extract a monolith from the bog.

**Plate 2.2** : Monolith from the bog. Note the colour difference between the *Sphagnum* layer and the dark brown humified layer near the surface.

Birch Grove : the general alignment of the Birch trees and regular pattern of depth measurements indicated that the area may have been cultivated at some time, possibly with lazy beds. The corer entered the sediment relatively easily however the small amounts of sediment that were extracted lacked cohesion. This site may have been of more recent origin than anticipated and therefore was abandoned for this project.

Second small hollow : examination of the site revealed a pattern of rocks broadly in line with the present day estate boundary. It was suspected that changes in the boundary may have disturbed the sediment, therefore the site was abandoned.

## 2.2 Laboratory Work

### 2.2.1. *Sediment description*

The composition and structure of the monolith were described using the Troels-Smith (1955) system of sediment description and classification. This objective system for sediment classification recognises that most sediments have a mixture of properties. Physical properties (e.g. stratification, colour) and composition properties (e.g. silt, gravel, plant remains) are described using symbols and a 5 point scale (0-4) for degree or abundance.

### 2.2.2. *Loss on Ignition*

To quantify the amount of organic and inorganic matter present in the monolith a loss on ignition profile was carried out at each level in which pollen sub-samples were taken.

Procedure:

1. Place samples in pre-weighed crucibles and dry in an oven overnight at 60°C.

2. Remove from the oven, place in a dessicator to cool and weigh.
3. Burn off organic matter by placing crucibles in a muffle furnace at 550°C for 7 hours. To avoid deflagration allow the temperature to rise slowly until the desired temperature is reached.
4. Remove the crucibles from the furnace, place in a dessicator to cool to room temperature and weigh.
5. Calculate the percentage loss on ignition for each sample.

$$\% \text{ LOI} = \frac{\text{Dry Wt. of Sample - Ignition Wt. of Sample}}{\text{Dry Wt. of Sample}} \times 100$$

### 2.2.3. *Humification*

This objective method of assessing the degree of decomposition of organic sediment is based on the methods described by O'Donnell (1984). Humification is the chemical and biological transformation of organic matter into dark coloured chemically complex substances such as humic and fulvic acids. As a result the intensity and colour of peat extracts increases as humification increases. This method therefore establishes a relationship between the amount of humic acids present in the sediment and the state of decomposition. The results are expressed as percentage humification.

Procedure:

1. Select sub-sample depths for analysis, e.g. every 5cm from the surface, get fresh weight and place in oven (*c.* 60°C) overnight to dry. Approximately 2g fresh weight will yield the 0.2g dry weight required however this amount will vary according to the sediment.
2. Remove from oven, place in dessicator and get dry weight.
3. Grind up to powder with pestel and mortar. Place in oven again to dry off moisture from the powder.
4. Remove from oven, place in dessicator and weigh again.

5. Measure 0.2g into conical flask containing 100ml 0.5% NaOH.
6. Place flasks onto preheated hot plate and heat until the solution begins to boil. To reduce the amount of NaOH lost to evaporation during this process place watchglasses on each flask. When the solutions begin to boil (after *c.*15 minutes) remove the flasks from the hot plate and r educe the temperature. Agitate each flask and replace on the hot plate for 1 hour.
7. Remove from hot plate, pour into 100ml graduated cylinder. Replace any solution lost through evaporation by making to volume (i.e. 100ml) using distilled water. Filter into 100ml conical flasks.
8. Pipette 25ml of filtrate and 25ml distilled water into 50ml volumetric flask and agitate fully.
9. Measure the absorbance of light by the filtrate using a photospectrometer at 540nm. Convert the values (y) to percent humification (x) using the formula:

$$\text{Absorbance } x = 8.3\ (y + 0.1)$$

**2.3 Pollen Analysis**

The reconstruction of past vegetation is largely achieved by analysis of fossil pollen preserved in sediments. This is the most important method of investigation used in this study.

2.3.1. *Sub-sampling and sample preparation*

A total of 20 sub-samples were taken from the monolith and one surface sample of *Sphagnum* was taken from the bog. Prior to sub-sampling, superficial material was removed by scraping perpendicular to the monolith axis with a clean sharp blade. This minimised the possibility of contamination above or below the sub-sample point.

The objective of pollen extraction techniques is to concentrate the pollen from a sub-sample and to remove the bulk of undesirable organic and inorganic sediment as possible. Standard physical and chemical extraction processes described by Faegri and Iversen (1990) were used to remove the sediment matrix.

Procedure:

1. Remove 0.5cm$^3$ sub-samples from the monolith using a volumetric copper syringe and place into appropriately labelled glass vials. Store in a cold room until required. Add a small quantity of distilled water to each vial to prevent desiccation during storage. Alcohol may also be added to prevent fungal activity. Place the live *Sphagnum* sub-sample from the bog surface into a conical flask containing 150ml distilled water. Shake the flask for *c.* 30 minutes. After shaking pour the contents through a coarse sieve concentrate the filtrate by centrifuging and place the remaining solution into a 10ml centrifuge tube.
2. Transfer sub-samples from the glass vials into 10ml plastic centrifuge tubes by washing with 10% KOH. Remove all material as it represents a volumetric sample. The KOH breaks down organic lumps, releases and removes soluble humic acids. Use tubes with numbers cut into the plastic as acids used in the extraction process can removes ink marker from the tube surface. Record the sub-sample level and corresponding test tube number.
3. Level off each test tube with 10% KOH and stir with a glass rod. Wash glass rod with KOH when removing from test tube. After stirring, centrifuge for 4 minutes at between 2,500 and 3,000 r.p.m. Remove from centrifuge and decant the supernatant.

4. To each tube pipette 0.5ml *Lycopodium clavatum* spore suspension as an exotic marker. The addition of a known quantity of an exotic marker enables absolute pollen concentrations in the sample to be calculated. Two *Lycopodium clavatum* batch solutions were used. One contained 33,333 spores per ml and the other contained 107,000 spores per ml. The *Lycopodium* solutions should be stirred for *c.* 1 hour before use.
5. Add 5-10% KOH to each tube and place in a hot bath for 5 minutes. Stir regularly with glass rods. When removing glass rod wash down with KOH and level off. Centrifuge and decant the supernatant.
6. Resuspend the pellets with distilled water and wash through a 125µm sieve into 50ml glass centrifuge tubes. Wash sieving into labelled petri dishes and set aside for charcoal fragments and other macrofossils analysis. If there is difficulty washing the material through the mesh sieve due to surface tensions, add a few drops of absolute alcohol to this residue. Level with distilled water, centrifuge for 5 minutes at 3,000 r.p.m. and decant the supernatant.
7. Use the fume cupboard for the next 3 stages. Wash pellets into 10ml centrifuge tubes using 10ml glacial acetic acid and stir with a glass rod. Level and wash rod down with glacial acetic acid, centrifuge and decant the supernatant into the sink in the fume cupboard. Glacial acetic acid dehydrates the sediment and prepares the sample for the next stage in the process.
8. Add 10ml of acetolysis mixture (acetic anhydride and concentrated $H_2SO_4$ in ratio 9:1). Level off with glacial acetic acid and place in hot water bath for 5 minutes stirring regularly after 2 minutes. Remove from hot bath, stir, wash glass rod off with glacial acetic acid and level off. Centrifuge and decant the supernatant into the waste bottle in the

fume cupboard. This process breaks down polysaccharides such as cellulose by the removal of water molecules.

9. Resuspend pellets with 10ml glacial acetic acid, stir with glass rod, level off, centrifuge and decant the supernatant.
10. Add 5mls tertiary butyl alcohol (TBA), stir, level off with TBA, centrifuge and decant the supernatant.
11. Transfer the residues to appropriately labelled glass vials with a Pasteur pipette, washing with TBA. Add 2 or 3 drops of silicone oil (viscosity 2,000 centistokes) and stir well with a clean wooden stick.
12. Place vials (un-lidded) into the oven at 80°C overnight until all TBA has evaporated. This concentrates the pollen in silicone oil. After TBA has evaporated place lids on vials and store until required for slide preparation and counting.

2.3.2. *Zinc chloride preparation*

The lowest two sub-samples at 68cm and 72cm received this treatment due to the gritty inorganic nature of the sediment. This method developed by Kummel and Raup (1965) is based on the principle that pollen is less dense than mineral particles and can be separated by flotation in a suitable heavy liquid such as zinc chloride solution. This method follows immediately after the KOH digestion and washing.

Procedure:

1. Wash with 10% HCL, centrifuge and decant the supernatant.
2. Add zinc chloride to the solution (concentration 2g $ml^{-1}$). Stir well to suspend pollen trapped in inorganic particles. Centrifuge at 2,500 r.p.m. for 3 minutes.
3. Pipette the top layer of the solution (i.e. containing pollen) into a 50 ml centrifuge tube and dilute with distilled water (x 4).

4. Centrifuge at 2,500 r.p.m. for 3 minutes. A pellet containing pollen forms at the bottom of the tube. Check for the presence of pollen grains in the supernatant. If present dilute and centrifuge again.
5. Wash with 10% HCL, centrifuge and decant the supernatant. The addition of HCL prevents the formation of zinc hydroxide.
6. Add glacial acetic acid and proceed with acetolysis (step 8 above).

2.3.3. *Mounting on slides*

Samples for pollen and microscopic charcoal analysis were mounted onto glass slides in the following manner.

Procedure:

1. Stir samples in vials with a wooden stick to ensure contents are well mixed.
2. Place a drop of the sediment suspension onto the slide, spread into a thin film and cover with a cover slip. If necessary add a drop of silicone oil to dilute the suspension before placing the cover slip into place. The principal advantage of mounting silicone oil is that it allows pollen grains to be freely rotated by applying a slight pressure to the cover slip. Pollen can then be viewed in both polar and equatorial view to assist pollen identification.
3. Fix the cover slip into permanent position by applying nail varnish at each corner. Label slide with location and sub-sample level.

2.3.4. *Pollen identification*

A Leitz Laborlux 12 light microscope (x 400) was used for pollen identification. Occasionally pollen which were difficult to identify were viewed under the oil immersion lens (x 1,000). A minimum of 300 pollen were identified and counted at each sub-sample level by traversing the slide at regular intervals. *Lycopodium* and other spore types were not included in the pollen count.

Brooks and Thomas (1967) have shown that smaller pollen tend to move to the sides of the cover slip therefore traverses were made evenly over the entire slide.

Pollen were identified to family, genus and where possible to species level using the keys and photographic illustrations in Oldfield (1959), Moore *et al.* (1991) and Reillie (1992). Comparisons were also made using the pollen reference collection in the Botany Department T.C.D.

2.3.5. *Processing of data*

Pollen counts for each sub-sample were converted to pollen percentages and pollen concentrations (grains/$cm^3$) using the *Tilia* plotting package designed to run on the IBM compatible PC's (Grimm 1991).

**2.4 Macrofossil Analysis**

2.4.1. *Charcoal*

Conclusion can be drawn about vegetation dynamics and human settlement by analysis of charcoal. The presence of charcoal preserved in sediments has been shown by Swain (1973) cited by Clark (1982) to reflect the fire history of regions investigated.

Macroscopic charcoal fragments generally suggest fire events occurred close to or on the site whereas microscopic infers fire in the region but not necessarily on the site itself. Both microscopic and macroscopic charcoal were used to interpret the effect of fire on the vegetation.

### Macroscopic Charcoal (>125µm)

Procedure:

The sievings retained from pollen preparation representing 20 sub-samples between the surface and 72cm were used to determine the presence or absence of charcoal fragments. As the sieve size used was 125µm only particles greater than this were retained for macroscopic examination. Fragments less than 125µm passed through the sieve and were counted microscopically. The petri dishes with the sieving were allowed to air dry and then placed onto circles with 20 random grids. This technique is based on the "random quadrat" technique described by O'Sullivan (1991). Charcoal abundance was calculated by counting the number of fragment present in each of the 20 randomly placed 1cm$^2$ quadrats in a circle the size of the petri dish. The results are expressed as the surface area of charcoal present per unit volume (cm$^2$/cm$^3$). Figure 2.2 shows petri dish random quadrats used in the charcoal analysis.

### Microscopic Charcoal (<125µm)

The technique used for estimating the surface area of charcoal in pollen preparations is the point count method described by Clark (1982). This systematic two-dimensional point count is a fast, simple and accurate way of estimating the projected area of charcoal in a plane surface. The points used are defined by the end of an eyepiece micrometer. The magnification and number of points chosen ensure that only one point falls on the majority of individual particles. Transects across the slide were chosen in a predetermined pattern using a calibrated stage. As pollen preparations are not usually dispersed over the entire slide the pattern of transects chosen minimised the possibility of the points falling on a small and potentially unrepresentative area.

At each level counted the following was recorded: (i) sub-sample level, (ii) number of transects, (iii) minimum of 200 fields of view, (iv) minimum

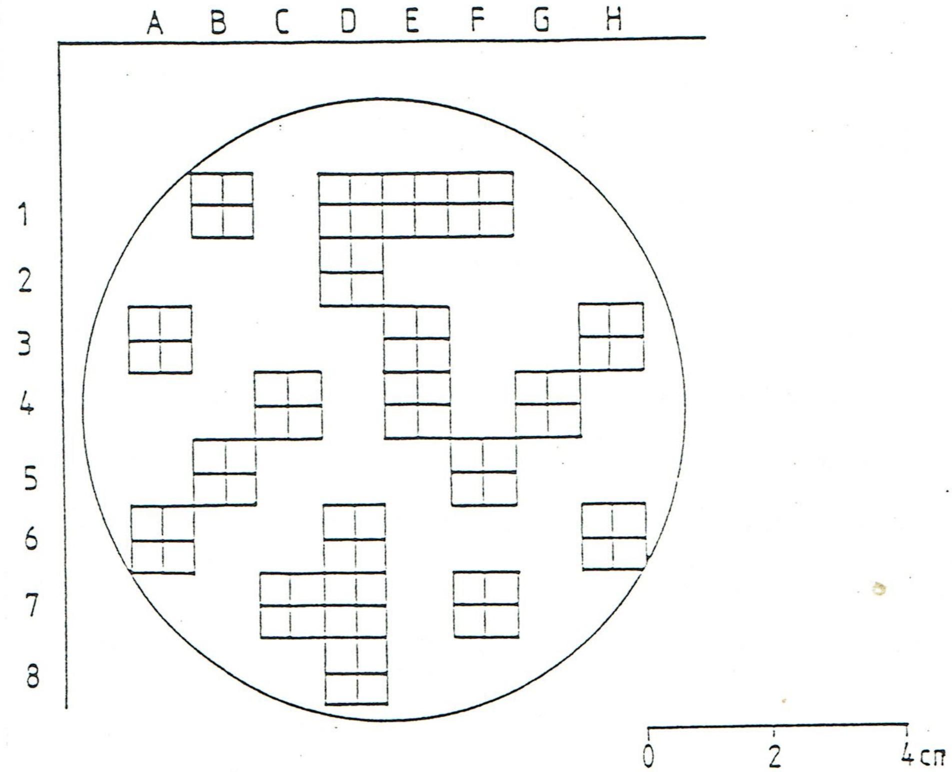



**Figure 2.2** : Random quadrats used for estimating the number of macroscopic charcoal fragments and SCP's in the sievings retained from pollen preparations.

of 10 *Lycopodium* and (v) the number of times charcoal fell on the micrometer points. The results are expressed as the surface area of charcoal present per unit volume ($cm^2/cm^3$).

### 2.4.2. *Macroscopic Spheroidal Carbonaceous Particles (SCP)*

SCP´s were identified in the pollen sample sievings and counted using the same random quadrats in macroscopic charcoal analysis (Figure 2.2). The number of SCP's in each sub-sample was converted to $g^{-1}$ dry weight. The principal source for these particles is considered to be the small number electricity generating stations which have existed in Dublin Port since the late 1920s. Data relating to the quantity of fossil fuel consumed by the generating stations was not readily accessible so the total number of units of electricity generated annually from the Dublin stations was used as an index of production. These data were then compared to the SCP profile in the sediment and used as an indirect dating method.

### 2.4.3. *Dating*

A Radiocarbon date was obtained for the lowest organic layer (62.5cm-65cm) at the base of the monolith which was considered to represent the beginning of the bog. Analysis was carried out by Dr. Ede Hertelendi of the Institute of Nuclear Research of the HAS, Hungary. This date was calibrated using the Groningen Radiocarbon Calibration Programme (Van Der Plicht 1993).

SCP´s were also used as an indirect dating method. These particles are produced during the combustion of fossil fuels and only appear in post-industrial sediments. Concentration depth profile in the sediment when compared with fuel combustion records in the same region can be used as an indirect dating method (Wik & Renberg 1985a).

Annual growth rings on a number of recently felled trees within 150 metres of the bog were also used for dating. Local sources report that these trees were uprooted *c.* 10 years previous (1984-85) during a storm. The trunks were subsequently removed leaving a flat cross section exposing the annual tree rings. As each tree ring represents one years annual growth the mean number of tree rings was calculated. An approximate date for the planting of the woodland immediately adjacent to the bog was therefore taken to be the mean tree ring value in addition a maximum 10 years since uprooting. To assist counting the surface of each cross section was planed before the rings were counted. Blue coloured marker pins were used to mark annual rings and green pins for each tenth ring.

Fire is frequent on the headland and in 1967 a major fire occurred very close to and probably on the site (O'Neill 1971). The occurrence of macroscopic and microscopic charcoal peaks at 6cm in the sediment is considered to refer to this time period. A date for the most recent fire was established by counting the annual growth rings on stems of *Calluna, Ulex* and *Betula* growing on the site.

### 2.4.4. *Soil and Pollen Source Area*

A general soil map was produced using aerial photographs taken in summer 1990 (scale 1: 5,000 : Flight lines 36, photograph no. 8306 and flight line 37 photograph no. 8308). A ground truth record of the maps was also carried out.

### 2.4.5. *Vegetation cover and land use change*

Ordinance Survey maps of 1843 and 1936-37 (six inches to one mile : sheets 15, 16 and 19) were used to examine vegetation changes and land use over time (Figures 2.3 and 2.4). An area of the headland was selected which represented the principal vegetation types identified on OS maps. Vegetation cover in each map was estimated using a leaf area meter and acetate sheets of the outlines of each vegetation types.

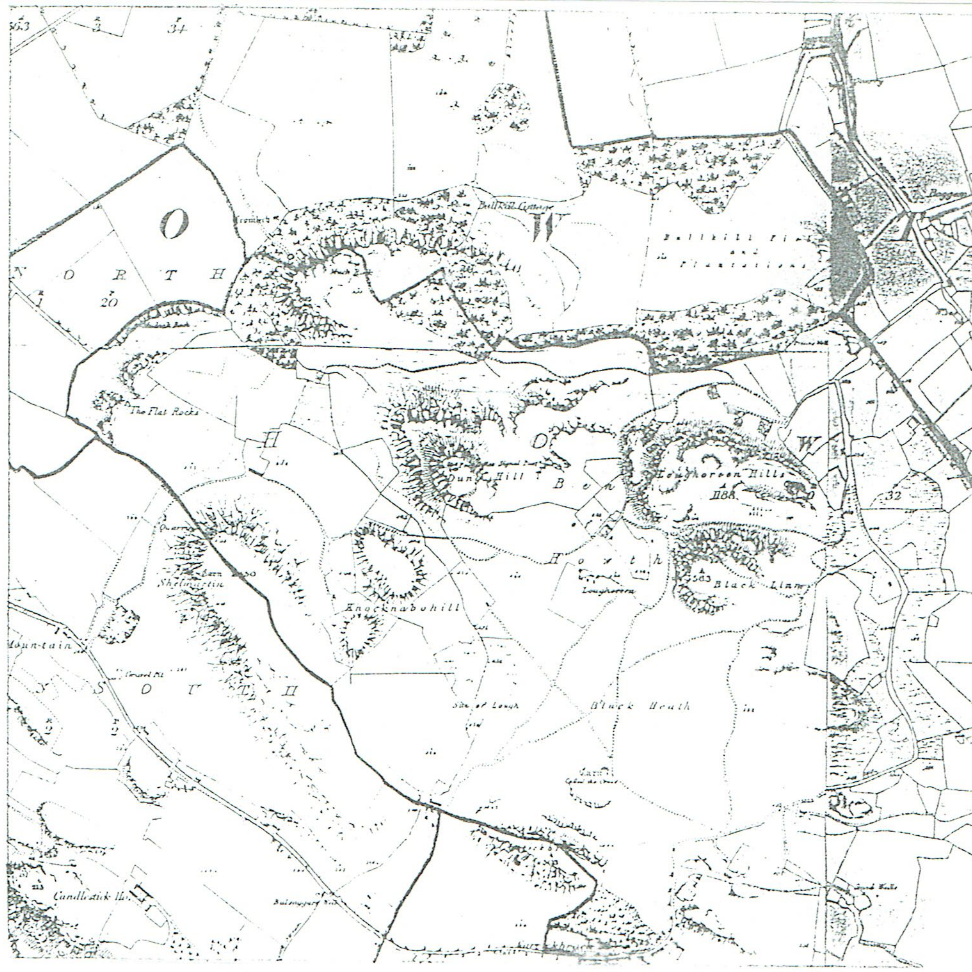
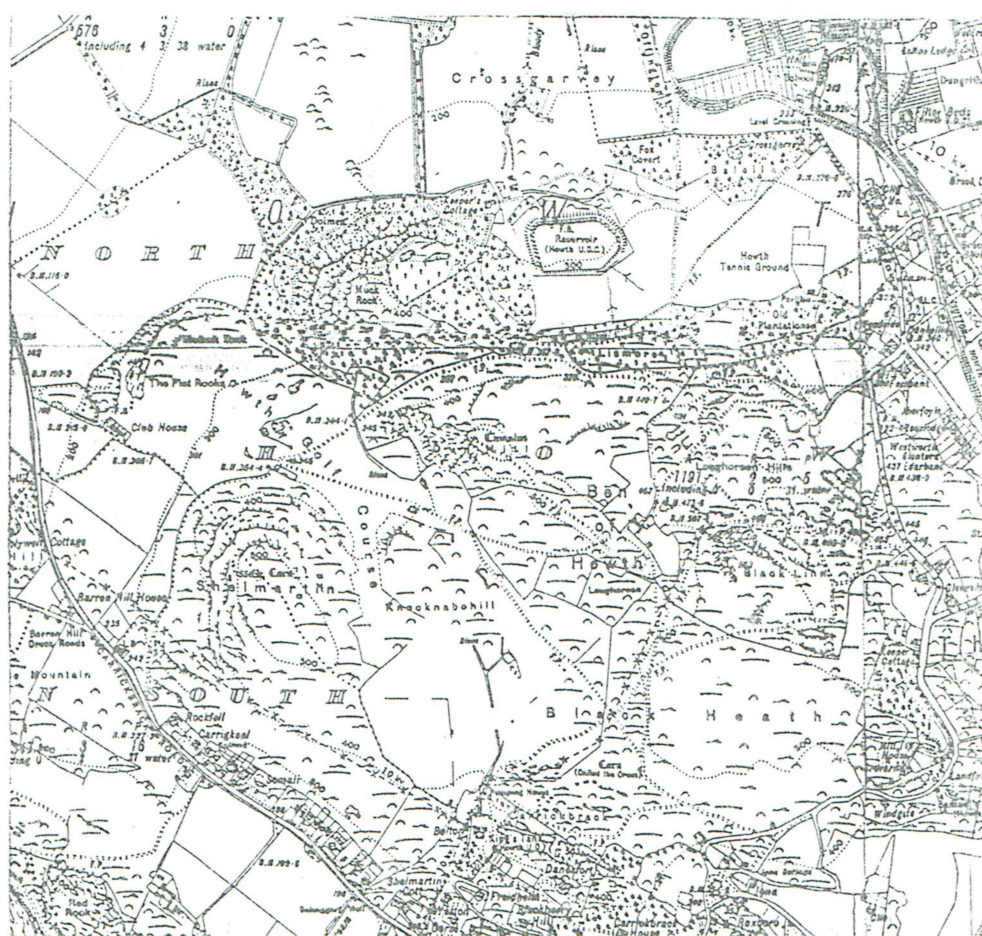



**Figure 2.3** : General map of part of Howth Head taken from 1843 Ordinance Survey maps (OS 6" to 1 mile).



Vegetation was classed into three categories : (i) woodland, (ii) heath/scrub and (iii) arable/pasture. The area of woodland was generally well defined by field boundaries. Boundaries between arable/pasture and heath/scrub were occasionally less clearly defined. Isolated map symbols for heath/scrub frequently appeared in what where otherwise areas of arable/pasture. A more subjective approach was therefore taken in assessing the area of heath/scrub. Errors in the estimated area of heath/scrub and arable/pasture may have occurred at this point. It is hoped however that any errors introduced are less than the true percentage change between 1843 and 1936/37.

Procedure :

1 An acetate photocopy of the three vegetation types within a selected area on the 1843 map was made.

2 Polygons of each vegetation type were in turn filled in with black marker and their area was measured using the leaf area meter.

3 The area of each vegetation type was then converted to actual land area (hectares). The overall change in area of each vegetation type between 1843 and 1936/37 was calculated.

# Chapter 3

# RESULTS

## 3.1 Sediment Analysis

### 3.1.1. *Loss-on-Ignition (LOI)*

Loss on ignition represents the total organic matter in each sample. Figure 3.1 presents percentage LOI for the core. Sampling resolution varied from 1cm to 8cm. LOI values throughout the core varied between 6.6% (72cm) and 92% (4cm). The LOI profile can be divided into five stages. (i) An inorganic layer at the base with highest value of 7.4%. (ii) Accumulation of organic material between 64cm and 48cm resulting in 53 to 57% LOI. (iii) Increased LOI values to 71% at 44cm followed by a decrease to 55% at 39cm. (iv) A gradual rise to 70% at 32cm and decrease to 59% at 24cm. (v) Highest organic values in this stage. LOI gradually increases to a peak of 92% at 4cm. Full details are listed in Appendix 2.

### 3.1.2. *Humification*

Percent humification values at 5cm intervals for the core are presented in Figure 3.2. Values varied between 2.2% (71cm) and 4.9% (66cm and 16cm). The amount of humic acids produced during decomposition is very variable and is largely dependent organic material in the sediment and decomposition conditions etc. These values are considerably lower than those reported

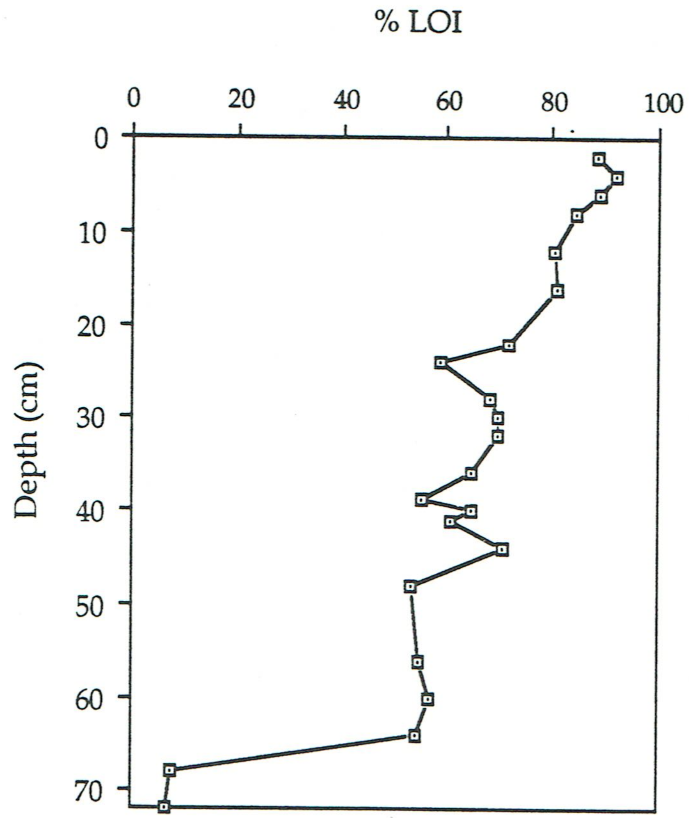



**Figure 3.1** : Loss on ignition profile.

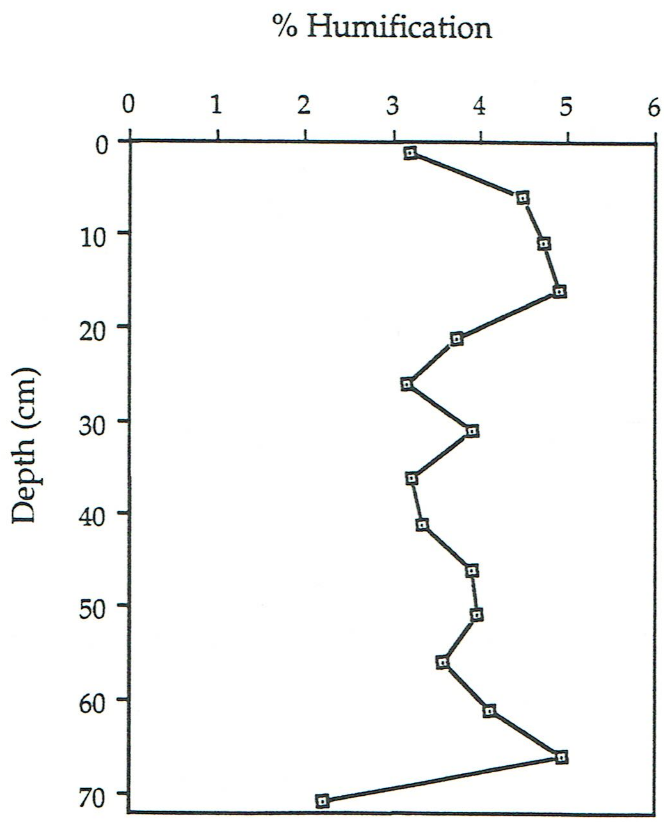



**Figure 3.2** : Humification profile.

elsewhere (O'Donnell 1984, Rosaleen O'Dwyer pers. comm.). Nonetheless the relative differences in humification recorded in the profile can be used to assess the different stages of decomposition in the sediment.

This profile can be divided into five stages. (i) Corresponding with the inorganic layer at the base, lowest values (2%) were recorded at 71cm. (ii) The highest value in the profile of 4.9% was recorded between 6cm and 56cm. (iii) A slight decrease occurred to 3.9% at 51cm and 46cm. (iv) Generally low values between 41cm and 26cm. The odd peak at 31cm (3.9%) possibly reflects one of the thin bands of darker peat in what is otherwise a predominantly *Sphagnum* layer. (v) A gradual increase occurs from 21cm to 6cm with a peak of 4.9% at 16cm. The decrease towards the surface may be due to the large number of plant roots at this level. Full details are listed in Appendix 3.

## 3.2 : Macrofossil Analysis

### 3.2.1. *Charcoal*

Apart from a microscopic charcoal peak at 64cm the majority of macroscopic and microscopic charcoal occurred from 8cm to the surface. This indicates that fire is a relatively recent influence in the area. Details of the macroscopic and microscopic charcoal record are presented below.

<u>Macroscopic Charcoal:</u>

Macroscopic charcoal fragments were recorded in 17 out of 20 sievings retained from pollen preparation (Figure 3.3). Low values were recorded at 12 levels between 72cm and 16cm inclusive. The number of fragments increased at 12 cm and 8cm with 992 $cm^2/cm^3$ and 400 $cm^2/cm^3$ respectively. A sharp increase then occurred at 6cm and peaked at 4cm at 3547 $cm^2/cm^3$. At 2cm 908 $cm^2/cm^3$ were recorded. Full details are presented in Appendix 4.

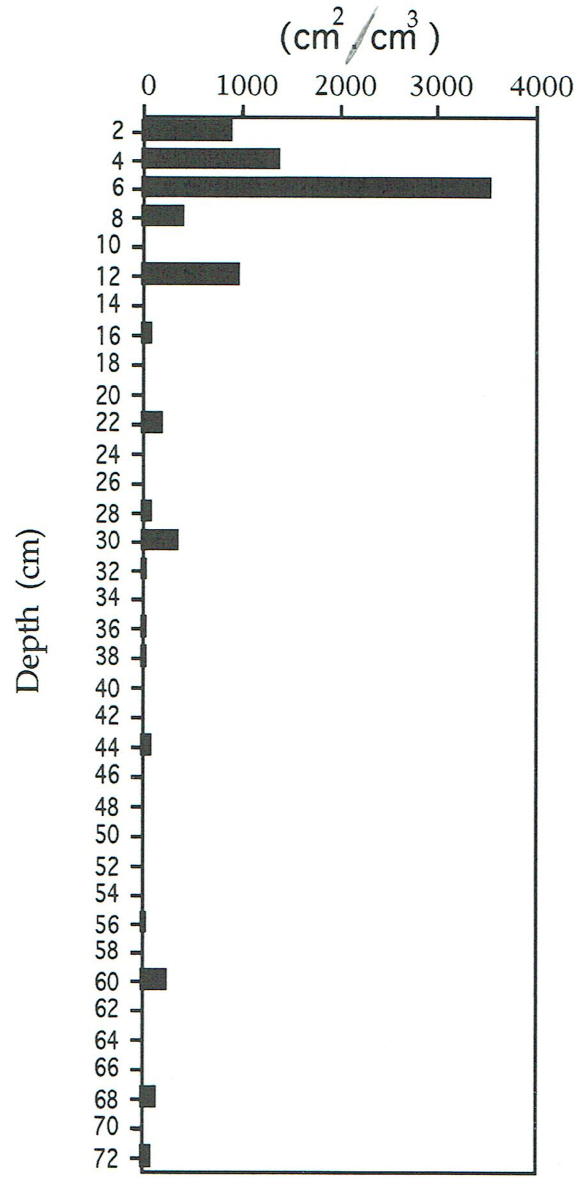



**Figure 3.3** : Macroscopic charcoal profile.

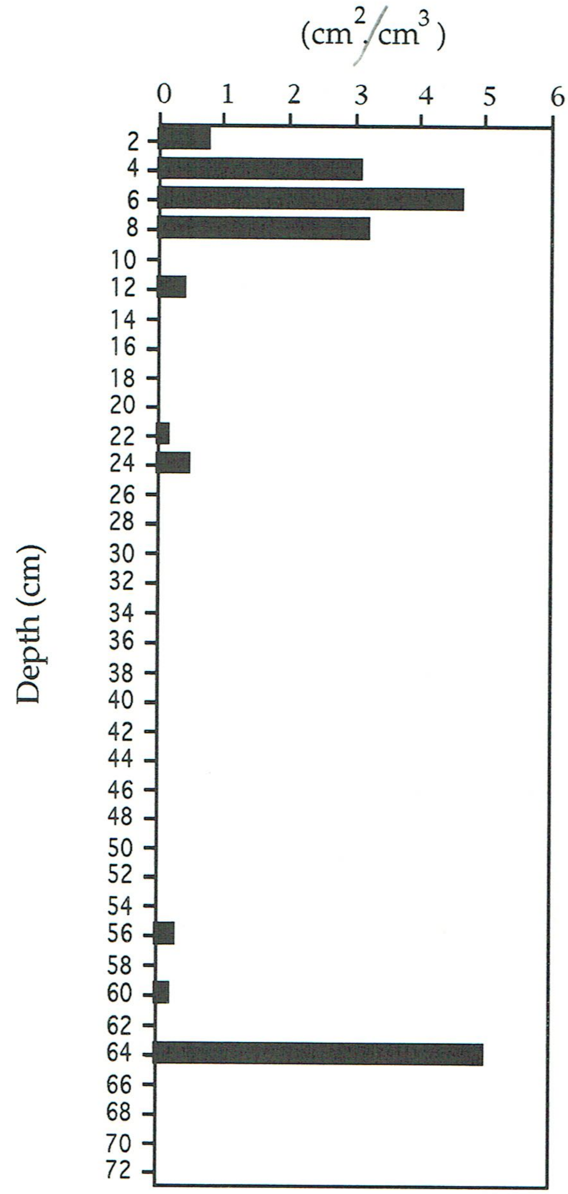



**Figure 3.4** : Microscopic charcoal profile.

Microscopic Charcoal:

The highest value in the profile was 5cm$^2$/cm$^3$ at 64cm (Figure 3.4). This is also the deepest level where microscopic charcoal was recorded and coincides with the radiocarbon date of mid-fifteenth century. Apart from the peak at 64cm values were generally very low up to 8cm. From 8cm to 2cm the amount of microscopic charcoal increased from 3.1cm$^2$/cm$^3$ and 4.6cm$^2$/cm$^3$. This increased frequency of microscopic charcoal near the surface is also observed in macroscopic charcoal. Full details are presented in Appendix 5.

### 3.2.2. *Macroscopic Spheroidal Carbonaceous Particles*

A concentration depth profile of SCP's in the sievings retained from pollen preparation are presented in Figure 3.5. It is important to note that the methods described by Wik & Renberg (1985a) for the preparation of SCP's was not used in this project. SCP's received KOH treatment during pollen preparation and were observed in the sievings retained for macrofossil analysis. The effect of KOH treatment on their structure and chemical composition is not known.

SCP's were recorded from 30cm to the surface. Concentrations increase rapidly from 24cm and peak at 8cm with 4.38 x $10^3$ $g^{-1}$ dry weight. Values decrease to markedly towards the surface.

The size range of SCP's measured during SEM work varied between 65µm and 145µm. Some smaller particles were also present but not measured. These measurements are greater than the average size of 50µm or less reported in other studies (Wik & Renberg 1987; Wik & Natkanski 1990; Schultz 1993). X-ray analysis of these particles show they are composed of elemental carbon (59%), sulphur (26%) with smaller amounts of silica, calcium and potassium. These results are in general agreement with data

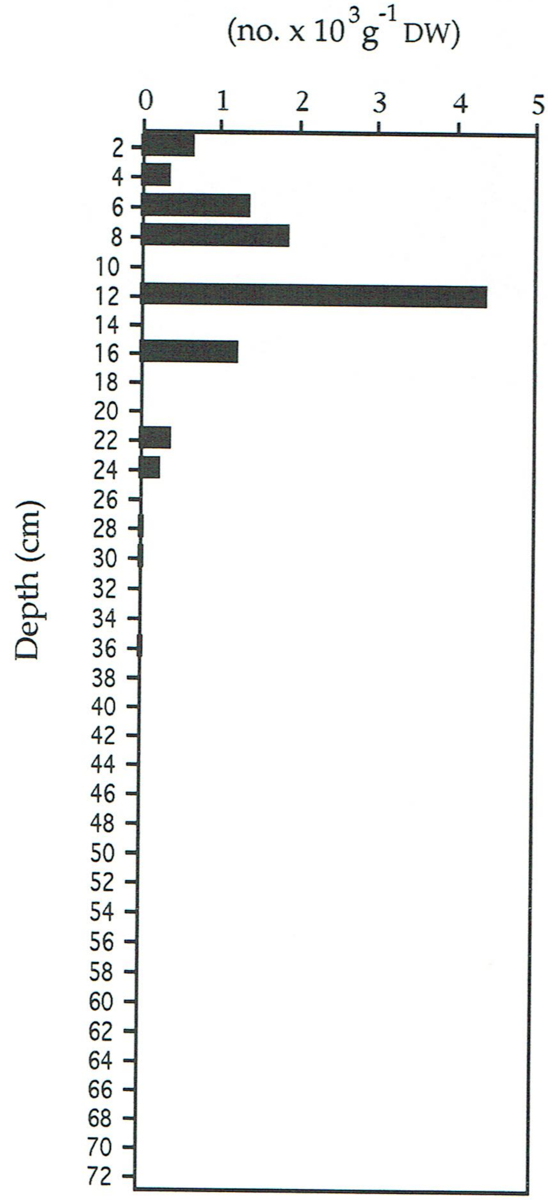



**Figure 3.5** : Spheroidal Carbonaceous Particle profile.

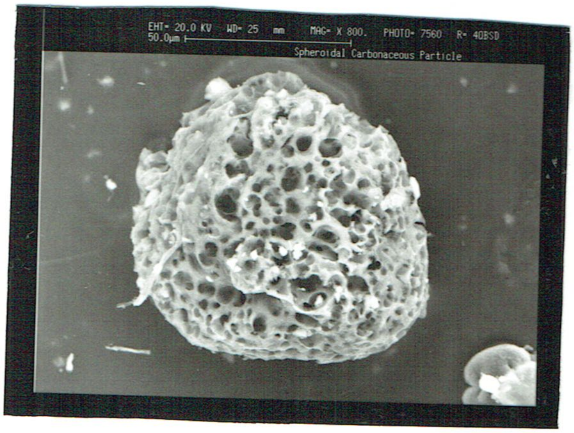



**Plate 3.1** : Scanning Electron Micrograph of a Spheroidal Carbonaceous Particle
These particles are x2 and x3 times larger than those reported in literature.

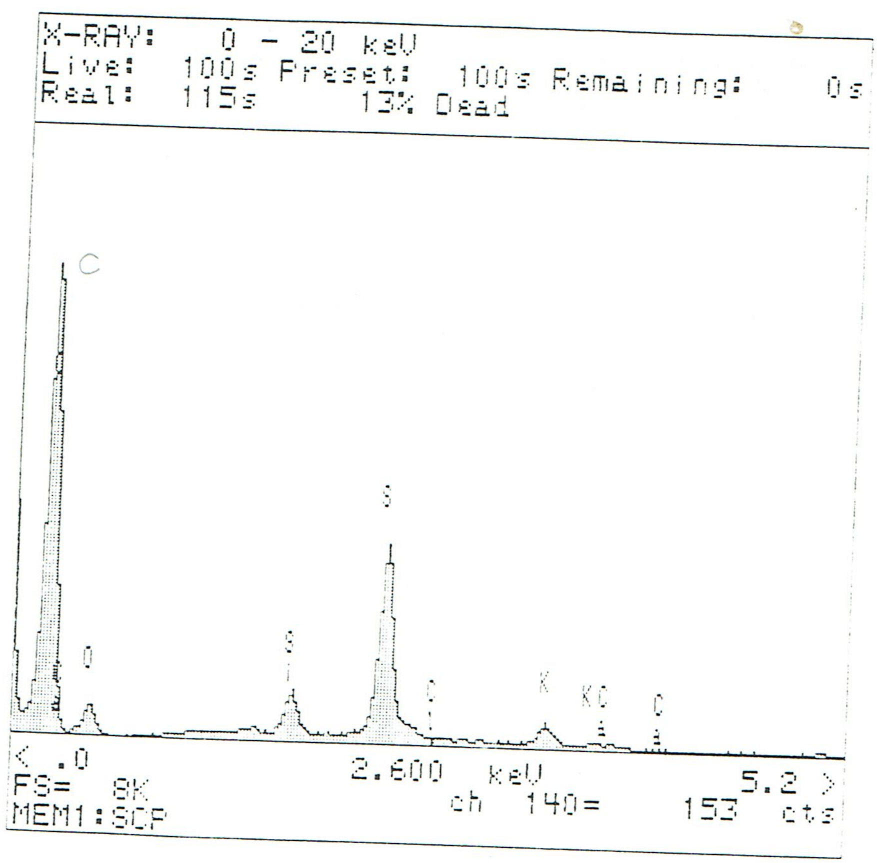



**Figure 3.6** : X-ray analysis of SCP's show that they are composed mainly of elemental carbon (59%) and sulphur (26%) with smaller quantities of other elements.

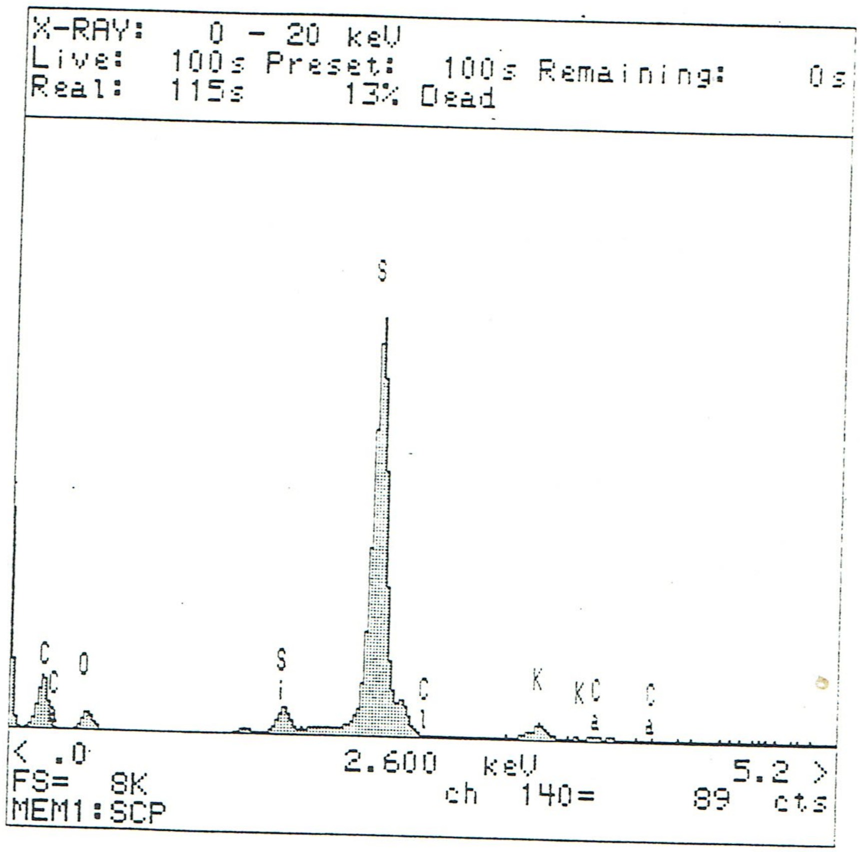



**Figure 3.7** : X-ray analysis of sulphide particle found in KOH extract.

published elsewhere. An SEM and X-ray spectra of an SCP are presented in Plate 3.1 and Figure 3.6. Full count details are listed in Appendix 6.

SCP's have not been recorded during daily air monitoring in Dublin City (Paul Dowding pers. comm.).

In addition to SCP's, smaller white crystals (*c.* 10 - 20μm) were observed in the KOH extract during SEM work. Analysis indicate they are composed largely of elemental sulphur (72%) carbon (9%), silicon (5%) and smaller amounts of other minerals. X-ray spectra of these \`sulphide´ particles is presented in Figure 3.7. It is likely that these particles may have originally been the \`cement dust´ particles as reported on leaf surfaces by Peacock (1992). It is possible that the particles recorded in this study were originally of a similar composition. After deposition in the acidic environment of the bog the calcium element may have metabolised e.g. via cation exchange or microbial activity. The KOH extract during pollen preparation may have also affected the chemical composition.

### 3.2.3 *Dating*

A total of five dates were attained for the bog. Four (1 to 4 below) of these are used in the construction of a time-depth curve for the growth of the bog (Figure 3.8).

(1) A radiocarbon date (calibrated) of A.D. 1438 ± 26 years as attained for the base of the deepest organic layer 62.5-65cm.

(2) A count of annual growth rings indicate the Pine trees near the site was planted in *c.* 1830. An allowance of 15 years was made for growth to flowering time.

(3) Electricity Supply Board (ESB) production records suggest SCP deposition began from the early 1930's and increasing markedly in the 1950's in the Dublin region. These dates coincide with the beginning of electricity production by the ESB in Dublin in 1930 and expansion of the Pigeon House

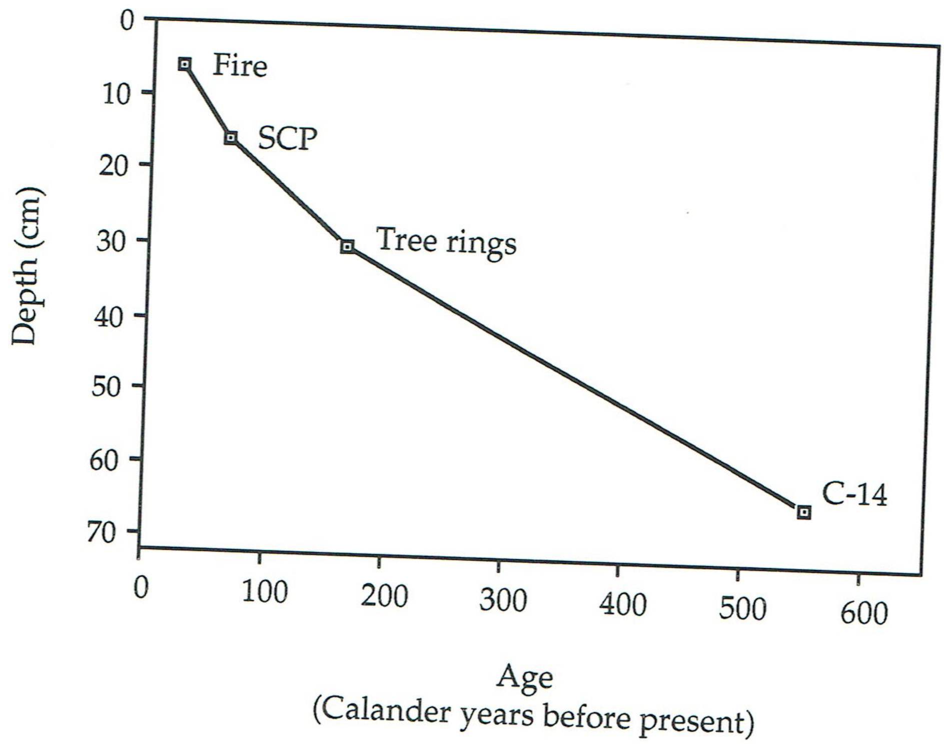



**Figure 3.8** : Time depth curve for the sediment using four dating methods.

plant in the mid-1940's (Manning 1984). Data on fossil fuel consumption was not readily available therefore the number of units generated was used as an index of consumption (ESB 1931-1991). There are two assumptions in using this approach as a dating method. Firstly, it is assumed that the ESB power stations are the main source of SCP's. Secondly, it is assumed that the number of SCP's produced remained fairly constant over time and unaffected by increased combustion efficiency. Although finer sampling resolution would be required for a more accurate date it would appear that 22cm in the profile corresponds with *c.* 1930.

(4) A documented record of a large fire in the vicinity of the bog in 1968 corresponds with charcoal peaks at 6cm (O'Neill 1971).

(5) Annual growth rings of vegetation on the site suggest the last fire event on the bog was in 1982/83.

## 3.3 Sediment Stratigraphy and Pollen Analysis

### 3.3.1. *Sediment stratigraphy*

The sediment monolith extracted was *c.* 72cm in depth. A description of the sediment was made based on the Troels-Smith system (Troels-Smith 1955) and a profile of the monolith is presented in Figure 3.9.

| cm | |
|---|---|
| 0 - 1 | Surface sample. Live leaves of *Sphagnum*. |
| 1 - 5 | Unconsolidated, poorly decomposed with live roots. Nig 3, Strf 1, Elas 3 ; Dh 2, Dg 1, Ld 1, Sh +, Anth +. Lower contact gradual. |

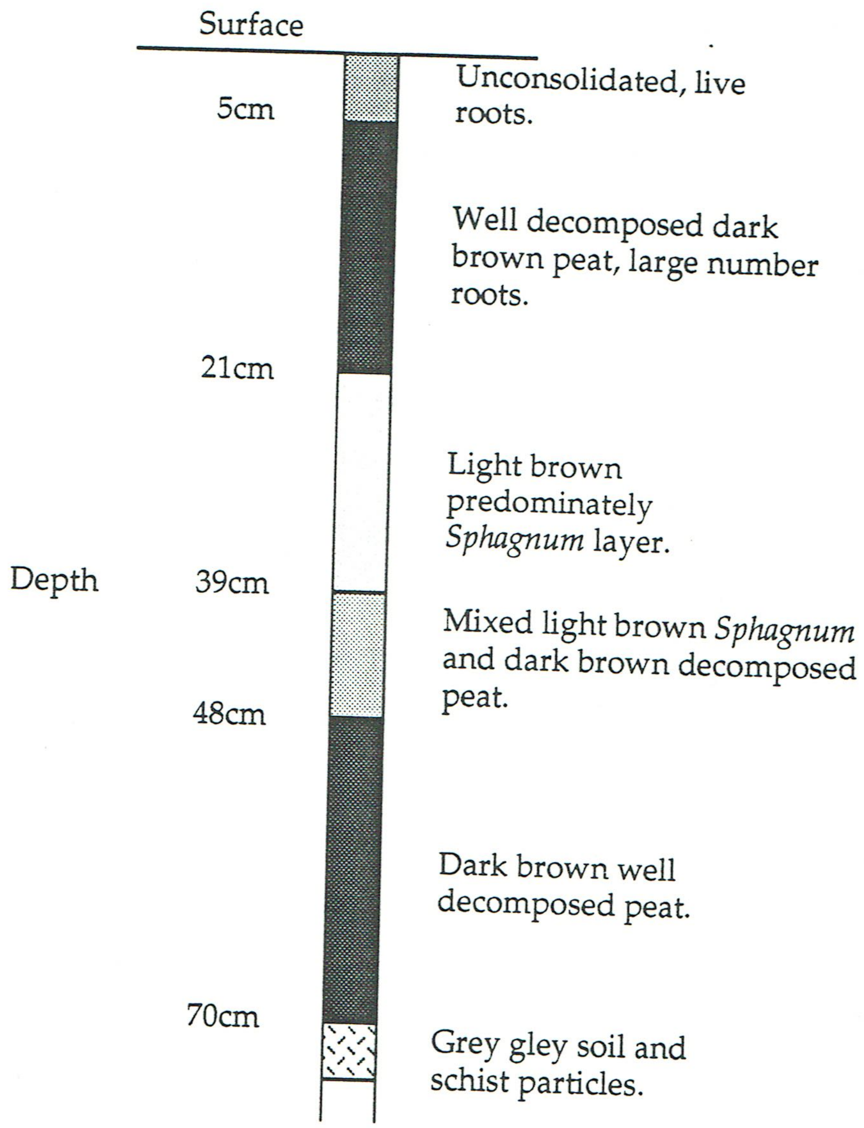


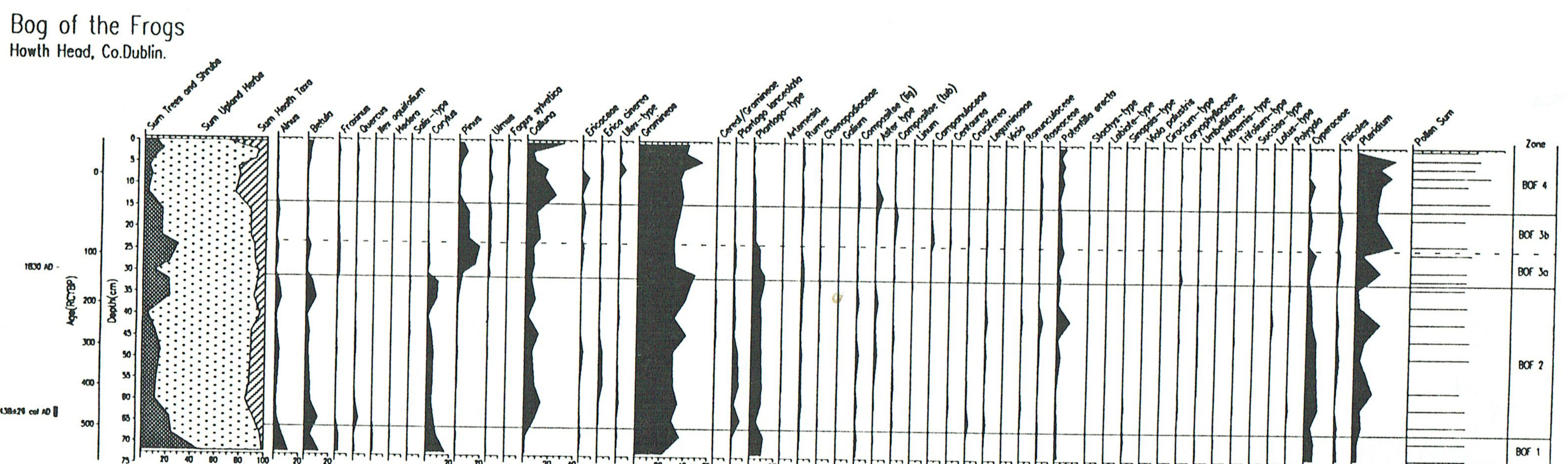

**Figure 3.9 :** Stratigraphic profile of monolith, Bog of the Frogs, Howth Head.

| | |
|---|---|
| 5 - 21 | Very dark brown, consolidated, well humified with several large roots. Nig 4, Strf 1, Elas 3, Sicc 3 ; Dg 2, Dh 2, Ld 1, Anth +. Lower contact sharp. |
| 21 - 39 | Light brown predominantly *Sphagnum* layer, poorly humified, several irregular thin bands of more decomposed peat. Nig 3, Strf 0, Elas 4, Sicc 3; Dh 2, Dg 2, Sh +. Lower contact gradual. |
| 39 - 48 | Mix of poorly humified *Sphagnum* and dark peat. Nig 4, Strf 1, Elas 3, Sicc 3; Dg 2, Dh 1, Ld 1, Sh +, Anth +. Lower contact gradual. |
| 48 - 68 | Consolidated dark brown fairly well humified layer. Nig 4, Strf 0, Elas 3, Sicc 3; Dg 2, Ld 2, Dh +, Sh +, Anth +. Lower contact gradual. |
| 68 - 70 | Gritty mix of peat and gley soil with particles of schist. Nig 1, Strf 2, Elas 1, Sicc 3; Ga 2, Ld 1, Dg 1, Sh +,Dh +, Anth +. |
| 70 - 72 | Predominantly gley soil. Nig 1, Strf 1, Elas 0, Sicc 3. |
| > 72 | Weathered bedrock fragments. |

### 3.3.2. *Pollen analysis*

The percentage pollen diagram for all taxa is presented in Figure 3.10 The pollen sum includes all identifiable pollen and spore types with the exception of *Sphagnum* and the microspore *Tilletia sphagni*. To assist in the interpretation of the results selected taxa are presented in Figure 3.11. For ease of interpretation and discussion the pollen percentage diagram of all taxa was divided into four Local Pollen Assemblage Zones (LPAZ), BOF-1, BOF-2, BOF-3a and 3b, and BOF 4. Absolute pollen diagram of selected taxa is presented in Figure 3.12. This is used to substantiate events described in the

**Figure 3.10** : Percentage pollen diagram for all taxa.



BOG OF THE FROGS, Howth Head.
Summary Percentage Pollen Diagram
Analyst: T. Cooney (1994)

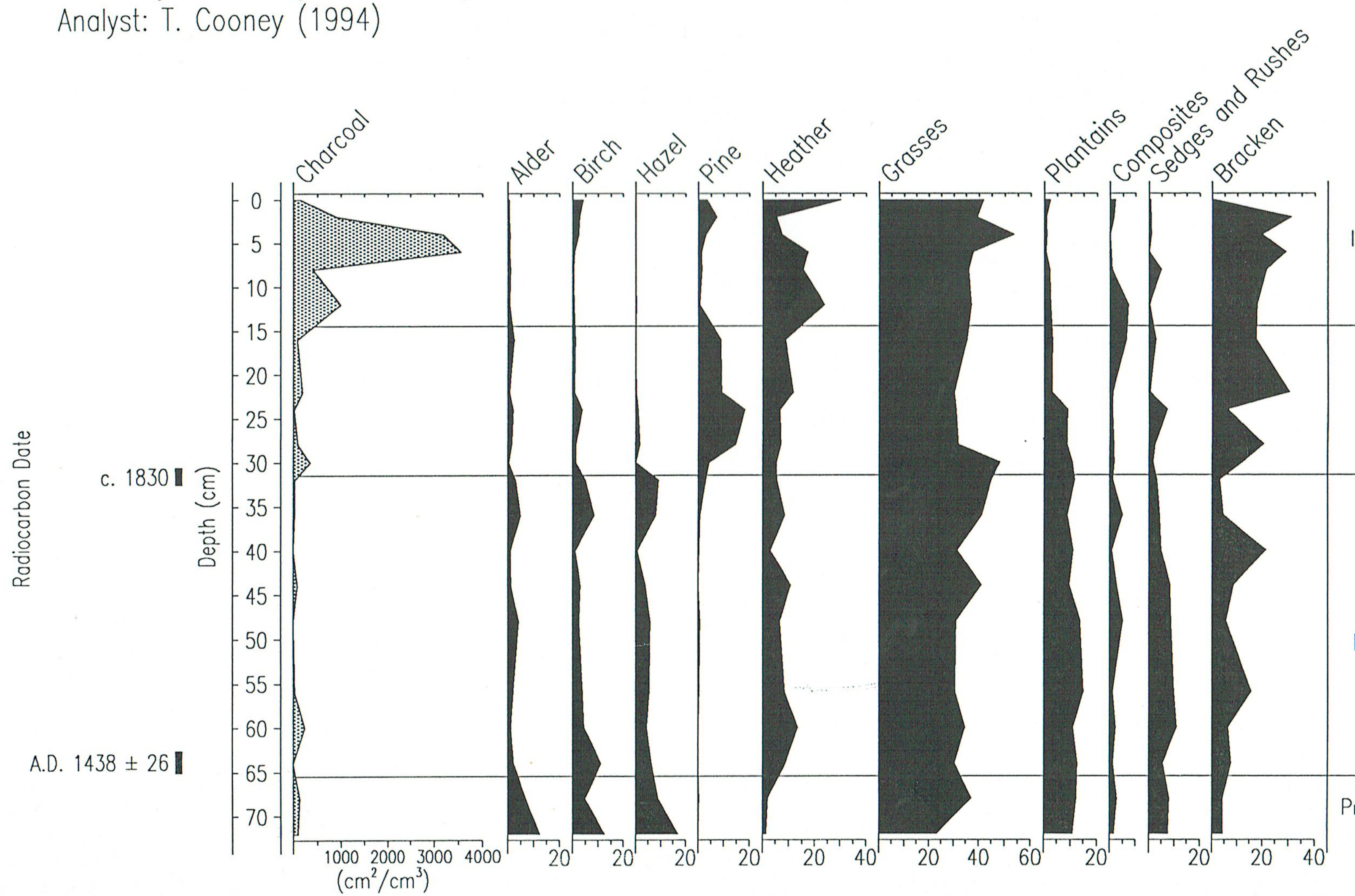


**Figure 3.11** : Percentage pollen diagram for selected taxa.

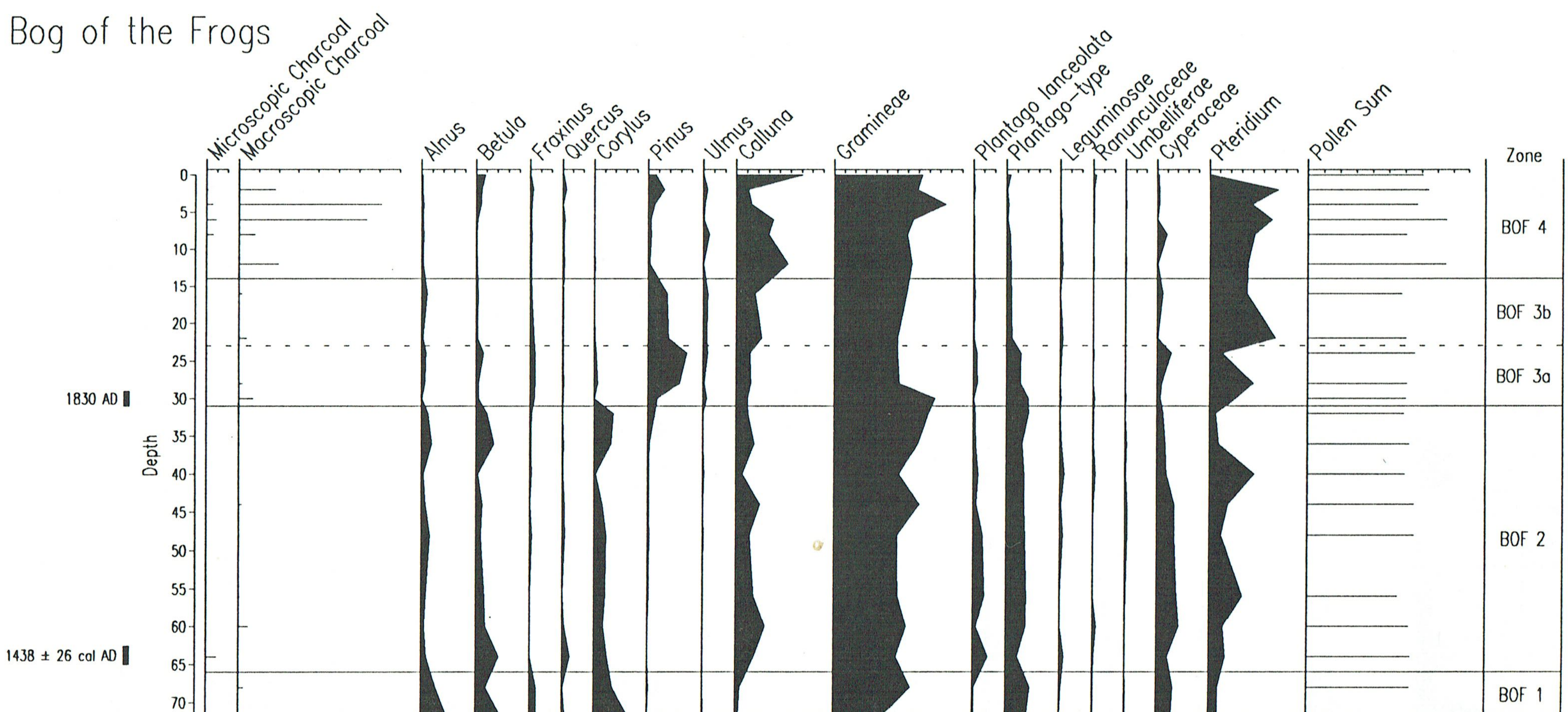
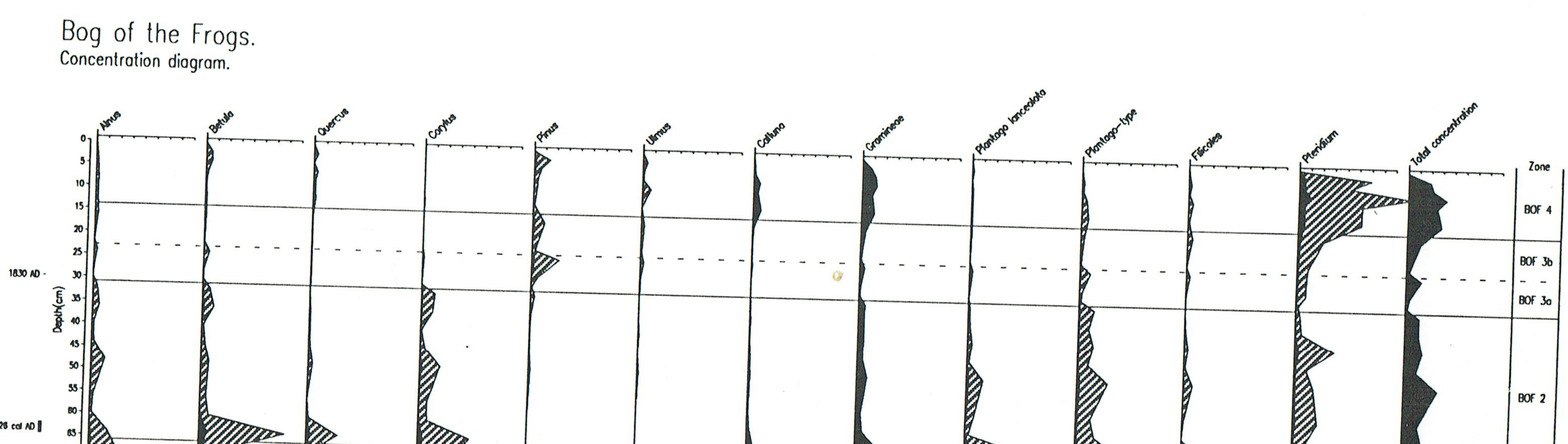


**Figure 3.12** : Pollen concentration diagram for major taxa.



percentage pollen diagram. Table 1 presents a quantitative assessment of tree and shrub, upland herb and heath taxa in each LPAZ.

Zone BOF-1 ( 72 - 66cm)

This zone is characterised by the highest values for tree and shrub taxa (25% to 47%). The main taxa concerned are *Alnus* (12%), *Betula* (12 %) and *Corylus* (16.5%). The absolute pollen diagram (Figure 3.12) confirms the importance of these three taxa which were probably growing close to the bog. Other arboreal taxa are represented by *Fraxinus, Quercus, Ilex, Salix* and *Ulmus* however percentage and absolute values are low which suggests they were not growing in the immediate vicinity.

Upland herb taxa (52% to 71%) are principally represented Gramineae (22% to 36%), *Plantago*-types (11.4%), Cyperaceae (7.9%) with lesser amounts of *Potentilla erecta*, Compositae and others.

Heath taxa (1% to 4%) are poorly represented in this zone with the highest value for *Calluna* only 2%. A small peak in *Tilletia sphagni* occurred at 64cm.

Zone BOF-2 (66 - 31cm)

High values (72% to 91%) and large diversity (28 taxa) of upland herbs characterise this zone (Figure 3.10 and Table 1). Gramineae, Cyperaceae and *Plantago*-types are the principal species. Cyperaceae and *Plantago lanceolata* attain their highest values in the profile at the beginning of this zone with 11% and 7% respectively. Both decrease gradually towards the end of this zone. *Pteridium* values throughout this zone are generally low (3% to 9%) but peak twice with 16% at 56cm and 21% at 40cm. An unusual and probably unrepresentative peak of 11% for *Potentilla erecta* occurs at 40cm. The apparent dip in percentage values of the main taxa at this level is probably

**Table 1 :** Distribution and abundance of pollen types according to Local Pollen Assemblage Zones (LPAZ) and the three general vegetation types as classified in percentage pollen diagram in Figure 3.10.

| LPAZ | Trees/ Shrub | Upland Herbs | Heath taxa | Totals |
|---|---|---|---|---|
| BOF-4 | 7 | 22 | 4 | 33 |
| BOF-3b | 8 | 19 | 4 | 31 |
| BOF-3a | 7 | 21 | 4 | 32 |
| BOF-2 | 8 | **28** | 4 | **40** |
| BOF-1 | 9 | 19 | 3 | 31 |
| Average | 7.8 | 22 | 3.8 | 33.4 |

caused by this peak. Absolute pollen values (Figure 3.12) indicate there is some evidence for this.

Arboreal taxa decrease through the zone where all taxa (including upland herb and heath taxa) reach their lowest values and dip at 40cm (Figure 3.10). This apparent dip is largely caused by a percentage anomaly caused by an uncharacteristic peak in *Potentilla erecta*. Above 40cm the main scrub taxa *Alnus* (5%), *Betula* (8%) and *Corylus* (9%) increase in value before decreasing sharply above 32cm. *Corylus* virtually disappears from the pollen record at the end of this zone (Figures 3.10 and 3.11).

An increase in heath taxa from 4% to 15% of total is mainly accounted for by *Calluna* which increases from 3% to 14%. The first records of *Erica cinerea* occur at the start of this zone.

Zone BOF 3a (31 - 23cm)

This sub-zone is characterised by an increase and change in composition of tree and shrub taxa from 4% to 29% of total (Figure 3.10). The introduction of *Pinus* which replaces *Alnus*, *Betula* and *Corylus* as the dominant arboreal taxa and accounts for most of this increase observed in the percentage and absolute pollen diagrams (Figure 3.11 and 3.12). *Pinus* represented 4% at the beginning of the zone but increased rapidly to 17.6% at 24cm the highest value in the profile. *Fraxinus* (3%) and *Ulmus* (2%) also increase at the beginning of this zone but remain at very low levels.

Upland herbs (62% to 84%) decrease from 30cm to 24cm. Most of this decrease is accounted for by Gramineae which decreased from 48% to 30%. A similar decrease also occurs with *Plantago*-types over the same depths from 10% to 7%. *Pteridium* increased from 12% to 20% at 28cm but decreased steeply to 6% at 24cm. Cyperaceae increased from 25% to 7% at 24cm. The absolute pollen diagram (Figure 3.12) suggests that the *Pteridium* peak may be over represented at the beginning of this zone. At the end of this zone *Plantago*-types, *Plantago lanceolata* and Cyperaceae decrease abruptly.

Heath taxa principally represented by *Calluna* remained relatively stable at between 6% to 9% of total.

Zone BOF 3b (23 - 14cm)

The lowest heath diversity (18 taxa) were recorded in this sub-zone (Table 1). *Pteridium* becomes an increasingly important component of the vegetation from the beginning of this zone (Figure 3.11). *Pteridium* peaks with 30% at 22cm with a slight decrease to 17% at 16cm. This may account for the apparent decrease in herb types which were probably out competed by the taller vegetation. *Pinus* values are generally lower than Zone BOF 3a at 9%. Fewer upland herb taxa were recorded in this zone than in BOF 3a. Also many taxa including *Plantago*-types, *Plantago lanceolata* and Cyperaceae occur at lower levels.

Zone BOF 4 (14 - 0cm)

The pollen record in this zone suggests taller vegetation types have encroached the area surrounding the bog (Figure 3.11). This zone is characterised by a peak in *Calluna* (24%) at 12cm declining to 5% at 2cm only to be followed by a steep increase to 30% at the surface. *Pteridium* values also increase from the start of the zone but remain high with peaks of 29% at 6cm and 31% at 2cm. A sharp decline occurs from 2cm to the surface (1%). *Betula* re-emerges in the pollen diagram from 4cm to the surface although at low percentage and concentration values. Low values for *Pinus* are recorded from the beginning of the zone but an apparent increase occurs from 8cm to the surface. Gramineae increase and peak at 4 cm with 53%.

### 3.4 Land Use

The vegetation categories used were based on the symbols on OS 6" to 1 mile maps 1843 and 1936/37. The area selected of the maps is equivalent to 370 hectares. Woodland was the easiest of the three categories to define. The boundary between heath/scrub and arable/pasture was at times less obvious (see Figures 2.3 and 2.4). Table 2 presents the overall changes of each vegetation category.

The small enclosures on the heath are of particular interest in inferring changing land use patterns over the period covered by the maps. These small farms which were surrounded by heath/scrub in the 1843 map are shown as heath/scrub in 1936/37.

**Table 2** : Vegetation changes on part of Howth Head using Ordinance survey maps of 1843 and 1936/37.

| | 1843 (hectares) | 1936/37 (hectares) | % change |
|---|---|---|---|
| Woodland | 20 | 36.6 | + 4.5% |
| Heath/Scrub | 126 | 136.0 | + 2.6% |
| Arable/Pasture | 224 | 197.4 | - 7.1% |

## Chapter 4

# DISCUSSION

The following discussion is divided into five sections. The first three sections deal directly with the vegetation of Howth. This is followed by a brief discussion of the recent atmospheric deposition record and a brief discussion of recent habitat losses on the peninsula.

### 4.1.1. *Late glacial to mid-15th century*

Although the time period covered by the pollen record described in this study dates from the mid 15th century, there is evidence from literature of earlier vegetation patterns on Howth Head.

Stokes (1914) described a sediment from `Bog of the Loughs´ on Howth which appears to date from the late glacial (13,000 BP). The remains of Giant Irish Deer *Megaloceros giganteus* (three skeletons and three skulls) were found at this site between 1886-87 and 1912. Figure 4.1 shows the sediment profile described by Stokes (1914) from excavations carried out in 1911 and 1912. Giant Irish Deer were present in Ireland during the Woodgrange Interstadial, a warm period at the end of the late glacial (Mitchell 1986). A re-invasion of Ireland by plants and animals occurred during this period. The end of the Woodgrange Interstadial was characterised by a grassland phase in an open landscape. Giant Irish Deer reached their peak at this time. The pollen record for the period indicates heath and open country dominated by grasses, Dock, Sorrel and Least Willow (Mitchell 1986).

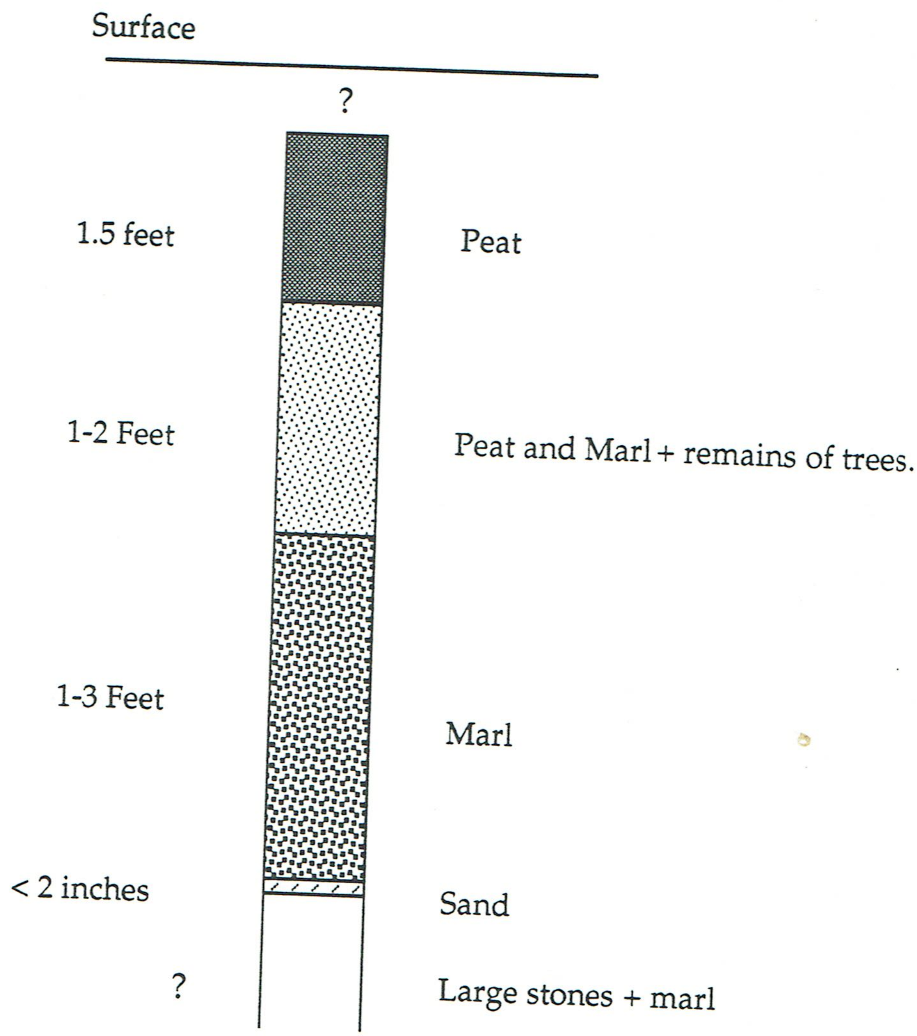



**Figure 4.1**: Stratigraphic sediment profile `Bog of the Loughs´, Howth Head redrawn from Stokes (1914).

The Howth stratigraphy described contrasts with that found at oth late glacial sites, for example Ballybetagh Bog in County Dublin. Stokes (191 and Mitchell (1986) describe sediments in which Giant Irish Deer have bee found. Deer remains are usually found in muds and peats of Woodgrang age and are typically sealed by a layer of sandy clay. The Howth site does no have an organic mud layer at its base which would correspond to th Woodgrange Interstadial.

The Woodgrange Interstadial was followed by a climatic deterioratio known in Ireland as the Nahanaghan Stadial from 11,000-10,000 BP (Mitchel 1986). These muds are possibly missing due to solifluction during the Nahanaghan Interstadial. Mitchell (1986) refers to sites at Howth (presumably `Bog of the Loughs´) and at Old Head, near Louisberg Co. Mayo where solifluction moved till downslope where it buried deposits of Woodgrange age. This may account for the absence of this material at Howth. The occurrence of tree remains in the sediment described by Stokes suggests that, at a later date, Howth had some tree cover on drift soils.

At approximately 10,000 BP. the first human inhabitants arrived in Ireland. The first evidence of human occupation in Howth is represented by a midden site at Sutton dating from 5500 BP. (McBrierty, 1981). Other Neolithic, Bronze Age and Early Iron Age field monuments are also found on the headland (O.P.W. 1993). These indicate that human habitation may have been continuous on Howth from early times. This suggests that the landscape on the headland has been modified for several millennia. One of the earliest records of grazing comes from 1 AD when a battle took place at site known as Dunboe. This means `fort of the cows´ (Shearman 1868; Ball 1917; McBrierty 1981). The battle was for the possession of 700 cows and 150 women! By 9 A.D. the population at Howth was sufficiently high to merit its own king, King Crimthann.

There are three possible origins for the name Howth Head, one of which is of particular botanical interest. It appears the name may have derived from the ancient Gaelic `Ben-na-dair´ when translated means ` Hill of the Oaks´. This may indicate that at least in very ancient times the vegetation of the area was distinctive enough to receive a descriptive name to separate it from the surrounding countryside. Oaks *Quercus spp.* are now very scarce on the headland. In 897 A.D. the name of Howth was changed from Etar to the Danish Hoved. This version of the name changed through time to Howth (Culliton 1962).

The next significant event on Howth was a battle fought in 1177 when Sir Almericus Tristram conquered the headland. Sir Almericus was the 1st Lord of Howth. This family owned and exercised control over a large parts of County Dublin, including Howth, for approximately 800 years (Aalen & Whelan 1992).

### 4.1.2. *Bog initiation and sedimentation processes*

It would appear from the radiocarbon date (1438 A.D.) that the bog was initiated early in the 15th century. There are a variety of reasons for the development of the waterlogged conditions that precede bog initiation. These include trees removal, climate change (i.e. increased wetness) and impeded drainage. The radiocarbon date was taken from the start of the organic layer in the sediment. Loss on ignition values below this indicate that the site was a dry hollow at this time. The pollen record corresponding to this inorganic sediment suggests that the hillside surrounding the hollow was occupied by an open *Betula-Alnus* scrub prior to bog initiation. The clearance of some of this scrub may be indicated by a peak in microscopic charcoal at 64cm.

It would appear likely that human activity in the area indirectly led to conditions favourable for bog growth. At about this time (mid 15th century) a licence was granted to Christopher, Baron of Howth to carry out mining and quarrying on the peninsula. Although no dates could be found for the abandoned quarry above the small hollow it is likely that it was one of the first on the headland and presumably dates from this period. Quarrying activity may have been associated with the initiation of the bog through changes in local hydrology. The spring which now feeds into the site may have been initiated or the enlarged at this time.

Waterlogging occurred when the nutrient poor spring waters entering the hollow were blocked by impermeable drift soils. A small peak in the microspore *Tilletia sphagni* occurred at 64cm in the monolith examined. *Tilletia* is a smut of *Sphagnum* and its presence at this level suggests the hollow was wet enough for *Sphagnum* growth. *Tilletia* curves often coincide with transitions from drier to wet vegetation's (Van Geel 1978). These waterlogged conditions were suitable for the growth of *Sphagnum*. *Sphagnum* absorbs cations in rainfall and releases hydrogen ions to the waters. This further decreases the pH of the sediment and creates condition unsuitably for the majority of micro-organisms thus increasing the rate of plant accumulation (O'Connell 1987). The beginning of this peat development in the small hollow is indicated by increased LOI values. Humification rates for the base of this organic layer suggest the initial growth was probably slow.

The presence of large quantities of poorly humified *Sphagnum* in the bog between 48cm and 21cm suggests a rapid accumulation of sediment. This *Sphagnum* layers indicate that a wetter conditions prevailed. There are two possible explanations which would account for increased waterlogging or wetness. These are local boundary changes and the influence of the `Little Ice Age'.

It seems likely that improvements to the estate boundary (discussed later) in the early 18th century led to impeded drainage on the bog. Increased waterlogging may have led to the rapid growth of *Sphagnum*. This rapid growth phase ends fairly abruptly at 21cm. It would appear that the bounda which was causing the obstruction was breached at this point. Water fro the bog now flows through a deepened gap in the boundary next to the bo However land use changes might not be the only explanation for th *Sphagnum* layer.

The alternative explanation for this rapid growth phase in the bog associated with the influence of the `Little Ice Age´. Lamb (1985) cited by Tallis (1991) has shown that in England and over much of Europe from the mi sixteenth to the early eighteenth century the lowest temperatures of the Littl Ice Age were recorded. In Ireland the Little Ice Age may have manifeste itself as increased precipitation rather than as a temperature decrease (Joh Sweeney pers. comm.). Meteorological records show that Howth is one of the driest areas in Ireland. This suggests the bog would be very sensitive to any changes in precipitation rates. These would be reflected in the sedimentation rate of the bog.

Several small bogs similar to that described exist on Howth Head. There are a number of anomalies associated with their occurrence on the headland. Geographically the nearest communities of this type are found to the south of Howth Head in the Dublin Mountains. The continuing existence of these water dependent communities adjacent to lowland dry heath also poses some questions.

A significant factor in the continuance of these bogs is their location, altitude and aspect. All `bogs´ on the headland are on north facing slopes, at the boundary between the heath and the deeper drift soils and at an altitude of 120m. The solid geology of the hillside leads to a quick run off from the nutrient poor heath streams. These stream waters feed directly into the hollows. Their north facing aspect implies that they receive less direct sunshine and therefore experience lower temperatures. These conditions would lead to less evaporation in summer when lower precipitation rates are phase ends fairly abruptly at 21cm. It would appear that the boundary was causing the obstruction was breached at this point. Water from now flows through a deepened gap in the boundary next to the bog. ver land use changes might not be the only explanation for this *um* layer.

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A significant factor in the continuance of these bogs is their location, de and aspect. All `bogs´ on the headland are on north facing slopes, at boundary between the heath and the deeper drift soils and at an altitude 20m. The solid geology of the hillside leads to a quick run off from the ient poor heath streams. These stream waters feed directly into the ows. Their north facing aspect implies that they receive less direct hine and therefore experience lower temperatures. These conditions ld lead to less evaporation in summer when lower precipitation rates are ded on the headland. During these periods of low precipitation, hill fog ation may also play a important role in the maintenance of these unities. Coastal hill fogs usually develop in summer with their base rally close to 120m (Jeffrey 1981). It is possible that these hill fogs pensate for the lower precipitation rates in summer when many local ms dry up.

### 3. *Mid-15th century to present*

en percentage and concentration values at the base of the bog imply two pendent vegetation types. These two vegetation patterns also reflect two nct land use patterns which are strongly influenced by anthropogenic rs. The deep fertile drift soils which occur in pockets on the mid slopes lower ground originally supported remnant scrub and thicket which was aced by broadleaf woodland early in the 19th century. The heath was nally grazed, almost certainly by goats, up to the 1930's or 1940's. Fire me an increasingly important influence on the vegetation from late in 19th century. The pollen record reflecting these two vegetation types are ribed separately.

te vegetation record

pollen record shows that *Alnus*, *Betula* and *Corylus* scrub covered the slopes from the mid 15th century up to the early 19th century. This is tly later than other areas in Ireland which were cleared by 1750 (Valerie pers. comm.). These scrub communities are probably all that survived Tudor clearances (1550-1700). Forbes (1932) noted that final phase of e woodland clearance occurred after the 1640 revolution. It appears that t of the native Irish woodlands were gradually destroyed by grazing and over a long period of time.

The values for these taxa are generally quite low which suggests that s scrub had an open or patchy distribution. It would appear from the phic requirements of *Betula* and *Alnus* that they are more suited to wing in less fertile, generally acid soils (McVean 1953). This would icate that *Alnus-Betula* scrub probably occurred wherever pockets of drift er existed on the heath. Drift soils, probably of local origin, are found tered in hollows and small valleys on the heath (see Figure 1.5).

*Corylus* was growing on the deeper drift soils at lower elevations re it was replaced by woodland in *c.* 1830. The woodland near the bog was ted at this time and replaced almost all of the *Corylus* and smaller unts of *Betula* and *Alnus*. *Corylus* values are negligible after the arance of arboreal taxa in the pollen record. This replacement of *Corylus* ther woodland taxa suggests that the majority of *Corylus* was growing in Howth demesne. The woodland taxa planted, mostly *Pinus* and s, can only thrive where soil depth and fertility are sufficient.

h vegetation record

the beginning of the organic layer in the bog there is evidence of the nce of heath communities. These are represented by the taxa *Calluna*, and *Ulex* which are the main components of the heath vegetation today. rincipal control on the heath vegetation from the initiation of the bog the 1930s - 1940s appears to have been grazing. This is suggested by the sity and abundance of herb taxa lower in the profile. *Plantago* species ther small herb taxa cannot survive unless the surrounding vegetation t (Sagar & Harper 1964). It is unlikely that the grazing on the heath was intensive otherwise many of these herb species would not have ged to survive. O'Sullivan (1965) suggested that low intensity or ive pasturing over a wide area for long periods leads to animals ming selective in their grazing habits. The net result of this selective -grazing is to hold back the taller vegetation such as *Pteridium*.

The removal of grazing from the heath enabled the taller vegetation to expand and out-compete the smaller herbs. It is suggested that this led overall decline in floristic diversity (see Table 1).

From the end of the 19th century there is an increase in fire frequency. is indicated by increased values for macroscopic and microscopic oal. Heath taxa such as *Erica* and *Calluna* are particularly well adapted to Gimingham 1960; Bannister 1965). These taxa burn easily due to the fact they have a low water content and are rich in oils (Jeffrey 1981). The ing of all above ground foliage on heathlands leads to the deposition of a of ash. Below ground parts are insulated from the fire. However the stimulates seedlings and new shoots which benefit from the ash sits. Other species, namely *Pteridium*, *Molinia* and *Deschampsia* spread derably after fire (Tansley 1939). Fire also prevents the establishment of seedlings.

Hobbs and Gimingham (1984) have demonstrated that the floristic position set up immediately after a fire is the main determinant in post- vegetation. The occurrence of fire is therefore the main factor in taining open heath vegetation (Pennington 1969). In addition to this, b and Suter (1971) have demonstrated that *Calluna* and *Ulex* acidify the below them. After the clearance of *Ulex* a mixture of calcifuges and fferent species become established, and calcicoles cannot return.

After the removal of grazing, it would appear that fire became the control of heath vegetation on Howth. There are indications of a ession from heath to *Betula* woodland in some areas of the heath where incidence of fire has decreased (Meleady 1993). Annual growth rings of tation on the bog suggest the last fire on the site was in 1982/83.

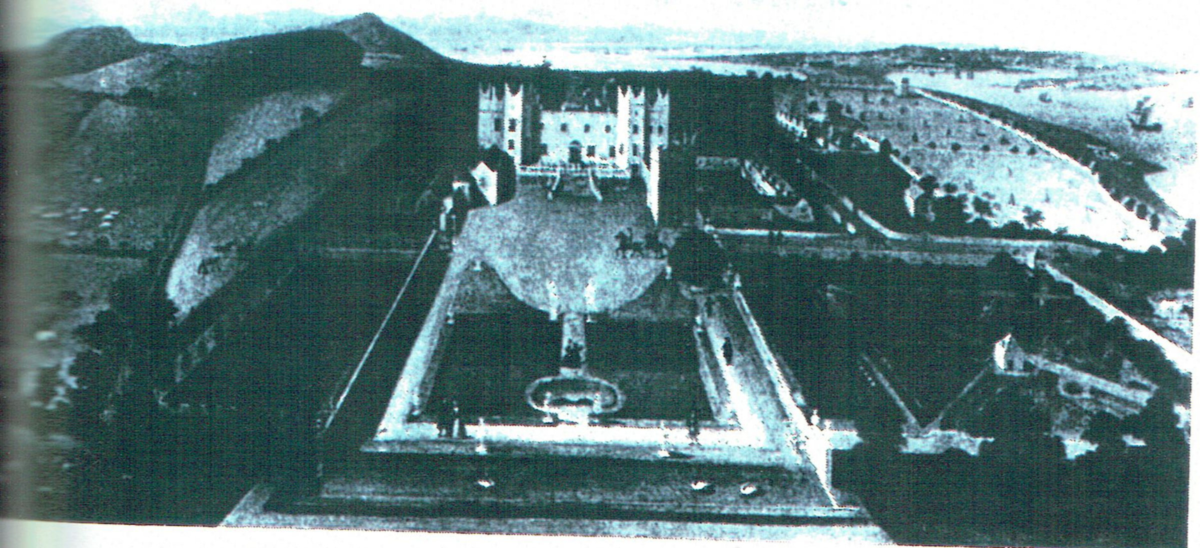
ugh *Betula* woodland has not increased in the vicinity of the bog, the has been invaded by *Rhododendron ponticum.*

mentary evidence for land use patterns

is documented evidence to support the pollen record for these two land nd vegetation types. No specific information of land use on the fertile lower on the headland, including Howth demesne, could be found prior mid 18th century.

In 1738 the house (Howth Castle) and grounds were greatly improved erty 1981). By the mid 18th century many of these improvements were ed in more efficient farming practices (Plates 4.1 and 4.2). Many of the es which are shown in Plate 4.1 reflect the influence of the Royal Dublin (RDS) which was established in 1731. One of the first campaigns by DS was to encourage more efficient farming (Forbes 1933). If the quality e was to be improved, controlled breeding was necessary. Improved e and hay and roots for winter fodder made it possible to carry bigger and here controls were necessary. Hedged fields prevented stocks from ering, controlled the degree of grazing and manuring, and provided while the ditch at the foot of the hedge improved drainage. Boundary es similar to those described can be found on the perimeter of the e today (Plates 4.3 and 4.4). As discussed earlier these improved g practices may have impeded or altered the hydrology on the bog. DS also offered premiums for tree planting. As wealthy landlords were ly ones who could afford to plant trees this led to increased polarisation landscape. Inside the estates the area of woodland increased while the utside the estates became increasingly barer (Mitchell 1986).

The planting of woodland on Howth occurred in different phases. For ple Ordinance Survey maps show that the broadleaf woodland now nding the Portal Dolmen in Howth demesne was planted sometime



4.1 : `Prospect of the House of Howth´ *c.* 1745 taken from McBrierty (1981).
the partitioning of livestock and field boundaries on the bare hills.

**Plate 4.2** : Field boundaries on the hill shown in Plate 4.1 in present day woodland at Howth demesne.

**Plate 4.3** : Ditch and walled embankment separating `Bog of the Frogs´ and Howth demesne.

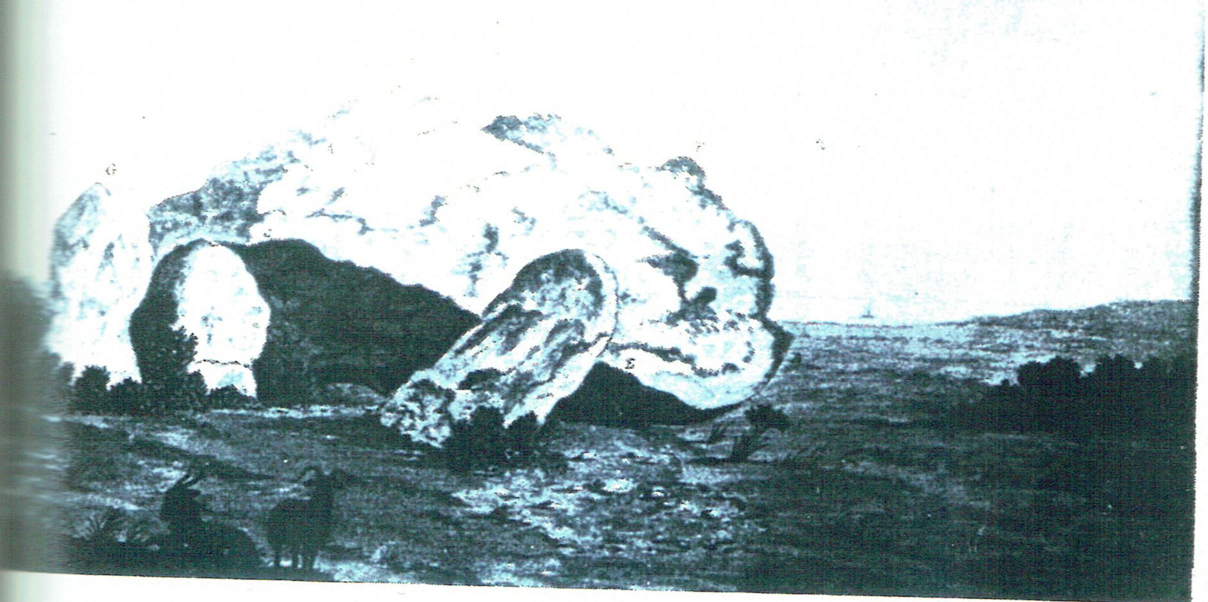
**Plate 4.4** : Ditch and walled embankment are more obvious on the lower slopes.

ween 1843 and 1870 (Plates 4.5 and 4.6). The painting by Banagher in 1820 Muck Rock shows that this area of the demesne was not planted at that ne (Plate 4.7). Counts of annual growth rings indicate the woodland near e bog was planted in *c*.1830 (Plate 4.8). The main planting in the ododendron gardens on the slopes of Muck rock took place in 1850 cBrierty 1981). The laying down of plantations in Ireland did not occur on arge scale until the 18th century and then chiefly in conjunction with the ation and improvements of demesnes (Forbes 1933). Lewis (1980) refers to ichly wooded demesne with a well stocked deer park at Howth. This deer rk was located on the lower slopes near the castle and not on the hillside.

In the Civil Survey of Ireland undertaken in 1655 it was considered t Howth was one of the few areas in Dublin that had more pastoral than ble lands. By 1659 out of a total of 600 acres, pastoral land accounted for 200 es and arable land for 300 acres (Aalen & Whelan 1992).

The first potato was introduced to Ireland in 1662 and commonly wn by the 1670's. This new crop initiated a rise in the population of land which continued until the mid 19th century. The population of wth increased from 206 inhabitants in 1659 to 1706 by 1837 (Lewis 1980; Brierty 1981). Of this 1706, 797 of were living in the townland. The aining 909 were presumably living on the land. By 1785 the population reland had almost doubled. Further increases in population occurred after passing of the corn laws in 1780 (Mitchell 1986). As the amount of corn wn increased there was a corresponding increase in the population.

This rise in population put additional pressure on the land to produce re food. There is evidence that at this time large areas of marginal land uding blanket bogs were cultivated (Mitchell 1986; O'Connell *et al.* 1988). 830 the RDS was offering premiums for schemes to divide up land so that quantity of land required to support a labourer's family with vegetables potatoes, and to enable him to keep a pig and a cow all year'(Mitchell



4.5 : Early Neolithic Cromlech (Portal Dolmen) *c.* 1760 by Banagher. Goats shown in the foreground.

4.6 : Cromlech in January 1994 surrounded by broadleaf woodland planted between 1840 and 1870.

**Plate 4.7** : Painting by J.A. O'Connor dated *c*.1820 showing Muck rock and Howth Castle prior to the planting of the woodland and *Rhododendron* gardens.

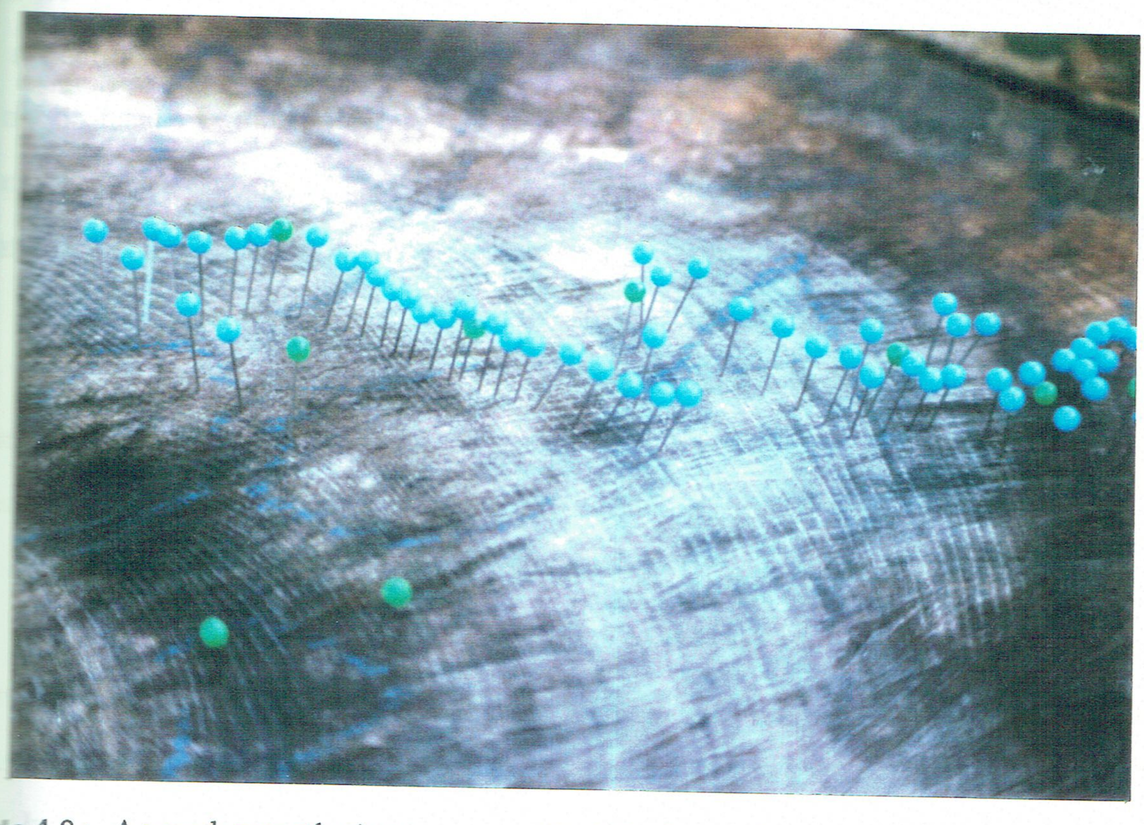


**Plate 4.8** : Annual growth rings on recently felled trees beside the study site suggest this part of the woodland was planted about 1830.

1986). In an effort to cater for this increased pressure, schemes to sub-divide land were promoted. On Howth evidence of smallholdings and lazy beds can be seen on the fairways at Howth Golf Course (Plates 4.9 and 4.10). The abandonment of these areas occurred either during or after the great famine of 1845-1847. OS maps of 1843 show field boundaries on the heath which may have been associated with grazing. The soils in these areas are thin (<15cm) and unlikely to support arable agriculture. Farming practices on the lower more fertile parts of the peninsula were largely unaffected by the famine. Hart (1887) observed that farming with the `highest skills' was carried out in these areas at the end of the 19th century.

Although the effects of famine were severe in many parts of Ireland, the population of Howth was not as seriously affected, with many making a living from fishing. The presence of Howth Harbour, which was finally completed in 1852, would have given easy access to work in England for those who were displaced. Any effect of the famine would most likely be reflected in a decrease in the amount of marginal land in use on the headland. Abandonment of smallholdings can be seen in OS maps from that time. OS maps of 1843 show many smallholdings in use on the heathland. Later maps after the famine years show that these have been abandoned.

Grazing on the headland continued into the present century with up to six 'fleets' of goats on the headland (T. Fox pers. comm.). It is not known how many of these goats grazed on the heath or were enclosed on private land. Grazing intensity was reduced in the present century and finally removed in the early 1940's when all the goats were sold off.

The area of lowland dry heath, similar to that on Howth, has decreased over most of the British Isles. Stephenson and Thompson (1993) suggested five reasons for significant long term losses in *Calluna* moorland in Britain and Ireland in recent times: (i) grazing, (ii) afforestation, (iii) atmospheric pollution, (iv) acidic deposition and (v) climate change. They concluded that

**Plate 4.9** : The rectangular pond is the site of the `Bog of the Loughs´ where Giant Irish Deer *Megaloceros giganteus* remains were first discovered at the end of the 19th century. Pre-famine cultivation ridges and old field boundaries are common in this area.

**Plate 4.10** : Remains of field boundaries on the heath. These areas were abandoned sometime after the great famine of 1845-47.

area of *Calluna* moorland cover in upland Britain and Ireland has decreased dramatically in the last 200 years. The trends however were not the same for the UK and Irish catchments studied. Losses were greatest in the UK and lower in Ireland largely due to the lower sheep grazing intensities in Ireland until the 1960's and 1970's. The greatest losses were in areas of high sheep grazing with subsequent losses due to large scale afforestation in upland areas from the 1920's onwards. This decline due to afforestation was particularly acute since 1945.

It would appear from the evidence presented in this study that the area of heathland on Howth has not declined within the last 100 years. This is probably due to a combination of increased fire frequency and the removal of grazing.

### *Atmospheric deposition*

The discovery of SCP's and sulphide particles in the Howth sediment provides a record of atmospheric deposition in the region over time. It appears that SCP's found in this study are probably the first described from sediments in Ireland. However, because the standard methods described by Wik and Renberg (1985) were not used, a direct comparison cannot be made with studies elsewhere. It is nonetheless possible to draw some general conclusions from the concentration profile.

The size of SCP's in the Howth sediment (up to 143μm) are generally greater than values reported elsewhere (Wik & Renberg 1987; Schultz 1993). Schultz (1993) has shown using Stokes settling velocity that the largest carbon particles in suspension will be deposited closest to the source. This supports the view expressed by Wik and Natkanski (1990) that SCP's greater than 5-10μm have a relatively short atmospheric lifetime and reflect mainly emissions from a more regional source. Another factor which may account for the unusually large particle size is the high elevation (120m) of the catchment. The altitude of the site is important because it intercepts particles which would normally be carried a greater distance from the source before being deposited. These factors indicate that the SCP's in the Howth sediment are of regional or local origin. The predominantly south-westerly winds and close proximity to source suggest that a fine resolution study at Howth would produce a good record of atmospheric deposition on the Irish east coast.

It has been known for some time that SCP's are produced during high temperature combustion of coal and oil and that sediments contain a record of SCP's that varies with the known history of fossil fuel combustion (Battarbee *et al.* 1989; Wik & Natkanski 1990). Wik and Renberg (1985a) have demonstrated that concentration profiles of SCP's in sediments can be used as an indirect dating method. This method relies on a knowledge of the fossil fuel consumption record in the region.

The concentrations recorded at Howth are slightly less than reported in other studies (Wik & Natkanski 1990; Jones *et al.* 1990; Jones *et al.* 1993). This may in part be due to the fact that Dublin is not as industrialised as other areas in Europe were most studies have been carried out. From late in the 19th century the principal and probably the most obvious consumers of fossil fuels in the Dublin region were a small number of local electricity generating stations. Up to the establishment of the Electricity Supply Board (ESB) in 1927 these stations probably contributed the small quantities of SCP's found lowest in the profile. However after the ESB was established the generation of electricity became centralised at the Pigeon House, Poolbeg and Ringsend generating stations in Dublin Port (Manning 1984; ESB 1931-1991). After 1930 and particularly from the early 1940's onwards generating capacity (and presumably fuel consumption) and output increased to meet the increased demands of an expanding network. It is considered that the main appearance of SCP's in the Howth sediment refer to this period. The apparent fall off in particle concentrations near the profile surface may be due to a change in fuel changes in recent years. In 1982 the main generating station in Dublin Port at Poolbeg switched to a combination of natural gas and oil. Prior to this the main fuel sources were coal and oil. Similar declines have been observed in other sediment profiles (Rippey 1990). Plate 4.11 shows the Poolbeg generating station in Dublin Port.

Although SCP's are not implicated in the process of acidification, they do act as markers for atmospheric deposition or acid rain. The detrimental impact of acidification on terrestrial and aquatic ecosystems has only been recognised within the last 25 years. This is largely due to the fact that the main changes occurred between 1930 and 1970 and the rate of this change was relatively slow (Flower *et al.* 1988).

The effect of this acid deposition on the vegetation of Howth is unknown. It has been suggested that, in south Wales, a shift from *Calluna* wet heath to those dominated by *Molinia caerulea* cover, which occurred after the beginning of the Industrial Revolution, may have been exacerbated by the high deposition of soot (Chambers *et al.* 1979 cited by Stephenson *et al.* 1993). It has already been established that acid deposition is the most likely cause of lake acidification in south-west Scotland. This has resulted in declines in diatom floras in recent years (Flower *et al.* 1987; Jones *et al.* 1993). Changes in floristic composition in terrestrial ecosystems as a result of increased atmospheric deposition are extremely difficult to separate from other possible causes. For example Stephenson *et al.* (1993) described five possible reasons for the decline in *Calluna* in upland Britain and Ireland over the last 200 years. These included afforestation, atmospheric pollution and grazing. At Howth the increased atmospheric deposition of SCP's began in the 1930's to 1940's. Grazing pressure was removed during this period. This would initially suggest that the effect of atmospheric deposition on the vegetation would be reasonably clear. However the increased fire frequency on the heath has almost certainly confused this record.

**4.11** : The twin ESB cooling towers at Poolbeg in Dublin Port are one
able source of SCP's. This generating station replaced the Pigeon House
n in 1967.

Although the sulphide particles found in the sediment were not stigated thoroughly in this study, they provide additional evidence of deposition. Long term trends in monthly pH values at nine stations in nd suggest an increase in the acidity of Irish rainwater from the early s. For example the quantity of sulphate (reported as sulphur) rose from milligrams per litre to 4.74 milligrams per litre between 1973 and 1980. e was a corresponding decrease in the pH of rainwater from 5.05 to 4.74 the same period (Meteorological Service 1983). The co-deposition of two particle types has been previously reported (Jones *et al.* 1993). stigations of Scottish lochs showed a general correlation between low entrations of both particles and least acidified lakes.

Palaeolimnological techniques and the study of SCP's are highly nmended in assessing long-term ecological stability and identifying opriate sites for nature conservation (Jones *et al.* 1993). Many upland are selected for protection for their prime condition of their current and fauna. Peatlands and aquatic systems are generally considered to be e and unaffected by anthropogenic influences. The impact of acid sition on the vegetation on Howth is unclear but merits further stigation.

*Recent habitat changes*

e would appear to have been a significant loss of habitat on Howth Head n the last 100 years. This is largely reflected by the apparent pearance of a number of specific species. The Howth Heritage Project 1991) compiled a list of species rare to Howth, including all known ds from visiting botanists, and compared them to Hart (1887) and Colgan ) lists. Of the 68 rare species listed, at 31 locations, 39 species were no r found at their location. Of those 31 locations three were completely up, four were considerably changed due to changes in land use and all others had been altered moderately. Some of the losses included *Ophrys apifera*, *Hyoscyamus niger* and *Ophioglossum vulgatum*.

One of the more important losses of habitat was the drainage of `Bog of the Loughs.' This is almost certainly the site referred to by Hart and Colgan as `marsh at the summit' and `central marsh'. Apart from its potential importance as a palynological site this was probably the largest area of wetland on the peninsula in Hart's time.

Howth Environmental Study (Anco/An Taisce 1987) identified a number of sources of pressures on the heath. The more important of these were from increased development, recreational uses (e.g. expansion of Howth Golf Course) and the invasion of *Rhododendron ponticum*.

Literature sources have shown that the vegetation on Howth Head has been altered by humans activity for several millennia. The palynological investigation in this study has shown that the heath vegetation on Howth has been modified by man from at least the 15th century. This dry lowland heath is probably unique in that it exists within the confines of a major city. Strategies for the conservation of the heathland needs to consider some of the factors identified in this study which have influenced the vegetation up to the present day.

## General Conclusions

There is possible evidence of a late glacial pollen record site in the literature which would merit further investigation. It is highly likely that the majority of native woodland on Howth, probably dominated by *Quercus*, disappeared in pre-Christian. The remains of this former woodland in the form of *Alnus*, *Betula* and *Corylus* scrub probably existed on the mid-slopes up to the mid 15th century. It would seem likely that quarrying activity in the mid 15th century resulted in changes in the local hydrology and contributed to the formation of the small hollow peat bog. Changes in sedimentation rates in the bog are due to either local field boundary alterations or increased precipitation during the `Little Ice Age´. The unique local microclimate is a significant factor in the maintenance of these disjunct wetland communities.

Fine resolution pollen analysis provides evidence for two vegetation types with two independent histories. On the deep drift soils on the lower slopes scrub and thickets were replaced by planted woodlands as part of estate management. On the heath the principal factor governing the vegetation from the mid 15th century to the 1930's was grazing with occasional fires. From the 1930's onwards grazing was removed and fire became the controlling factor. The sediment has a record of atmospheric deposition which requires further investigation.

Towards the end of the 19th century increased pressure on the woodland generally has led to the loss of some habitats. This has resulted in the loss of a number of species from the area. The *Betula* woodland which is now re-invading the north and east of the heath provides strong evidence that this sort of woodland could have existed in the 15th century as suggested by the pollen record.

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**Appendix 1 :** Cross section depth measurements of `Bog of the Frogs´.

Transect North to South

| Metre(s) | Depth(cm) |
|---|---|
| 0 | 39.0 |
| 2 | 50.0 |
| 4 | 59.0 |
| 6 | 58.0 |
| 8 | 76.5 |
| 10 | 88.0 |
| 12 | 82.0 |
| 14 | 81.5 |
| 16 | 72.0 |
| 18 | 79.0 |
| 20 | 70.0 |
| 22 | 65.0 |
| 24 | 57.0 |

Transect West to East

| Metre(s) | Depth (cm) |
|---|---|
| 0 | 70.0 |
| 2 | 72.0 |
| 4 | 86.0 |
| 6 | 65.5 |
| 8 | 60.0 |
| 10 | 50.0 |
| 12 | 28.0 |

**Appendix 2**: Percentage Loss-on-Ignition data.

| Depth (cm) | % L.O.I. |
|---|---|
| 2 | 88.6 |
| 4 | 92.1 |
| 6 | 89.0 |
| 8 | 84.7 |
| 12 | 80.4 |
| 16 | 81.1 |
| 22 | 72.0 |
| 24 | 58.7 |
| 28 | 68.3 |
| 30 | 70.0 |
| 32 | 70.0 |
| 36 | 65.0 |
| 39 | 56.0 |
| 40 | 65.4 |
| 41 | 60.7 |
| 44 | 70.7 |
| 48 | 53.2 |
| 56 | 54.6 |
| 60 | 56.7 |
| 64 | 54.4 |
| 68 | 7.5 |
| 72 | 6.6 |

**Appendix 3** : Humification data. The mean value of two spectrophotometer readings was used to calculate the percentage humification.

| Depth (cm) | Spectrophotometer (540nm) | | | % Humification |
|---|---|---|---|---|
| | 1st | 2nd | Mean | |
| 1 | 0.285 | 0.287 | 0.286 | 3.2 |
| 6 | 0.442 | 0.441 | 0.442 | 4.5 |
| 11 | 0.470 | 0.469 | 0.470 | 4.7 |
| 16 | 0.492 | 0.490 | 0.491 | 4.9 |
| 21 | 0.341 | 0.343 | 0.342 | 3.8 |
| 26 | 0.280 | 0.249 | 0.280 | 3.2 |
| 31 | 0.335 | 0.338 | 0.372 | 3.9 |
| 36 | 0.289 | 0.288 | 0.289 | 3.2 |
| 41 | 0.423 | 0.423 | 0.423 | 3.3 |
| 46 | 0.373 | 0.372 | 0.373 | 3.9 |
| 51 | 0.377 | 0.378 | 0.378 | 4.0 |
| 56 | 0.329 | 0.332 | 0.331 | 3.6 |
| 61 | 0.396 | 0.395 | 0.396 | 4.1 |
| 66 | 0.495 | 0.493 | 0.474 | 4.9 |
| 71 | 0.166 | 0.166 | 0.166 | 2.2 |

**Appendix 4** : Macroscopic charcoal data.

| Depth (cm) | No. fragments $1cm^2/cm^3$ |
|---|---|
| 0 | 147 |
| 2 | 908 |
| 4 | 3184 |
| 6 | 3547 |
| 8 | 400 |
| 12 | 992 |
| 16 | 80 |
| 22 | 190 |
| 24 | 13 |
| 28 | 93 |
| 30 | 351 |
| 32 | 27 |
| 36 | 27 |
| 40 | 0 |
| 44 | 80 |
| 48 | 0 |
| 56 | 27 |
| 60 | 240 |
| 64 | 0 |
| 68 | 133 |
| 72 | 93 |

**Appendix 5** : Microscopic charcoal data.

Explanation of terms:

Hits = number of times charcoal fell on micrometer points.

Fields = total number of fields of view at x400 magnification.

Markers = total number *Lycopodium* recorded.

| Sample depth (cm) | Hits | Fields | Markers | Charcoal ($cm^2 . cm^{-3}$) |
|---|---|---|---|---|
| 2 | 4 | 212 | 22 | 0.7787 |
| 4 | 8 | 242 | 11 | 3.1189 |
| 6 | 79 | 210 | 73 | 4.6409 |
| 8 | 8 | 201 | 34 | 3.2391 |
| 12 | 3 | 221 | 31 | 0.415 |
| 16 | 0 | 214 | 31 | 0 |
| 22 | 1 | 203 | 28 | 0.1532 |
| 24 | 2 | 220 | 55 | 0.5006 |
| 28 | 0 | 203 | 20 | 0 |
| 30 | 0 | 208 | 40 | 0 |
| 32 | 0 | 268 | 117 | 0 |
| 36 | 0 | 210 | 23 | 0 |
| 40 | 0 | 207 | 59 | 0 |
| 44 | 0 | 209 | 17 | 0 |
| 48 | 0 | 210 | 33 | 0 |
| 56 | 1 | 213 | 48 | 0.2868 |
| 60 | 1 | 216 | 23 | 0.1865 |
| 64 | 4 | 238 | 11 | 5.0058 |
| 68 | 0 | 348 | 12 | 0 |
| 72 | 0 | 350 | 13 | 0 |

**Appendix 6** : Macroscopic Spheroidal Carbonaceous Particle (SCP) data.

| Depth (cm) | No. SCP's | No. SCP's $g^{-1}$ DW |
|---|---|---|
| 0 | 189 | 189 |
| 2 | 50 | 641 |
| 4 | 27 | 333.8 |
| 6 | 83 | 1347.4 |
| 8 | 129 | 1861.5 |
| 12 | 294 | 4375 |
| 16 | 75 | 1209.7 |
| 22 | 22 | 367.9 |
| 24 | 12 | 252.1 |
| 28 | 2 | 26.5 |
| 30 | 2 | 37.2 |
| 32 | 0 | 0 |
| 36 | 2 | 23.8 |
| 40 | 0 | 0 |
| 44 | 0 | 0 |
| 48 | 0 | 0 |
| 56 | 0 | 0 |
| 60 | 0 | 0 |
| 64 | 0 | 0 |
| 68 | 0 | 0 |
| 72 | 0 | 0 |

**Appendix 7 :** Pollen count data at each sub-sample level.

| | 0cm | 2cm | 4cm | 6cm | 8cm | 12cm | 16cm |
|---|---|---|---|---|---|---|---|
| *Alnus* | 2 | 2 | 3 | 3 | 3 | 3 | 7 |
| *Betula* | 15 | 10 | 8 | 3 | 1 | 2 | 3 |
| *Fraxinus* | 0 | 5 | 2 | 2 | 2 | 2 | 2 |
| *Quercus* | 1 | 6 | 0 | 4 | 2 | 3 | 1 |
| *Ilex aquifolium* | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Hedera* | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| *Salix* | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Corylus avellana* | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| *Pinus* | 12 | 27 | 10 | 5 | 4 | 2 | 25 |
| *Ulmus* | 0 | 7 | 0 | 1 | 8 | 0 | 6 |
| *Fagus sylvatica* | 5 | 1 | 4 | 1 | 0 | 2 | 1 |
| *Calluna vulgaris* | 107 | 20 | 24 | 73 | 45 | 101 | 25 |
| Ericaceae | 3 | 0 | 0 | 0 | 17 | 0 | 8 |
| *Erica cinerea* | 3 | 0 | 4 | 4 | 3 | 2 | 1 |
| *Ulex*-type | 0 | 6 | 1 | 21 | 0 | 3 | 2 |
| Gramineae | 147 | 147 | 177 | 160 | 105 | 157 | 100 |
| Cereal/Gramineae | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Plantago lanceolata* | 1 | 2 | 0 | 1 | 1 | 1 | 2 |
| *Plantago*-type | 7 | 1 | 3 | 2 | 5 | 9 | 7 |
| *Artemesia* | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Rumex* | 5 | 5 | 5 | 1 | 1 | 6 | 4 |
| Chenopodiaceae | 0 | 2 | 0 | 0 | 1 | 2 | 0 |
| *Galium* | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Compositae (Lig). | 3 | 0 | 0 | 1 | 2 | 8 | 2 |
| *Aster*-type | 0 | 0 | 0 | 0 | 0 | 22 | 3 |
| Compositae (Tub). | 2 | 0 | 0 | 0 | 0 | 0 | 8 |
| *Linum* | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Campanulaceae | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Centaurea* | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Cruciferea* | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Luguminosae | 0 | 0 | 0 | 2 | 1 | 4 | 0 |
| *Vicia* | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| Ranunculaceae | 4 | 1 | 1 | 1 | 0 | 1 | 0 |
| Roseaceae | 1 | 1 | 1 | 2 | 5 | 4 | 4 |
| *Potentilla erecta* | 22 | 7 | 18 | 11 | 15 | 5 | 8 |
| *Stachys*-type | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Labiate*-type | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Sinapsis*-type | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Viola palustris* | 1 | 0 | 0 | 0 | 0 | 0 | 0 |

| | 0cm | 2cm | 4cm | 6cm | 8cm | 12cm | 16cm |
|---|---|---|---|---|---|---|---|
| *Ciracium*-type | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Caryophyllaceae | 3 | 0 | 0 | 3 | 0 | 2 | 0 |
| Umbelliferae | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| *Gentianella*-type | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| *Anthemis*-type | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Trifolium* | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| *Succisa*-type | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Lotus*-type | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Polygala* | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cyperaceae | 2 | 3 | 3 | 0 | 14 | 1 | 8 |
| *Pteridium aquilinum* | 5 | 116 | 66 | 122 | 63 | 76 | 50 |
| *Filicales* | 0 | 2 | 4 | 1 | 5 | 2 | 11 |
| *Tilletia sphagnii* | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Potamogeton* | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Lycopodium* | 0 | 261 | 207 | 174 | 510 | 194 | 1025 |
| *Sphagmun* | 1 | 0 | 2 | 3 | 1 | 0 | 1 |
| Deterioated | 8 | 7 | 4 | 6 | 14 | 6 | 11 |
| Crumpled | 4 | 19 | 13 | 10 | 17 | 9 | 10 |
| Broken | 11 | 12 | 29 | 4 | 12 | 7 | 5 |
| Concealed | 26 | 16 | 9 | 0 | 1 | 5 | 1 |