The ecological basis for tee conservation of thorne waste, Yorkshire

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THE ECOLOGICAL BASIS FOR THE CONSERVATION OF THORNE WASTE, YORKSHIRE

by

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CONTENTS

INTRODUCTION

The areas of peat formed on the Humberhead levels have received relatively little attention when compared with the much studied East Anglian Fenland just over one hundred miles to the south. It seems remarkable that after several centuries of severe interference by man areas of peat still exist here which support a varied and interesting flora. Some of man's later activities have actually increased the variety of mire communities on Thorne Waste by creating a greater diversity of habitats on the remnants of the former raised bog (Peacock 1920; Skidmore 1970).

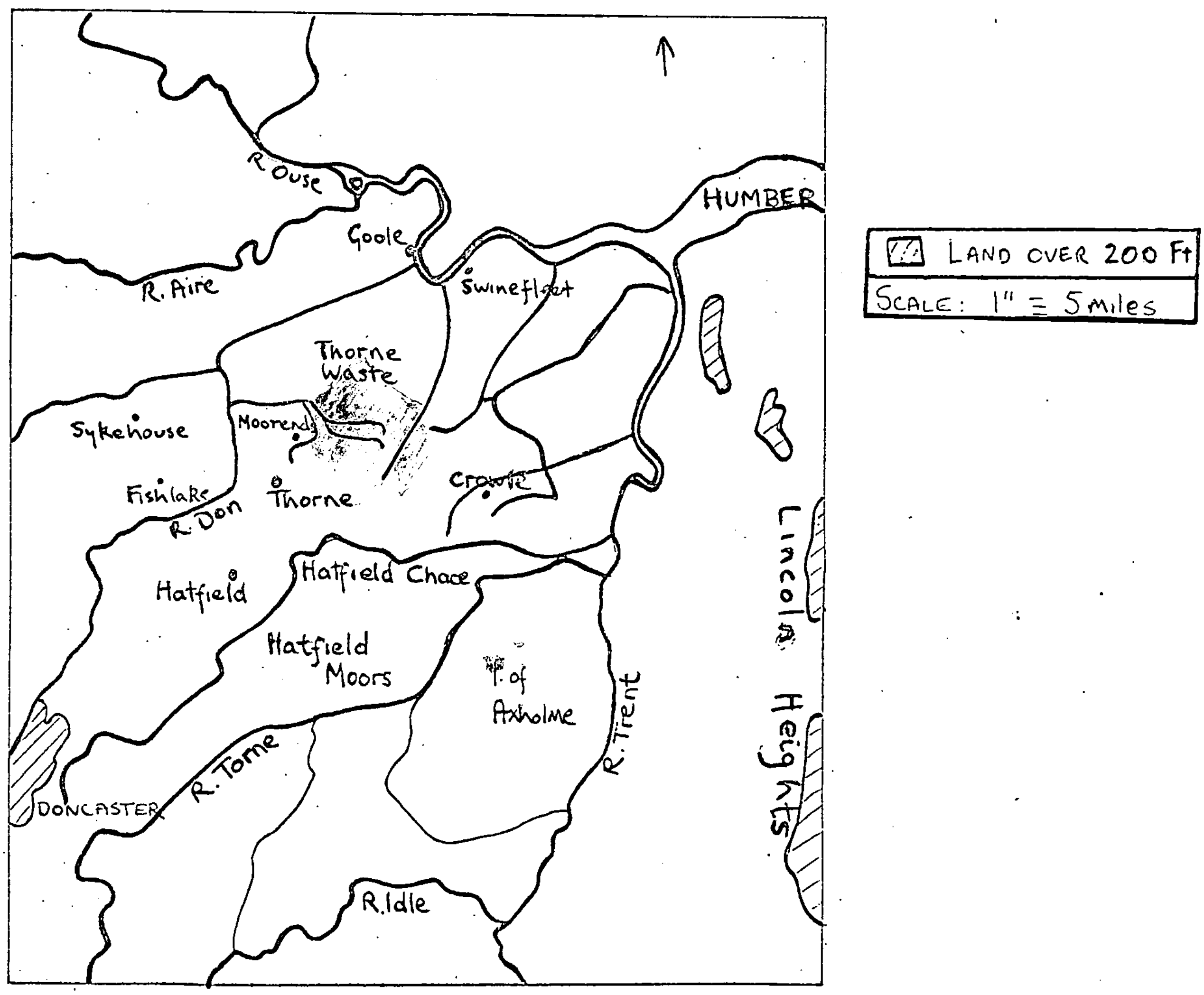
Recently however, the interest of naturalists has been stimulated by the latest threats to the future of the peat bog. In 1969 it was proposed as a site for the dumping of pulverised fuel ash from Drax Power Station, which will be the largest coal fired generating station in Europe. Another suggestion, which has considerable backing from the local authorities, is to build a large new airport here to serve the North East region. The arguments for conserving the area are therefore being considered and its potential scientific and recreational value investigated.

At the present time intensive modern peat cutting together with drainage is changing the environmental conditions over large areas of the peat bog at a faster rate than ever before. If Thorne Waste is to be preserved the potential changes in vegetation produced by these factors must be investigated. The aim of this survey is to relate the present distribution of plant communities with existing chemical and physical conditions; to distinguish the factors causing these and to attempt to predict their relative importance as a basis for future management.

Geographical location

Thorne Waste is situated in a flat, lowlying region 5 miles south of the River Humber between the villages of Moorends and Crowle. The Ordnance Survey $2\frac{1}{2}$ inch map refers to only a part of this area of peat as Thorne Waste. The north and east borders are named, Snaith and Cowick Moors, Goole Moors and Crowle Waste. However locally Thorne Waste is used to cover the whole expanse and this is the sense in which it will be used in the description of the development of the peat bog.

Map of Humberhead Levels around Thorne Waste.



HISTORY OF THE VEGETATION

Knowledge of the vegetational history is an important factor in understanding the present plant distribution. Several sources provide information on the nature of Thorne Waste before human interference on a large scale. A first-hand description of the bog in 1874 is given by Peacock. He describes it as a "shaking bog trembling in waves when you jumped on its scurf or floral blanket, till the undulations were lost in the distance or at the edge of the nearest ditch". He estimates that the highest parts, the central portions and southern edge, were once 20 to 15 ft. deep and that the lower, thinner and wetter outside edges were up to 11 ft. deep. The whole area was much higher, then, than the surrounding land. Later he remarks upon the seasonal rise and fall of the central mass of peat which in winter when full and swollen with rain was some 6 to 8 ft. higher than in dry summer weather.

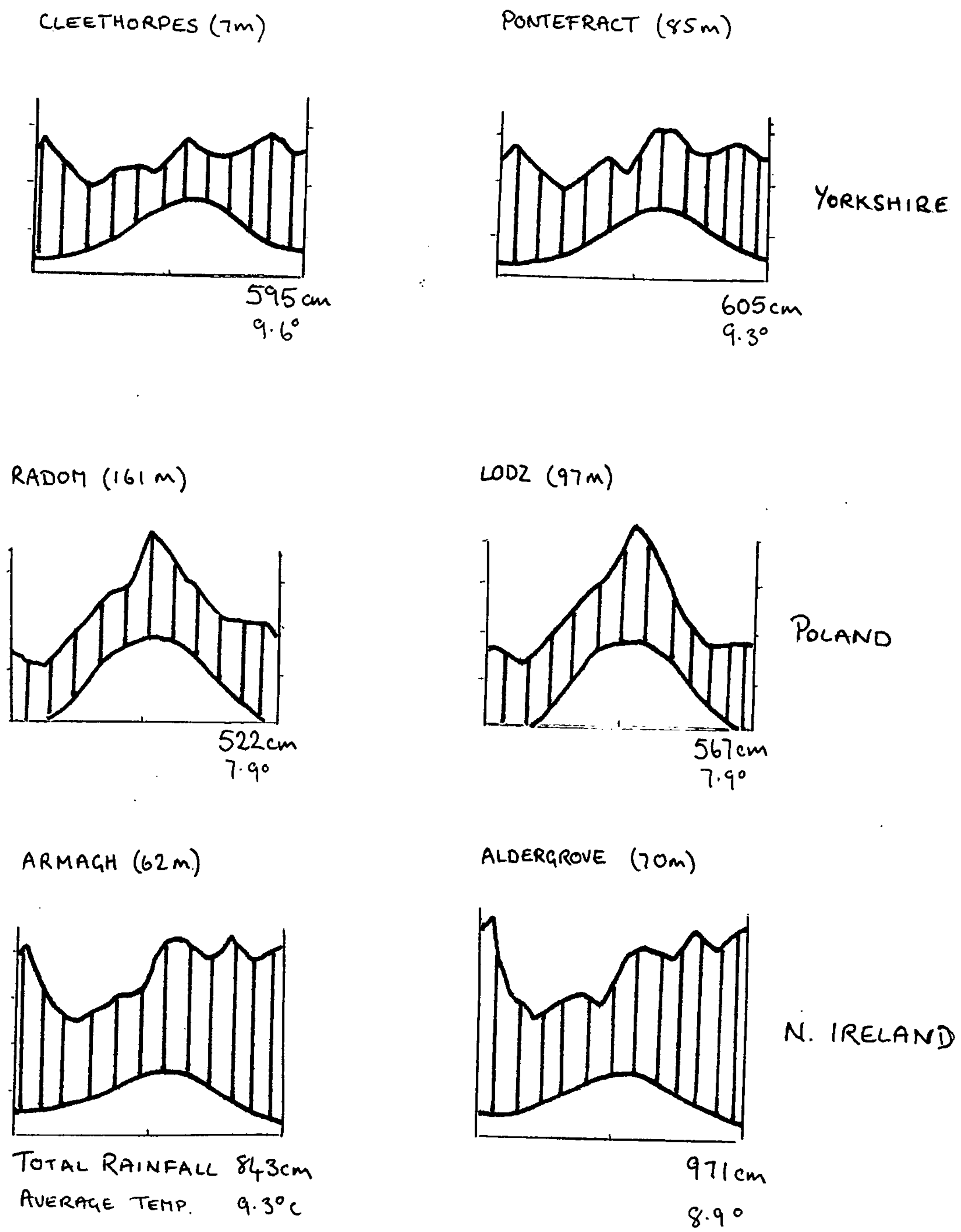
Stratigraphical evidence today confirms that Thorne Waste was a raised bog; the upper layers consisting of an anbrogenous accumulation of Sphagnum peat which was deepest in the middle and thinner towards the edges. The development of this dome would have been a response to both the nature of the physical environment and climatic factors. Comparison with other raised bogs shows that as the Sphagna grow upwards they become less dependent on ground water and more reliant on the minerals supplied in rainfall for their continued growth (Godwin & Conway 1939, Morrison 1955). Thus the ratio, evaporation to precipitation is likely to play a very important role in determining the height and convexity of the dome. In a dry climate a state of equilibrium with the water table will be reached more quickly and the raised bog will only attain a small degree of convexity. As one passes eastwards across Europe towards more continental climates the raised bogs assume an almost perfectly flat shape as in Polesie or Central Russia

(Kulczynski, 1949).

The comparison of Thorne Waste with raised bogs in other geographical locations is of interest because at first sight the extensive upward growth of Sphagna at Thorne appears inconsistent with the prevailing climate in this region. Reliable records going back to 1870 show these eastern lowlands of Yorkshire to have a low average rainfall of about 22.5 in. or 557 mm. a year. Although more evenly distributed throughout the year this rainfall compares with that of Polesie in Central Europe (see Fig. 1). In fact some large bogs with convex outlines do occur in Polesie apparently contradicting the above mentioned trend towards a decrease in convexity. However as Kulczynski (1949) points out, size may be an important factor in the relative appearance of convexity.

The most notable feature about Thorne Waste was perhaps the large seasonal rise and fall in the height of the dome. A possible explanation of the growth of peat at Thorne would be that it is comparable to the raised bogs of N. Ireland, as described by Morrison (1955). He noted four examples of raised bogs where the _Sphagnum_ peat was separated from the lower fen peat by a distinct lens of liquid material. The _Sphagnum_ peat here formed a thin crust enclosing a saturated peat. Evidence of similar bogs in England and Ireland are given. The importance of this inner volume of liquid material is its ability to act as a buffer against seasonal or even longer term fluctuations in the wetness of the climate. The upper strata of peat would be able to move up and down quite considerably with the level of liquid held within its crust. Even in periods of prolonged dryness the surface of the bog could remain saturated with water so that no check to the growth of the _Sphagna_ need have occurred. This situation is apparently operating today in Fairy Water Bog in N. Ireland as is evident from both stratigraphical and floristic data (Morrison 1959).

Fig. 1 Climatic Diagrams.



Taken from: Walter and Leith, 1960.

Morrison makes two 'conjectures' as to how such a feature originated. It is possible that before a former lake or waterlogged area was entirely colonized by fen or marsh vegetation the Sphagna spread far in advance of the marginal fen and captured the lake beneath a floating carpet. Since the Sphagna are light and spongy peat growth could continue on top of this reservoir of underlying water. This type of colonization would be dependent on the cligotrophic nature of the lake waters. A less likely explanation is that the Sphagnum layers grew directly on the fen peat and became separated from the underlying strata by a very rapid rise in the water level.

There is both stratigraphical and historical evidence for a substantial rise in the water table of this area at least once since its original formation.

Stratigraphy

Smith (1958) in his investigations of post glacial deposits around the Humber estuary finds evidence for a total relative rise in sea level of about 3 m. since the Iron Age. He points to the apparent coincidence of marine transgressions and "flooding horizons" in the stratigraphy of these deposits. At Hatfield Moor, only 4 miles to the south of Thorne Waste, the penultimate flooding horizon correlates with a Neolithic marine transgression. This suggests there may have been a backing up of drainage waters in these lowlands causing the instances of increased waterlogging on the surface. The flooding horizons are distinguished by a very fresh light Sphagnum growth plus the absence of evidence of ericaceous plants whereas the intervening drier periods are indicated by a much greater humification of the peat.

Smith's investigations at Hatfield provide a very useful comparison in building up a picture of the development of Thorne Waste. The raised bog at Hatfield developed directly on the nutrient poor deposits of

Triassic Sandstone. This ombrophilous peat growth apparently began in the Atlantic period, Godwin's zone 7a, a time of increasing oceanity of climate. However both Erdtman and Clapham (quoted by Smith and Piggott respectively) come to the conclusion that peat growth at Thorne Waste began later in zone 7b. Borings carried out during this survey indicate silty clay deposits of unknown origin overlying the Triassic Sandstone on some, but not all, parts of the peat bog. Clapham also reports finding alluvial deposits which he believes were laid down by a Neolithic marine transgression. This compares favourably with Smith's findings elsewhere in this region. (Clapham's pollen diagrams are unfortunately unpublished.)

An underlying woody peat layer is found at Thorne Waste. Remains of pine and birch have been described and also oak and yew which probably flourished on the richer alluvial deposits.

A significant flooding horizon at Thorne Waste and Hatfield occurs at the end of the Romano-British period about 400 A.D. This is marked not only by the beginning of a very fresh *Sphagnum* peat but also by rhizomes of *Scheuchzeria palustris* which are found at this level. This species may be generally taken to indicate the development of a high water table and the rapid formation of bog pools; its preferred habitat (Tallis & Birks, 1965). At the same time there is a notable decline in agricultural activity as shown by the decrease in indicator species in the pollen counts (Smith).

Coincidental with this horizon Smith has found evidence of occasional flooding at a site near the Humber estuary. Although this does not amount to evidence of a transgression it suggests, at least, a rise in sea level.

Historical evidence concerning the vegetation of Thorne Waste

The increased waterlogging of the bog surface was apparently a reaction to only local conditions. In general the climate of Britain was becoming drier and warmer during the Roman Era. This amelioration reached an optimum about 800-1000 A.D. (Lamb, 1969). There is also adequate proof that E. Yorkshire was sharing this improvement in climate; in 1085 the Domesday Book records vineyards at York! As there is no evidence of a humified layer in the upper strata of peat, it is possible that the conjectured inner reservoir of liquid peat prevented the drying out of the mire surface during this dry period. If the water table remained high active Sphagnum growth may have occurred. There is evidence of a general waterlogging of the forests in this region at this time. Stonehouse (1812) quotes the Charters of the Lord of Axholme in 1100 A.D. which describe lands to the east of Thorne Waste as being covered with "a great, old decaying forest of oak and firs".

However the recorded colonization of the Waste by Pinus sylvestris indicates that the growth of Sphagnum was in some kind of stable equilibrium with the water balance. Kulczynski (1949) relates a similar invasion of the large raised bogs of Polesie with the fact that they are nearing their climax or the critical height of the dome. Later historical evidence summarized by Peacock shows the decline of these great pine trees, indicating an increased waterlogging. An account in the early sixteen hundreds describes, "great fir trees standing one here and another there in a languishing condition". The forests of the bordering, Hatfield Chace, once a Royal hunting ground, fell into disfavour and the last stag hunt took place in the "forests surrounding Thorne Mere" in 1609. Remnants of the forest finally died out about 1700. Slightly earlier records are found of small pine trees and shrubs over the bog's surface further reflecting the decline of the forsts and the renewed growth of Sphagnum (Kulczynski).

The fate of these pines was possibly hastened by the extensive clearance of neighbouring forests in about 1630 as described by De la Pryme (Skidmore, 1970). Kulczynski suggests that deforestation of peat will improve the water balance in the direction of a rise in water level.

Early nineteenth century descriptions of the vegetation show that the bog, prior to severe interference by man, possessed a high water level as there are reports of Scheuchzeria palustris growing here in great abundance in 1831 (Skidmore, 1970). It is a matter of speculation whether the upward growth of Sphagna would have continued until the present day.

HISTORY OF MAN'S INFLUENCE

Artificial drainage *

Agricultural activity had practically ceased in this area since the end of Romano-British times, presumably because of waterlogging of the surface. So there was very little cultivation, the land being agriculturally poor and very difficult to manage. However in 1620 large scale drainage was attempted of the land south of Thorne, including Hatfield Chase and East of the Waste around Crowle. The venture directed by the Dutch expert Vermuyden was not very successful. There are even records of increased flooding between the two moors of Thorne and Hatfield. In the 1790's this area was still impassable. Drainage schemes continued on a smaller scale around the Waste resulting in a gradual lowering of the water table of the cupola or dome. Peacock records that before the 1870's the bog was much nearer Crowle than Thorne; deep peat extending to within ¼ mile from the town. But here it was "opened up by the digging of turbaries, wells, decoys and ditches". His remarks on the thick bracken cover on the bog confirm that the surface was beginning to dry out.

Further drainage on a larger scale was carried out in association with warping and commercial peat cutting.

Warping *

This is an old term for a method of soil improvement whereby the land was flooded with silt laden waters from, at best, tidal river estuaries. A system of canals and drains conveyed the water to the enclosed area of land to be warped. Here it was allowed to stand so that its load of silt was deposited. The water was then drawn off with an outgoing tide. As much as three feet of silt might be laid down in one season (Creyke, 1845).

This practice is of very great importance to the vegetation of Thorne Waste. It resulted in areas of peat bordering the present peat bog being covered in a rich mineral deposit. Where the warped peat land was abandoned for arable cultivation areas of fen vegetation have developed next to the anbrogenous non-warped mire communities. These areas were usually abandoned because of the high water table here, which would rise up into the warp. Good drainage is essential for cultivation of these silty clay deposits and where the water table has stayed in the peat fertile agricultural land has resulted (Heathcote 1951).

The peat to be warped must first be drained and cut to below sea level so as to be warpable (Peacock 1920, Creyke 1845). The level of peat was then reduced still further by the weight of the warp material laid down on top of it. The effect on the remaining non-warped bog would be to lower the water table and increase the drying out of the dome's surface by increasing the run off to the drained, cut and warped areas. The extensive series of drains and canals constructed for carrying the tidal waters were later used for maintaining land drainage.

Large scale warping of land around Thorne Waste began in 1821. By 1826 the following areas were covered :

1600 acres ... Goole, Swinefleet and Reedness

800 acres ... Eastoft

250 acres ... Crowle Moors

(Creyke).

Peat cutting

A Right of Common Turbary existed so cutting in a small way must have continued for several centuries. Commercial peat cutting got under way in the late nineteenth century. Three companies were originally removing peat so that differing management and techniques were reflected in the style of cutting. For example the Dutch cut wide canals and used barges for transporting the peat. The differences in the old cuts can still be seen today. Hand cutting left much variation in the width, depth and extent of each cut. Often broad baulks or banks of peat were left in between the wide cuts. In contrast modern machine cuts are far more uniform. The two arms of the peat cutting machine cut channels 4 ft. wide by 4 ft. 6 ins. deep leaving only about a 10 ft. wide dividing bank. With the change in method of cutting there has also been a change of emphasis on the type of peat required. In the past, when it was used for fuel the underlying dark humified peat was preferred. Now the peat is used for compost the 'white' light sphagnum peat is at a premium. This therefore affects the area and depth chosen for cutting.

Thus attempts to correlate the vegetation with merely the age of peat cut must be treated with caution as the resulting environmental conditions may differ considerably for plant growth.

Coal mining

Moorend Colliery is situated on the western edge of the peat. The possibility of drainage water pumped out of the mine, or run off from the tips, affecting the borders of the Waste cannot be discounted. However most of this would have been collected in the drains, which separate the colliery and moors. The pit was in fact closed down about 1955 and the pumps stopped working. This has apparently affected the water table in the vicinity as local inhabitants report a noticeable rise in water level in some of the deeper cuts. The rise might also be partly due to less efficient maintenance of the drains formerly associated with the conveyance of colliery flood waters.

Fires

With such large quantities of dried peat exposed Thorne Waste is especially vulnerable to burning. In 1969 a fierce fire swept across the greater part of the peat bog. Peacock records several moorland fires when the centre of the bog burnt for weeks together as in 1874 and over twenty years later when one thousand acres were in flames. In some of its effects burning is similar to cutting, that is, soil moisture content will be reduced and more peat is exposed to oxidation. The composition of plant communities may be altered because of the variable regeneration capacity of species.

* For additional information see Appendix.(p 53-54)

THE FLORISTIC ANALYSIS

From the preceding account it is obvious that anthropological factors have severely modified the vegetation: no part can be said to be unaffected; nor can the environmental effects of the various factors be considered separately. In the nineteenth century drainage would have obliterated the inner liquid reservoir for the upper layers would sink until they rested, as now, on the underlying more humified peat. This drainage was only possible because of a compensatory lowering of the surrounding land under the weight of warp. Peat cutting has further reduced the level of the bog but in a very uneven manner. The surface is now a mosaic of cuts of different ages and depth in relation to the water table.

The habitats created can be broadly divided as follows:

Peat cuts at or below the mire water table

Baulks of dry peat between the cuts

Drains

Canals

Warped areas

(Paths and tracks)

Each area was examined floristically. The boundaries between each zone of vegetation were divided subjectively on the basis of the above division of habitat. Where possible within the limits of each area quadrates of 10m square were paced out. Wherever narrow drains or canals necessitated smaller quadrates this is indicated in the results. The plant community was recorded by eye using Braun Blanquet's index scales of cover and sociability. The percentage cover of a species is an estimation of the area covered by the aerial parts of terrestrial plants and the uppermost parts of aquatic species. It gives a picture of the abundance of each species. The degree of abundance is represented as follows:

						% cover value
Species	covering	80-100%	of	quadrate	....	5
"	"	60-80%	"	"	....	4
"	"	40-60%	"	"	....	3
"	"	20-40%	"	"	....	2
"	"	2-20%	"	"	....	1
Species of small cover value					....	+

The sociability of each species is also graded:

Plants growing in pure stands	5
Plants growing in large patches/open stands	4
Plants growing in small patches/cushions	3
Plants grouped	2
Plants growing singly throughout quadrat	1
Plant growing singly in one place	+

Thus the different quadrates can be compared by the different species present, by the quantity of each species and by the growth of each in relation to the other plants present.

Because of the extremely large area of Thorne Waste the quadrates were taken in areas which apparently typified the main variations within each habitat. Only broad differences in vegetation were considered. In view of the relatively simple plant communities over the greater part of the bog this was judged to be sufficient for the needs of this study. More varied communities were found on the warped peat and in the canals. In the latter especially a more concentrated study was made to give an indication of the range of communities encountered. The number of quadrates therefore bears no relation to the actual area covered by the plant communities they typify. The results are summarised in the phyto-sociological table (Fig. 2 p. 55a).

Peat cuts

These vary in age, size, shape and depth. Within this category a number of distinct large areas may be recognised:

A. With a regular pattern of alternating channels and dry peat baulks in the order of 30 ft. across.

(i) North East corner bordered by a warped area

This was probably cut within the last 50 years. The channels contain deep water up to 2-3 ft. in depth. Each separate channel has been colonized by one of three main types of vegetation:

(a) *Juncus effusus* with very little else except *Drepanocladus fluitans*.

(b) *Eriophorum* dominated communities with no *J. effusus*. *Eriophorum angustifolium* is more abundant but *E. vaginatum* is also represented. *Drepanocladus fluitans* and a variety of *Sphagna* occur including *S. cuspidatum*, *S. recurvum* and *S. plumulosum.*

(c) A mosaic of both *J. effusus* and *Eriophorum* species.

(ii) South East Area

This was last cut in 1900. Again there is a high water level with deep water up to 2-3 ft. in depth. The alternating banks of peat are not so obvious here probably because of the accumulation of the upward growth of mire communities in the intervening channels. It therefore appears as a vast expanse of *Eriophorum*. *Sphagna* are well represented including *Sphagnum recurvum*, *S. plumulosum* and *S. cuspidatum*.

(iii) North West Area

A similar area to (ii). Deep water occurs but the level decreases westwards. Although this was cut later, in 1947, a

Showing N.E. Channel cut, backed by warp.

Betula
← pubescens
seedlings

← Juncus
effusus

Narrow drain, lined by J. effusus, with Eriophorum vaginatum and B. pubescens on higher peat.

Showing northern area of modern peat cutting

Showing three levels of peat with characteristic plant communities.

Central area

Betula pubescens and Pteridium aquilinum

Juncus effusus in 'channel'.

Eriophorum vaginatum on 'damp' peat

similar plant community occurs (i.e. Eriophorum with a good Sphagna cover). Where the water level is lower Betula pubescens is invading. Further west a birch scrub is well established.

(iv) North Central Area

Cuts of various ages and depth are found here. Some, where the water level is at or below the bottom of the cut, are of interest as a comparison. Eriophorum is abundant here; so also is Erica tetralix. Betula pubescens and Pteridium aquilum are found in the drier cuts where expanses of bare peat may be found.

B. Canal region peat cuts (excluding the canals themselves)

This is the area of oldest peat cuts dating back to 1870 although some parts have been re-cut more recently. The water level is therefore variable. This area has the most interesting flora in this category. Eriophorum flats occur with Sphagnum fibriatum, S. recurvum, S. cuspidatum and Polytrichum commune. Vaccinium oxycoccus and Andromeda polyfolia were also found and in one place Drosera intermedia. D. rotundifolia is fairly abundant in some of the deeper cuts (but with little depth of water); Calamogrostis canescens and Carex species including C. curta were frequent.

C. Flooded areas

Two areas in the centre of the peat bog have such a high water level that little can be distinguished of the former peat cuts. The baulks are also submerged and the water is often over 4 ft. deep at the path edge. The flooding is the result of bad drainage possibly connected with the cessation of colliery pumping as discussed previously. The area above the Sherburn and Pitts Drain was cut in 1947.

Both these areas of very deep water support little but Juncus effusus. Higher areas are indicated by small Salix and Betula partially submerged in the water. The most northerly area has been colonized by Black Headed Gulls. Over two thousand were estimated to be present during the breeding season. A smaller colony was reported several years ago on the Mill Drain Juncus swamp.

Dry peat baulks

These vary in the height above the water table and the length of time they have been exposed to drying and oxidation. This habitat was probably most affected by the extensive fire in 1969.

1. High dry baulks

Betula pubescens, at various stages of growth is found on all such areas. Many trees were badly burned.

(i) Burnt areas

Areas of bare peat are being recolonized by B. pubescens seedlings, Calluna vulgaris, Erica tetralix, Rumex acetosella, Pteridium aquilinum and Chamaenerion angustifolium, Campylopus flexuosus and C. pyriformis.

Calluna vulgaris previously covered large areas of the drier peat. In other places Pteridium aquilinum must have grown as thickly as it is now encountered elsewhere.

(ii) Recently cut areas

Similar species to above occur here although the species present to some degree reflect the composition of the community of the area before cutting. The spread of P.aquilinum appears to be greatly enhanced by the cutting. B. pubescens is also flourishing.

2. Damper peat baulks

These of course grade into the drier peat cuts. Eriophorum vaginatum dominated communities are found with E. angustifolium, Erica tetralix and sparse Calluna vulgaris. Pohlia nutans is abundant.

Drains

The surface of the bog is traversed by a complex network of drains. A large number are required owing to the absorptive nature of the peat which often results in water being drawn only from the immediate vicinity of the drain (Morrison, 1959). The characteristics of each drain are widely different not only because of variations in length, width and depth but also in geographical location and the direction and strength of the water flow. Changes in association with peat cutting are easily and frequently imposed on the system. Of the drains which flow across the bog the following are noteworthy:

1. Swinefleet warping drain

This runs in an approximately north-south direction on the east side. In view of its former purpose it is not surprising that mesotrophic plant communities flourish here. The drain now also receives run-off from agricultural land. The following species vary in abundance along its length: Phragmites communis, Typha latifolia, Plantago alisma-aquatica, Epilobium palustre, Lycopus europaeus, Hottonia palustris, Ranunculus scleratus, Lemna minor.

2. Cottage Dike

This flows in an east-west direction from the Swinefleet Warping Drain, through the area of warped peat. It crosses the Thousand Acre Drain which borders the edge of the cut warped peat and continues across the bog through the middle of the canal region to collect some warp and agricultural run-off on the west side.

Interesting communities are reported on the east end of this Dike (Shimwell, 1970). This area was impenetrable in late July. Stands of Scirpus maritimus are found associated with Callitriche platycarpa and C. intermedia where the water table is high. Where it's lower Polygonum persicaria, Epipactis palustris, Eriophorum angustifolium, Glycera maxima, Lysimachia mimmularia and Epilobium obscurum occur. Such communities were not seen on Cottage Dike in the centre of the bog.

3. Mill Drain

This Drain runs parallel to Cottage Dike to the north. It flows in the opposite direction (i.e. from west to east). For the most part it consists of open water with abundant Drepanocladus fluitans.

4. New Drain

A newly dug or recently cleared cut drain is found south of the canal region through ombrophilous mire communities. It connects with the Swinefleet Warping Drain on the east side but was not followed through to the west (neither can it be distinguished on the O.S. Map). It is a narrow drain bordered on both sides by an unbroken line of Juncus effusus with no other species.

The Dutch Canals

The most important remaining series of canals occur to the north and south of Cottage Dike. The connecting "Main Canal" runs in a southerly direction giving off branches to the east which extend out across the centre of the peat bog. The least interfered with section is south of Cottage Dike where the Main Canal continues eastwards giving off side canals at intervals of about 220 yds. Each canal was originally bordered by a wide retaining bank of peat but some have been removed in subsequent cutting. The canals were hand cut in the 1870's and so vary greatly in their dimensions. They are generally wider than the drains; depth is difficult to compare. They do not have any connections with the drainage system or any other waterways, and merely led to the old peat mill.

The south set were studied in the greatest detail. The most remarkable feature of these canals is that although they extend right across the peat bog and are surrounded on all sides by ombrophilous mire communities, within them are found a most interesting and varied mixture of bog and reed/swamp communities. A comprehensive survey relating changes in the plant community to environmental factors was not possible in the time available but would probably be rewarding. (The total length of the canals is about 20 miles.) The Main Canal was followed along most of its length south of Cottage Dike as were the Side Canals 1 and 5. Parts of Side Canals 3, 4, 10 and 12 were also studied. (See Map.) A full list of species seen in this area is given with general details of their abundance and extent of distribution. Little attempt has been made to define the communities. Some indication may be gained from the phytosociological table.

Abundant and widespread:

Potentilla palustris*; Lythrum salicaria*, Scirpus tabernaemontani*; Phragmites communis*, Juncus effusus; Typha latifolia*, Eriophorum angustifolium; Hydrocotyle vulgaris*; Lemna minor; Utricularia vulgaris; Betula pubescens; Salix cinerea, Sphagnum fimbriatum, S. recurvum; S. subsecundum, S. squarrosum; S. cuspidatum and Drepanocladus fluitans.

Frequent and widespread:

Andromeda polyfolia; Erica tetralix; Ranunculus scleratus; Galium palustre*; Drosera rotundifolia; Typha angustifolia*; Scirpus lacustris*; Calamagrostis canescens*; Carex curta*; C. elata*; Juncus bulbosus;

J. articulosus; Myriophyllum alterniflorum*; and Aulocomnium palustre.

Occasional or in one area only:

Cladium mariscus* (in large stands on Main canal); Lysimachia vulgaris*; Osmunda regalis (two plants, one fruiting), Dryopteris dilatata; Salix repens, S. pentandra (one only noted) and Drepanocladus revolvens.

The mesotrophic indicator species have been marked with an asterisk.

Warped peat

Large areas of warped peat are found to the south and east of the peat bog. A Betula-Salix carr covers most of the drier parts of these areas. A thick almost impenetrable growth of bracken borders the carr in summer. A varied understory of the carr on the east warp was sampled.

Wetter areas of the warp were found to support the following types of poor fen communities:

(i) Open pools with Sparganium erectum dominant.

(ii) Typha latifolia dominated communities.

(iii) Large stands of Phragmites communis.

(iv) Large stands of Glyceria maxima.

The first two only were sampled and details may be found in the table along with one quadrate from the southern warp.

Footpaths and tracks

The system of narrow gauge track for the peat trains, now often abandoned or used as a route for footpaths, has created yet another habitat for plant colonization. As the tracks cross the whole area a variety of species and communities are seen. The more open paths tended to be dominated by bracken during the latter part of the survey. The most interesting species were seen on tracks bordering the warp and on those in the canal region. Detailed sampling was not carried out. The following are a few of the species noted on the tracks which have not been recorded elsewhere in this study.

Canal region

Lotus uliginosus; Lysimachia vulgaris, L. mimmularia; Scrophularia nodosa; Dipscacus fullonum; Calamagrostis epigejos; Rhytidiadelphus squarrosus; Eurhynchium praelongum.

Discussion of Floristic Data

The "basic" mire community in the wetter areas (if any may be called that in this much interfered with environment) would seem to be an ombrogenous Eriophorum and Sphagnum community. As its upward growth continues a gradual drying out of the surface occurs with colonization of the Sphagnum hummocks and drier areas by other species. There is every indication that in time a variety of ombrogenous mire species will invade such areas; species such as Andromeda polyfolia, Vaccinium oxycoccus and Drosera rotundifolia as well as the more common ericaceous plants. Birch scrub (Betula pubescens) seems to be the natural climax to this succession. Where there is a lower original water level and on peat baulks the invasion of birch is, as expected, more rapid.

Juncus effusus swamp has developed in several regions of peat cut. This type of community is undesirable for several reasons. Very few other species are associated with it. It is unaccessible and liable to be invaded by Black Headed Gulls whose effect on the chemical environment is of interest. Gilham (1956) found several plant species unable to tolerate the conditions in the region of Gull colonies.

The swamps are established in deep cuts of all different ages from the most recently abandoned modern cuts on Crowle Waste to an area cut in 1926,"Black Flats". J. effusus also appears to be a rapid coloniser of new areas of open flowing water as demonstrated by its presence along the edges of new drains which cut across older established communities of Eriophorum. It is also associated with the new drains of modern peat cuts. No other species occur in these border communities.

The alternate and mixed communities of J. effusus and E. angustifolium in the apparently similar deep water channels presents an interesting situation. They possibly represent stages in competition between the two species. Reference may be made to the 1900 cuts where Eriophorum flats have developed. Here J. effusus is present only at the very edge, along the route of a former drain. In this time it has either not spread into the acres of Eriophorum or has been ousted out of its previous habitat.

The Warp and the Canals both stand out as much "richer" areas with more varied and interesting communities. The warped peat are sharply defined border areas whose historical development has already been explained. Similar conditions are unlikely to arise again in the foreseeable future; the practice of warping being now too uneconomic to attempt (Harwood, 1969).

The Canals represent an isolated reservoir of both bog and fen species which stretches right across the peat bog, throughout the much poorer communities of subsequent peat cuts. Several questions remain unanswered. Why do the mesotrophic communities only grow here in the middle of an otherwise ombrophilous mire? What factors distinguish this region from other equally old or equally deep cuts?

The subsequent study was an attempt to elucidate the problems outlined by this floristic analysis.

CHEMICAL ANALYSIS

The following analysis is an attempt to further clarify the differences in environmental conditions which are reflected in the changes of vegetation over the mire surface. It has long been recognised that chemical factors are very important in differentiating mire plant communities (Newbould and Gorham, 1956; Sjors, 1950).

Water collection and storage

Water samples were collected in clean 250 ml. polythene bottles either directly from open water or by pressing the bottle gently into the mire vegetation to below water level. It was realised that samples from flowing water in drains were unlikely to be in equilibrium with the surrounding peat water. The samples were filtered within 12 hours using Whatman 6 papers. They were stored at 0° C. Analysis was carried out as soon as possible. Estimation of pH, bicarbonate, phosphate, and strong acid salts were generally completed within four days. The cation concentrations are unlikely to fluctuate sufficiently over the period before analysis to invalidate the results (Bellamy, 1967). Weather conditions at the time of sampling were noted.

Acid Digestion of Peat

The peat samples were dried at 85°c for 48 hours. 1 gm. of the ground, dried sample was transferred to a conical flask on a heated sand tray. A strong oxidising mixture of the three concentrated acids: nitric; hydrochloris and perchloric, was used to digest the peat. Care was taken to minimise foaming which would have resulted in loss of sample. The digestions were continued for about 8 hours until the samples looked clear. On cooling they were diluted, filtered and made up to 250 ml. with more distilled water.

These solutions were analysed for the main cations and phosphate.

Measurement of pH

This was measured potentiometrically on a standard laboratory pH meter.

CATION ANALYSES

1. Estimation of sodium and potassium

Principle of method. The concentration of both these cations was estimated using a flame photometer. By this technique a metallic salt, drawn into a non luminous flame, ionizes and emits a light of characteristic wavelength which energises a photocell; the output of which is used to deflect a galvanometer. The relationship between the flame intensity and the concentration of ions in solution is non linear. For this reason it is necessary to draw a calibration curve using a series of standard solutions.

Procedure. An Eel Mark II flame photometer was used. Standard solutions for each element were prepared and the machine calibrated for sodium and potassium respectively. A calibration curve within the range of 0-100 ppm was constructed for each. Both water samples and acid digests were analysed directly. The scale readings for each sample were recorded and the concentration of each element obtained from its calibration curve.

2. Estimation of magnesium and calcium

Principle of method. Atomic absorption spectrophotometry was used in the analysis of both these elements (Allen 1958). This method is similar in principle to flame photometry; the ions are excited in an oxy-acetylene flame.

Interference. This is reduced by the use of a high temperature flame. However the method has the disadvantage of interference in the determination of calcium by phosphate, bicarbonate and sulphate (Bentley and Lee, 1967). This can be minimised by the addition of standard solutions of lanthanum or strontium chloride. The former is more highly recommended by the manufacturers but strontium chloride is also routinely used (Dixon, pers. comm.) and was more readily available.

Procedure. An Eel Atomic Absorption Spectrophotometer was used for magnesium determinations. However this instrument gave no consistent readings on calcium standards. As it appeared unreliable, calcium and later magnesium determinations were carried out on another make of spectrophotometer. A calibration curve for each element was prepared and readings taken as before but with equal quantities of 1% strontium chloride solution added to the samples and standards to be analysed for calcium.

3. Estimation of manganese and soluble iron

A Unicam Atom Spek Atomic Absorption Spectrophotometer was used. Calibration curves were prepared from a series of standards and used to obtain the concentration of each element in the sample. Only two samples were analysed.

ANION ANALYSIS

1. Estimation of weak acid salts (largely bicarbonate)

Procedure. A solution of .01 N hydrochloric acid was titrated to pH 4.5 against aliquots of the sample water. B.D.H 4.5 indicator was used containing 0.2% methyl red and .1% bromocresol green in neutral 95% alcohol. (Mackereth, 1963)

Estimation of strong acid salts (largely sulphate, chloride, and nitrate

Principle. An ion-exchange method was used (Mackereth, 1963). When a solution of salts in water is allowed to percolate through a column of cation exchange material in the hydrogen form, all the cations present in the solution are exchanged for hydrogen ions. The effluent from the column therefore consists of a solution of the free acids corresponding to the salts originally present and in an equivalent concentration.

If this is then titrated with standard alkali to pH 4.5 the amount of alkali used will be a measure of the concentration of free strong acids (weak acids being still undissociated at this pH). Therefore the concentration of strong acid salts initially present in the solution may be calculated.

Reagents. (i) Cation exchange material "Amberlite 1R 120.

(ii) 2N hydrochloric acid.

(iii) N/100 potassium hydroxide solution.

(iv) B.D. H. 4.5 indicator.

Procedure

Preparation of the exchange material. A stock of cation exchanges in the hydrogen form was prepared. One end of a large glass tube was drawn into a funnel shape and fitted with a length of rubber tubing closed with a screw clip. A glass wool plug was inserted at this end. The tube was filled with exchange resin and water. Care was taken throughout to keep the resin column continually covered with water. The top of the glass tube was then connected to a reservoir of about 4 litres of 2N hydrochloric acid. The screw clip was opened to allow the acid to percolate through the bed of resin. This large excess of acid ensured that the whole of the resin was converted to the hydrogen form. Several litres of distilled water were then percolated through in a similar manner. A series of small tubes were made with rubber tubing and screw clip attachments as before. These were then filled with the prepared resin taking care to keep it under water and not to draw air into the columns.

Method. The small columns were fitted into the bottom tier of a two-tiered rack. 50 mls of sample were drawn into a pipette and the tip of the pipette inserted into the top of the column. The pipette was supported by the upper tier of the rack. The screw clip was adjusted to allow water to percolate through the column at a rate of about 5 ml/min. The first 20 ml of effluent was discarded. 10 mls of the rest was titrated to pH 4.5 with N/100 potassium hydroxide. The resin in these columns was found to be sufficient for the entire analyses.

2. Estimation of sulphate plus nitrate

Principle. If a water sample is passed through an exchange column, of which the upper half is in the silver form and the lower half in the hydrogen form, the cations of the sample exchange for silver ions and insoluble silver choride is deposited on the resin particles. Silver sulphate and nitrate are however soluble and so pass through the upper part of the column exchanging their silver for hydrogen on the lower half and emerging as sulphuric acid and nitric acid. The net result is the removal of chloride.

Procedure.

Preparation of silver exchanger. A column of resin was set up as before but instead of passing hydrochloric acid through a 2% solution of silver nitrate was allowed to percolate through the column until excess silver ions were detectable in the effluent. The column was then washed through with distilled water. Small columns, as before, were set up by half filling them with hydrogen exchanger on top of which was deposited an equal amount of silver exchanger.

Method. 50 mls samples were percolated through these resin columns and the effluents titrated as before. However these consist only of sulphuric and nitric acids.

3. Estimation of chloride

The concentration of chloride may be calculated from the results of the above procedures for strong acid salts. It is the difference between the total strong acid salts and the amount of sulphate plus nitrate found to be present.

4. Estimation of nitrate

Principle. The standard method for the estimation of nitrate is based on the reaction between phenoldisulphonic acid and nitrate, which gives rise to an intense yellow colour on the addition of alkali. The intensity of this colour is proportional to the nitrate concentration.

Interference. This method is subject to severe interference from chloride content ~~to a minimum~~ (to, at least, below 10 mg/l). However silver sulphate used for this removal presents problems owing to incomplete precipitation of the silver ions which produces an off colour or turbidity when the final colour is developed.

Reagents. (i) Standard silver sulphate solution.

(ii) 25% phenoldisulphonic acid reagent.

(iii) Calcium carbonate suspension.

(iv) 30% hydrogen peroxide solution.

(v) 1:1 ammonium hydroxide solution.

Procedure. The chloride concentration was estimated as above. 20 mls of sample were treated with an equivalent amount of standard silver sulphate solution. It was extremely difficult to precipitate the silver chloride so formed. Coagulating with heat was tried with little success. The samples were left to stand overnight in the dark. If any precipitate had come down the supernatant was filtered off. This was generally unsatisfactory; most of the samples still having a cloudy appearance. Each was then centrifuged at speeds up to 1000 revs/min. (Higher levels might have been more successful.)

10 ml aliquots of the supernatants resulting from this treatment of samples were transferred to evaporating dishes and 2 mls of the calcium carbonate suspension plus 1 ml of hydrogen peroxide added. The dishes were covered and the contents heated on a steam bath for two hours. Timing here is critical. After uncovering the samples were evaporated

to dryness and left on the steam bath for a further fifteen minutes to destroy any residual hydrogen peroxide. After cooling 2 ml of phenol-disulphonic acid was added. This reagent must be added quickly, covering the entire residue at once. After ten minutes 20 ml of 1:1 ammonium hydroxide was added, the solution cooled and made up to 50 ml volume.

The colour of the solution after adding ammonium hydroxide should be pure yellow, as usually happened. A brown tinge in the solution is an indication of incomplete oxidation of organic matter. These samples were repeated with double the amount of hydrogen peroxide solution.

The intensity of the yellow colour was measured using an Eel photoelectric colorimeter using a blue filter. A standard nitrate nitrogen solution was prepared and put through the same procedure. A reagent blank was also prepared using distilled water.

Calculation. In sample of known size:

$$\text{ppm } NO_3^- - N = \frac{R - B}{R\,std} \times 4.43 \quad \text{~~in standard~~}$$

Where R = reading of sample
B = reading of blank
R std = reading of standard (·01 ppm)

5. Estimation of ortho-phosphate

Principle. In strongly acid solutions ortho-phosphate (= PO_4-P) will form a yellow complex with molybdate ions. Phosphate bound to organic substances does not react with the molybdate reagent. These compounds must therefore be hydrolysed in order to convert the phosphate to H_3PO_4. The high temperature and high acidity of the acid digestion of peat is sufficient to do this. So the estimation of these samples was of total phosphate content.

Interference. The colour inherent in all the samples produced interference with this method. Organic matter may be eliminated by coagulation with Aluminium hydroxide suspension as suggested for standard methods of nitrate determination (APHA 1966). However the effect on the organic phosphorus content of the water samples was unknown. This would not normally be measured by this method. Absorption with activated carbon also decolourises the sample. Neither methods appeared to affect the inorganic phosphate standard.

Reagents.

(Yarwood) (i) A. 1.25 gm Ammonium metavanadate in 400 ml dilute nitric acid.

B. 50 gm Ammonium molybdate in 400 ml of distilled water.

Pour B into A, mix and make up to 1 litre with water.

(ii) Standard phosphate solution.

(iii) Aluminium hydroxide suspension.

Procedure. Aluminium hydroxide suspension made up from supplied crystals had no effect on colour removal. A freshly prepared suspension was therefore made using ammonium alum and concentrated ammonium hydroxide solution. This too was ineffective on the acid digestion of peat samples but successfully removed the colour from peat water samples. 0.5 ml of aluminium hydroxide suspension was added to 20 ml of water sample. It was filtered, the first part of the filtrate being discarded. A series of standards from 0-15 ppm phosphate were made up in a similar manner. The samples from the acid digestion of peat were treated with 0.5 gm activated carbon. This was filtered as before. Another series of standards were prepared using the decolourising carbon.

6 mls of the treated sample or standard plus 2 ml reagent (i) were made up to 10 ml with distilled water. This was left for ten minutes only for the yellow colour to develop. Its intensity was measured using a Hilger and Watts Uvispek. Readings were taken at 430 μ and using a slit width of 0.05. A calibration curve was prepared and used to obtain an estimation of the concentration of phosphate from the recorded readings.

Results of chemical analyses

The full results of the water analysis may be found in Table 1. They show the peat bog to be a complex pattern of varying chemical conditions. An attempt has been made to group together distinctive areas in a meaningful way.

Reference should be made to the map (Fig. 3) for the exact location of sample sites and where possible to the same number in the floristic table for a fuller description of the plant community. The date has been given and the weather conditions at the time of sampling may be found at the end of the Tables.

The following is a brief outline of the main groupings.

Group I This includes all water samples from ombrophilous mire communities where *Eriophorum* was dominant.

Group II This includes sites where *Juncus effusus* was dominant excluding the drains and canals and the area of the gull golony. These first two groups may be taken to indicate the chemical characteristics of the greater part of the peat bog.

Group III The first two samples are from near the centre of the black headed gull colony; the third and fourth are taken where the water level decreased at the western edge of the colony.

Group IV All the samples here are from the canals. IV.A includes sites on the network south of Cottage Dike. IV.B includes sites north of this Dike.

Group IV.C (Fig.3b) includes samples from the canals and from contrasting neighbouring communities. These were analysed for pH, calcium and magnesium only.

Group V All these samples are from a scatter of sites on the east warp. The first is a flowing drain at the visible boundary of the warp soil.

Group VI This is a miscellaneous group including all the main drains which were sampled.

The results of the analysis of the acid digestion of peat samples from a variety of sites may be found in Fig.

(Statistical data is included at the end of these tables.)

Summary of chemical data

1. pH

This can be seen to vary fairly consistently between the different groups. Areas of similar pH in different groups may be distinguished on other chemical characteristics. A considerable range in the total ionic content may occur between sites of the same pH as demonstrated by samples from the canals and from the warped peat.

A statistical comparison of the results has been made (Table 4). The *Eriophorum* dominated communities are found to be at a significantly lower pH than any other type. Bias of results due to small sample numbers may be especially relevant with groups I and II. Here the number of samples taken per unit area covered by the same vegetation is very much smaller than for any other group.

Differences which are more significant are shown between Group II, *J. effusus* community, and Group III, the Juncus swamp in the area of the gull colony.

Group IV, the canal region, is shown to be of significantly higher pH than the more ombrophilous mire type communities.

2. Group V. Total ionic concentration of samples from the warp

Comparatively high values of total ionic concentration are found in all Group V. The high values of each cation or anion should be considered as a proportion of the total.

The results of a simple "ashing" experiment on "top soil" from warped and unwarped peat about 10 yds apart demonstrates the high mineral:organic content of the warp (see Table 5)

3. Group I-IV. Cation concentration in water samples and acid digests

Potassium was constantly low in all the water samples and acid digests; the highest values were found in the latter.

Higher levels of sodium were found in the water samples. No predictable differences may be found between the groups. Much lower values were given for the acid digests.

Calcium showed a more consistent variation in the water samples. Magnesium followed a similar trend. Levels were generally low in the *Eriophorum* communities and sometimes slightly higher in the *J. effusus* areas selected for sampling with the surprising exception of the region of the Gull Colony. Here both cations were extremely low.

Both were highest in the canal region - a very interesting result. "t" tests showed calcium concentrations here to be significantly higher than samples taken from other mire communities.

Less than 2 ppm soluble iron and no manganese was recorded in the two samples tested.

4. Groups I-IV. Anion concentration of water samples and acid digests

The concentration of sulphate and chloride varied considerably and no correlation is apparent in either with the sampling site.

As expected, bicarbonate increased with pH.

Nitrate levels were low and unpredictable.

High values of orthophosphate were found in the water samples from the Gull Colony, Group III. These should be compared with similar areas of *J. effusus* swamp elsewhere. A trend towards increasing values for total phosphate was found in the acid digests.

Fig 3. SAMPLE SITES

Fig. 3. MAP OF THORNE WASTE SHOWING MAIN DRAINS AND AREAS OF PEAT CUTTING.

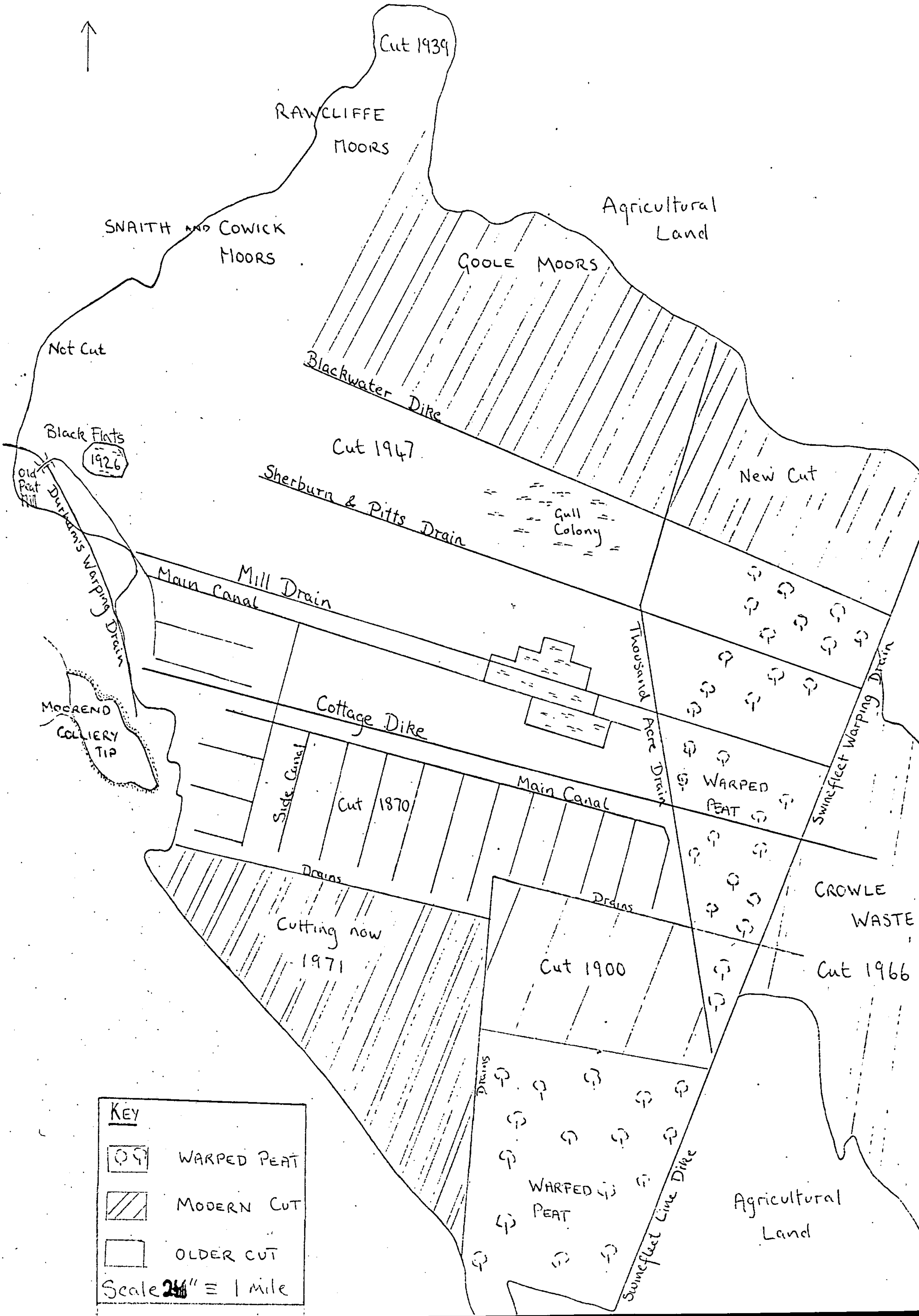


Fig. 3a TABLE 1. KEY TO WATER ANALYSES

Abbreviations:

NR	no reading taken
-	only negligible amounts recorded

Group	I	E	mainly Eriophorum dominated communities
"	II	J	Juncus effusus dominated communities
"	III	Jc	Gull Colony
"	IV	C	Main and Side Canals of southern network
		Nc	Main Canal of northern network
"	V	W	Warp area
"	VI	MD	Mill Drain
		JD	New drain
		CD	Cottage Dike
		TA	Thousand Acre Drain
		WD	Swinefleet Warping Drain

Weather Conditions:

9/5	Cloudy	13/7	Very hot and dry
25/5	Cloudy, drizzle	29/7	Rain
26/6	Cloudy, dry	9/8	Dry after thunderstorms

Fig. 3a TABLE 1

WATER ANALYSES

GROUP I	Site	Date	pH	H^+	Na^+	K^+	Ca^{++}	Mg^{++}	Total cation	$SO_4^=$	Cl^-	HCO_3^-	Total anion		NO_3	P
m.eq.	E1	9/5	3.4	.40	.39	.03	.35	.54	1.71	1.70	0.70	-	2.40	p.pm	NR	.001
	E2	"	3.2	.63	.41	.01	.33	.41	1.76	1.60	0.70	-	2.40		NR	.001
	E3	"	3.6	.25	.48	.03	.53	.54	1.58	1.50	0.80	-	2.30		.051	.001
	E4	"	3.6	.25	.44	.05	.23	.41	1.38	1.80	0.60	-	2.40		.021	.001
	E5	25/5	3.8	.16	.61	.03	.40	.51	1.71	1.20	1.10	-	2.30		.013	.001
	E6	"	3.6	.25	.50	.03	.61	.67	2.03	2.00	1.10	-	2.10		.004	.001
	E7	"	4.1	.08	.50	.04	.40	.43	1.45	1.40	0.80	-	2.20		.053	.002
	E8	"	3.8	.16	.57	.04	.50	.59	1.86	1.50	0.90	-	2.40		-	.001
	E9	13/7	3.45	.35	.57	.10	.23	.43	1.68	1.80	1.10	-	2.90		NR	.004
	E10	"	3.7	.20	.52	.08	.23	.63	1.66	1.90	1.00	-	2.90		NR	.001

TABLE 1 continued

WATER ANALYSES

GROUP II	Site	Date	pH	H^+	Na^+	K^+	Ca^{++}	Mg^{++}	Total cation	$SO_4^=$	Cl^-	HCO_3^-	Total anion		NO_3^-	P
m.eq.	J1	13/7	4.3	.05	.57	.03	.45	.45	1.35	1.30	.90	-	2.20	ppm	.021	.001
	J2	"	4.4	.04	.48	.04	.45	.59	1.60	1.10	1.30	-	2.40		.051	.002
	J3	9/5	3.8	.16	.43	.02	.53	.63	1.77	1.20	1.10	-	2.30		.011	.001
	J4	25/5	4.4	.04	.54	.13	.70	.77	2.18	2.00	.80	-	2.80		.133	.005
	J5	"	4.3	.05	.91	.02	.75	.67	2.40	1.70	1.30	-	3.00		.013	.005
	J6	"	NR	NR	.61	.03	.55	.53	1.72	NR	NR	-	NR		NR	.002

TABLE 1 continued

WATER ANALYSES

GROUP III	Site	Date	pH	H^+	Na^+	K^+	Ca^{++}	Mg^{++}	Total cations	$SO_4^=$	Cl^-	HCO_3^-	Total anions		NO_3^-	P
m.eq.	Jc1	25/5	6.0	-	.48	.05	.25	.18	.96	1.20	1.50	.30	3.00	ppm	.018	.009
	Jc2	"	6.2	-	.48	.05	.25	.20	.97	1.50	.70	.40	2.60		.111	.010
	Jc3	"	5.4	-	.46	.05	.20	.23	.94	1.30	1.40	.10	2.80		.062	.007
	Jc4	"	5.4	-	.50	.05	.25	.25	1.05	1.60	.70	.10	2.40		.053	.007
GROUP IV	C1	26/6	5.9	-	.44	.05	.65	.42	1.56	.90	.70	.51	2.11		.081	.002
m.eq.	C2	"	6.8	-	.37	.04	.78	.38	1.57	.80	.50	.70	2.00		.035	.006
	C3	13/7	6.5	-	.57	.05	1.40	.83	1.75	.90	1.80	2.41	4.11		.055	.003
	C4	29/7	5.8	-	.31	.05	.50	.50	1.36	.80	.70	.65	2.15		NR	NR
	C5	"	6.4	-	.57	.04	.80	1.08	2.49	1.30	1.20	.80	3.30		NR	NR
	C6	26/6	4.8	.02	.52	.04	.68	.58	1.84	1.20	.80	-	2.00		NR	.001
	C7	"	6.75	-	.35	.04	.85	.57	1.81	.80	.90	.85	2.55		NR	.005
	C8	29/7	6.1	-	.46	.04	.80	.75	2.05	.90	1.20	.70	2.80		NR	
	Nc1	26/6	6.0	-	.50	.03	1.15	.71	2.39	1.30	.70	1.25	2.25		.044	.005
	Nc2	"	4.4	-	.48	.01	.50	.47	1.45	1.20	.70	-	1.90		.044	.002

TABLE 1 continued

WATER ANALYSES

	Site	Date	pH	H^+	Na^+	K^+	Ca^{++}	Mg^{++}	Total cations	$SO_4^=$	Cl^-	HCO_3^-	Total anions		NO_3	P
GROUP V																
m.eq.	W1	26/6	6.2	-	1.13	.03	1.80	1.08	4.04	2.80	.90	3.05	6.75	ppm	.050	.003
	W2	"	7.1	-	1.83	.05	4.60	1.58	8.01	4.70	1.10	5.80	11.60		.091	.001
	W3	"	6.9	-	1.61	.05	5.04	1.83	8.53	6.90	1.10	5.45	13.45		.118	.001
	W4	"	7.2	-	1.44	.04	5.02	2.50	8.99	5.50	1.20	6.00	11.70		.098	.001
	W5	"	6.9	-	1.09	.08	4.45	2.00	7.61	3.90	1.50	5.50	10.90		.142	.003
	W6	"	NR	NR	1.09	.05	2.05	1.83	5.02	NR	NR	NR	NR		.159	.002
GROUP VI	MD1	25/5	4.0	.10	.54	.03	.55	.63	1.85	1.7	1.0	-	2.7	ppm	.016	.002
m.eq.	MD2	13/7	3.4	.40	.57	.05	.55	.53	2.09	1.4	1.0	-	2.4		NR	.001
	ND1	29/7	5.8	-	.52	.01	.70	.58	1.81	1.40	.80	.20	2.40		NR	NR
	JD1	29/7	6.7	-	.39	.03	1.30	1.70	3.47	1.10	.80	1.25	3.15		NR	NR
	JD2	29/7	6.6	-	.52	.03	1.15	1.0	2.69	1.00	.60	1.20	2.80		NR	NR
	CD1	13/7	4.0	.10	.44	.04	.56	.58	1.72	1.30	.90	-	2.20		NR	.003
	CD2	29/7	7.1	-	.74	.04	2.05	2.0	4.83	.60	1.20	4.40	6.20		NR	NR
	TA1	"	6.1	-	.48	.04	.70	.83	2.05	1.10	.90	.90	2.90		NR	NR
	WD1	"	6.7	-	.52	.05	1.00	1.42	2.99	.60	.70	1.80	3.10		NR	NR
	WD2	"	7.5	-	.65	.07	3.30	1.91	5.93	1.60	1.10	6.50	9.20		NR	NR

Fig. 3b TABLE 2 WATER ANALYSES

Sample Site		Date	pH	Ca^{++}	Mg^{++}
CANALS					
North E-W	a	9/8	4.85	.50	.58
	b	"	6.10	.40	.55
	c	"	6.05	.65	.59
	d	"	4.75	.50	.50
South E-W	a	"	6.20	.90	.70
South Side	1a	"	6.80	.90	.70
	b	"	6.50	.95	.70
	c	"	6.45	.80	.70
	d	"	4.90	.50	.29
Side	5	"	6.05	.64	.53
OTHER					
Shallow drain	4/5	"	3.65	.25	.40
15 yr. re-cut	15	"	4.8	.4	.40
100 yr. cut	100	"	4.0	.29	.31
Cut	50	"	3.8	.32	.30
Cottage Dike	CD3	"	5.8	.60	.70

Fig. 3c TABLE 3 ACID DIGEST ANALYSES

m.eq.

Site		Na^+	K^+	Ca^{++}	Mg^{++}	P ppm
Gull Colony	Jc1	.07	.03	.23	1.37	.003
	Jc2	.07	.04	.60	1.08	.004
	Jc3	.13	.05	.75	1.08	.008
	Jc4	.07	.04	.90	.97	.002
J. effusus Swamp	J4	.04	.04	.40	.70	.001
	J5	.05	.01	.95	.60	.001
	J6	.07	.10	.50	.58	.005
Eriophorum	E6	.11	.13	.25	.33	.004
	E7	.07	.09	.20	.33	.002
	E8	.05	.04	.35	.4	.001
Warp	W3	.20	.33	1.85	1.5	.002
Dry peat	1	.02	-	.35	.08	.001
	2	.02	-	.40	.08	-

STATISTICS

Let $\bar{x}$ = mean

S^2 = variance

S = standard deviation

S.E. = standard error

1. pH

GROUP	$\bar{x}$	S^2	S	S.E.
I	3.61	0.052	0.229	0.076
II	4.22	0.045	0.212	0.095
III	5.75	0.013	0.357	0.206
IV	6.15	0.419	0.647	0.180
V	6.83	0.106	0.325	0.145

T values found by computer using standard Statistical Programme

T-values

Means	T	Degrees of Freedom	P
1 vs 2	4.938	14	.001
1 vs 3	12.323	12	.001
1 vs 4	11.370	22	.001
1 vs 5	21.709	14	.001
2 vs 3	7.616	8	.001
2 vs 4	6.777	18	.001
2 vs 5	15.093	10	.001
3 vs 4	1.108	16	.3
3 vs 5	4.439	8	.01
4 vs 5	2.343	18	.05

2. Calcium m.eq.

GROUP	$\bar{x}$	s^2	s	S.E.
1	0.377	0.016	0.127	0.042
2	0.588	0.014	0.119	0.053
3	0.238	0.001	0.022	0.013
4	0.828	0.049	0.221	0.074
5	3.892	2.002	1.415	0.633

T-values

Means	T	Degrees of Freedom	P
1 vs 2	3.075	14	.01
1 vs 3	2.030	12	.1
1 vs 4	5.308	18	.001
1 vs 5	7.299	14	.001
2 vs 3	5.213	8	.001
2 vs 4	2.300	14	.05
2 vs 5	5.203	10	.001
3 vs 4	4.942	12	.001
3 vs 5	14.620	8	.001
4 vs 5	6.280	14	.001

3.

	GROUP	$\bar{x}$	s^2	s
Magnesium	1	0.506	0.15	
	2	0.606	0.86	
	3	0.215	0.164	
	4	0.639	1.13	
	5	1.803	0.8	
Sodium	1	0.499	0.320	
	2	0.590	0.240	
	3	0.480	0.770	
	4	0.449	0.385	
	5	1.471	0.471	

Fig. Results of ashing experiment

Calculation:

Let, weight of crucible = x gm.

" " " + soil = y gm.

" " " " " after 2 hrs at 500°c = z gm.

$$\text{Then \% inorganic content} = \frac{z - x}{y - x} \times 100.$$

Table 5

Sample		y - x	z - x	% inorganic content
Non Warp	1	.500	.0135	2.70
	2	.496	.0215	4.34
	3	.505	.0194	2.82
	4	.500	.0141	2.60
Warp	1	.500	.4285	85.70
	2	.500	.3248	64.96
	3	.500	.3570	71.40
	4	.5012	.3520	70.23

Discussion of chemical analyses

The importance of correlations between changes in pH and changes in plant communities has been well established by many studies on the chemistry of mires (Newbould and Gorham, 1956; Bellamy, 1967). This is further substantiated by the results of this study. Gorham (1956) points to the intercorrelations between pH and bicarbonate which make it difficult to decide which factor is most important.

The continued low pH of Group I and to a lesser extent Group II may be especially associated with the presence of *Sphagna* and the process of cation exchange (Clymo, 1964). Another source of acidity is the oxidation of sulphides produced in the anaerobic, waterlogged depths of peat:

$$S^{--} \rightarrow SO_4^{--}$$ (Gorham, 1956)

Oxidation of sulphide when peat is exposed to drying by cutting or burning may also lead to decreased pH. However fluctuations in the results due to hot dry weather conditions are unlikely to be large enough to affect the characteristic pH of each area (Bellamy, 1967). Hydrogen sulphide may also be released on the disturbance of bottom peats.

Water flow through an area will tend to work against the accumulation of hydrogen ions. These will either react with any bicarbonate present in the water to form carbon dioxide and water;

$$H^+ + HCO_3^- \rightarrow H_2O + CO_2$$

and/or will be flushed away (Bellamy, 1967).

Variation between *Eriophorum* and *J. effusus* communities in pH and calcium concentration is interesting, but, as explained before, should be treated with caution.

The extremely low levels of calcium and magnesium in the water samples of the Gull Colony are not explained. It is possible that low calcium values were recorded owing to interference in the method by the high phosphate levels which occurred here. However the acid digests of peat of this region showed calcium and magnesium to be relatively high.

There is a marked significant difference in pH, calcium and magnesium between the canals and other non warped areas. This is substantiated by the results of more sampling in and around the canals. They are shown to be a chemically distinct region.

The absence of marked differences between the sodium and potassium levels of different groups suggests they are not very important in this respect. A similar result was found by Gorham (1956).

Low levels of nitrate and phosphate were found. Both were found to be similarly low by Loach (1964) in his study on ombrophilous valley bog in the South of England. Higher levels of nitrate might be expected in the Gull Colony samples. Gilham (1956) found that a breeding colony of Black Backed Gulls increased the soil nitrate content by one hundred fold. It may be that nitrate being very soluble was flushed out of the area.

Higher levels of orthophosphate were however found. A trend towards increased concentrations of total phosphate was seen in the acid digest samples.

The very low levels of soluble iron and the lack of manganese together with the absence of very high sulphate concentrations on the western edge of the bog suggest little or no effect from Colliery drainage (Glover, pers. comm.).

The discrepancies between the total anion to total cation concentration cannot be explained other than by the presence of some element not investigated for, or interference in the methods used or because of experimental error.

INVESTIGATIONS INTO THE STRATIGRAPHY AND WATER LEVEL OF CERTAIN PEAT CUTS

Borings were made using a Russian pattern peat borer. Cuts containing three different types of plant communities were investigated.

(a) *Juncus effusus* and *Eriophorum angustifolium* communities.

Five peat borings were made in the North East area of peat cuts. Here for no immediately obvious reason otherwise similar "channel" cuts contain different plant communities, either dominated by *Juncus effusus* or *Eriophorum angustifolium*. This feature has already been discussed. Two pairs of borings were made. Each pair being taken from neighbouring channels which demonstrated the difference in communities. In this way differences in water level due to small topographical changes or different overall drainage were hopefully avoided. The channels are about 20 ft. apart.

A pair of borings in a similar area was made in the centre of the bog.

(b) One borning was made on Side Canal I on the southern network of canals.

(c) One boring was taken at the northern region of modern peat cutting.

It is difficult to measure the exact depth of water in the peat cuts partly because of the semi-solid nature of the bottom. No indication can be gained from comparing the level of peat above the water as this is certainly not constant from cut to cut.

However at the first three pairs of borings it was found that *J. effusus* was growing in greater depths of water than *E. angustifolium*. This was judged from a comparison of the depth of peat above the mineral deposit. More peat had apparently been removed from the channels containing *J. effusus*. (See Fig. 4)

Even within the short distances between borings variation in the underlying mineral deposit was found. A sandy, silty sand or pure silt deposit was encountered but no correlation could be made with the respective plant communities.

A brief examination of the macroscopic peat deposits of the North East corner showed them all to be basically similar and to consist of ombrophilous peat. The lower layer was a highly humified woody peat showing remains of birch. Above this at about 10 cms from the mineral deposit a sedge and birch peat began, again well humified (see Fig.4.) Most of the light Sphagnum peat has been removed by cutting.

The boring in the canal region gave very interesting findings. A silty mineral deposit was reached 1.5 m below the surface of the water. Microscopic examination was carried out later. The underlying mineral deposit was a sapropel with evidence of wind blown sand and fern sporangia. The lower peat deposit was a poor fen or marsh peat characteristic of shallow edge communities, with much Phragmites communis and Chara. A sample from above this deposit was of a well humified moderately rich Sphagnum peat. Three species were identified: S. plumulosum; S. tenellum and S. teres. The last is indicative of flowing ground water. Other species noted were Aulacomnium palustre, Molinia caerulae and members of the Cyperaceae.

Discussion of stratigraphical differences

The contrast between the ombrophilous peat deposits in the north east area with the richer fen deposits in the Canal region is in accordance with the proposed possible early development of the peat bog.

The presence of fen peat in the canal with no overlying deposit of ombrophilous peat has important implications. This may well be the source of the recorded relatively high levels of calcium and magnesium in this habitat. The extent of the fen peat should be further examined. The distribution of Cladium mariscus restricted to the western edge of the Main Canal may be an important indication of the extent of the underlying fen peat deposits. On the few occasions when this mesotrophis plant has been reported associated with acidophilous species, its root systems were in richer fen peat. (Conway, 1942).

The second important finding was the differences over only short distances in the depth of peat remaining after cutting. Although this might be expected from a knowledge of the past cutting methods it is interesting to find that it is also associated with differences in the type of plant community. J. effusus occurred at the deepest level of cut, on each of the six borings made to compare this with E. angustifolium communities. In view of the small number of borings too much emphasis should not be placed on these findings. However they highlight the variations in peat depth which are characteristic of this mire and lead to a consideration of the possible implications of this variability.

A deeper cut may reach a strata of peat which is more humified or richer in mineral nutrients. It might also bring a "richer" peat deposit within the reach of the roots or rhizomes of a species.

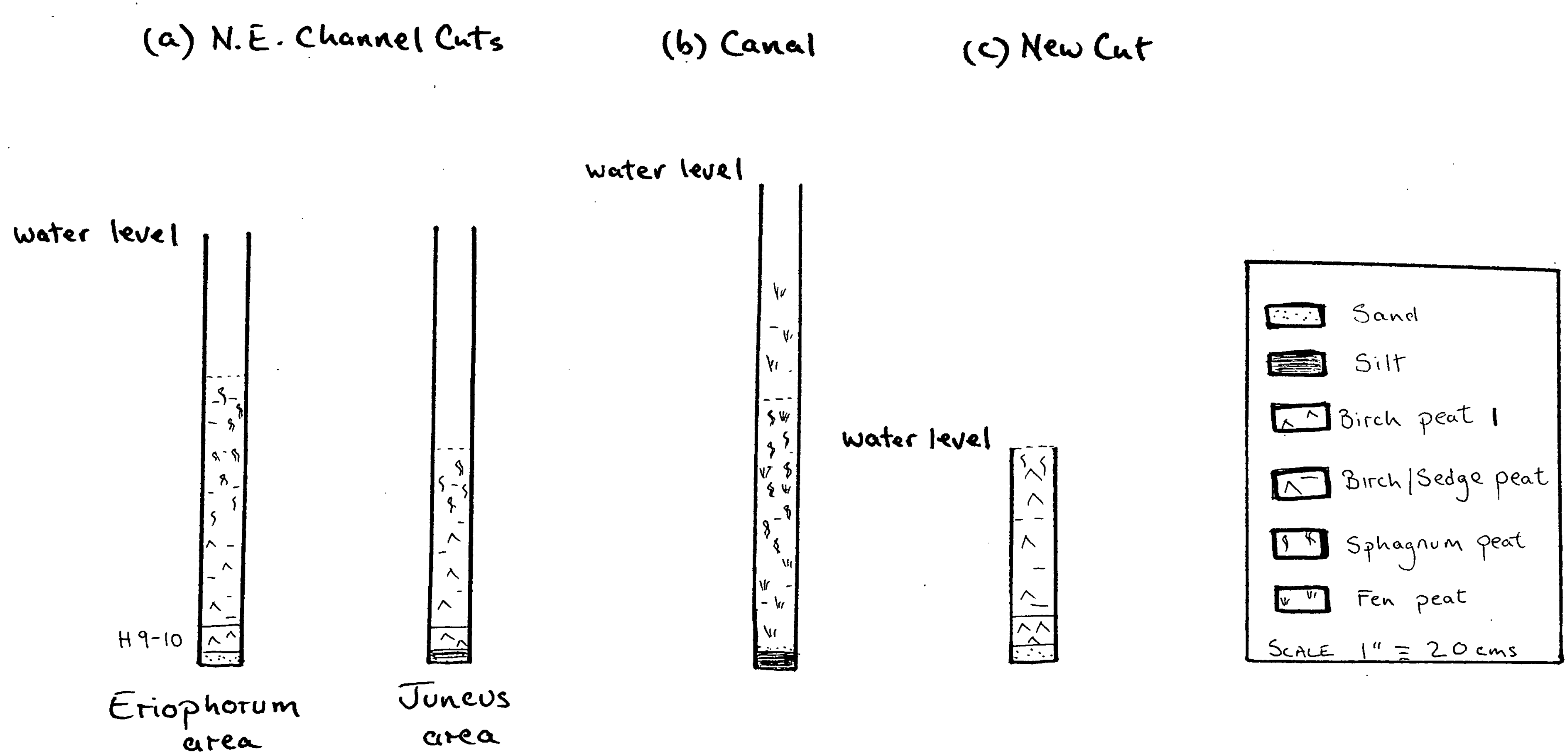
Another possibility is that a deeper cut, resulting in a shallow depth of peat above the basal mineral deposit, may alter the relationship of the surface layers to the mass ground water flow. Ingram (1967) has stressed the importance of water movement in mires on plant development. Vertical and horizontal movements may together effect ion transport through the peat and uptake from exchange sites on the peat. He suggests that the resulting effect on the availability of ions to a species may determine the outcome of interspecific competition during establishment. Water movements will also influence the state of aeration of the peat.

The influence of water flow on the distribution of Eriophorum and J. effusus communities is worthy of further examination. Certainly J. effusus thrives where water flow is apparent. For example it has rapidly colonized any new or cleared drains. The deep water of the Juncus swamps suggests inflow drainage from outside possibly connected to a deeper cut in this region. Water was observed running off the edge of the Gull colony Juncus swamp. The presence of J. effusus in the deeper channel cuts, where the borings were taken, may also reflect the influence of water flow. In particular the upper layers and roots of plants of deeper cuts would be more susceptible to the effects of vertical water movements than would those of a shallower cut.

Only a general comparison may be made of depth of peat recorded from the borings in ombrophilous regions with the one from the Canals. The amount of water flow in the Canals is again a matter of speculation. It may vary considerably throughout the network; some areas now show considerable "silting" up. These Canals were obviously wide and deep enough to allow peat barges to pass. A great deal of mixing of water must then have occurred along their lengths. However as mentioned previously they were a self-contained system with no connection with other waterways.

Topographical features affecting water movement were not considered owing to the extremely flat overall appearance of the peat bog and surrounding land and to the uneven level of surface peat.

Fig.4. Diagram to show examples of peat borings.



Peat core showing underlying sandy deposit with humified birch peat above.

GENERAL DISCUSSION

The main habitats were first described on the basis of general physical characteristics. However the canals, drains and narrow channel cuts all look rather similar and are difficult to distinguish on these features alone. They have been further differentiated by chemical factors. When examining the chemical environment of a mire community knowledge of the chemical composition of the water at one point in time is insufficient. Other factors such as water flow and the rate of replenishment of ions must be considered. The importance of water flow has already been briefly discussed; both horizontal movements, in bringing nutrients from outside, and vertical movements (e.g. in conveying minerals from a different strata). The underlying peat deposits are probably also of great importance in connection with this. Chemical analysis of contrasting peat deposits with different plant communities growing on them, would be needed to further substantiate this theory. Other characteristics such as the permeability of each strata should also be taken into account.

Other potential sources of mineral nutrients are the warped areas and the surrounding agricultural land. Effects of both were recorded in flowing drainage waters but the effect on bordering cuts has not been properly investigated. It may account for slightly higher cation concentrations in some samples. No large differences were detectable.

Colliery drainage seems to be of little consequence.

The Gull colony has been shown to affect the chemistry of a limited area.

Rainfall may be the main source of mineral nutrients in some ombrogenous mires. It may still be of consequence here despite the low rainfall of this area because of the proximity of the sea and tidal estuary and the relatively high ionic content of sea spray (Bellamy, 1967).

In this region industrial pollutants may be expected in the rainfall, especially sulphur dioxide.*

Before predicting the importance of each of these factors on the future development of modern peat cuts, a review of their influence on existing plant communities would be valuable.

The warped peat is a very distinct region; the source of its high mineral content is now obvious. The water table has remained high in spite of the general lowering of the surrounding peat by cutting. This is because the weight of warp has compressed and lowered the underlying peat.

The source of relatively high levels of pH and certain cations in the Canals is more obscure. That it is not warp is substantiated by comparing the nature of the ionic values; by the lack of mineral sediment overlying the original fen peat deposits; by the absence of any reason to warp this area and the fact that no direct connection with warping drains or warped land exists.

Relatively high levels of calcium and magnesium here may be explained by the presence of the underlying poor fen peat deposit. This is less satisfactory in accounting for the higher pH and bicarbonate. Some water flow would seem likely especially on considering the length and depth of these canals which would tend to collect drainage water. If the historical picture of the development of the peat is correct it would seem unlikely that this fen peat stretches right across the peat bog in the path of the Canals. Considerable mixing during at least one period in the past (such as when in use for conveying the peat barges) could explain the distribution of richer material. On the other hand present day water flow could be of particular relevance here.

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* Attempts to obtain fresh rain water samples to analyse unfortunately failed.

An important factor in the development of the varied communities of the Canals has been the lack of interference over a long period. During this time the water level has remained sufficiently high to allow these species to flourish.

The factors distinguishing Eriophorum and Juncus effusus communities are not so obvious. Both are found above ombrogenous deposits but slight differences in potential nutrient value may occur.

An examination of the relationship of the different strata to the plant roots and a chemical analysis would be particularly interesting here. Water movement may be important in this respect. There is some indication that J. effusus "prefers" areas of water flow. It may be that it requires the conditions of increased aeration associated with this flow or that it cannot compete so successfully with Eriophorum on more anaerobic peat. The latter is known to flourish in such conditions (Phillips, 1954) whereas J. effusus has been described as "probably confined to substrata aerated at least part of the year" (Richards and Clapham, 1941). It is also found to be confined to the lagg communities of undrained bogs. Further work is required to establish a correlation between the distribution of these two species and the presence and absence of water flow.

The effect of water level on their respective occurrence is unclear. Both species are found over a range of depth of water. J. effusus was growing in over 3 ft. of water but it was not known whether the community became established under these conditions or in retrospect whether there was any sign of new growth. A community may continue to flourish in an environment much changed from the one in which it became established. J. effusus is apparently not suffering from effects of higher phosphate levels.

Possible future development of modern cuts

The style of cutting has already been described. Two cuts are usually made down to a total depth of about 9 ft. The peat is well drained before cutting and this good drainage continues for some time afterwards. The bottoms of the cuts are therefore only just at or below the water table.

On examination part of the north cut was found to have exposed ombrogenous deposits similar to those found in the neighbouring Juncus and Eriophorum communities. If the water level rises it seems that one or other of these species will invade this area. Any water flow is likely to encourage colonization by a J. effusus swamp. There may then be subsequent use of the area by breeding colonies of Gulls. Few other plant species may be represented in this community. If Eriophorum became established, it is more likely to have a variety of Sphagna associated with it. The outward spread of other oligotrophic species from the canal region has already been noted. In time these species might also colonize the new cuts.

Enrichment by agricultural and warp 'run off' cannot be ruled out but the establishment of mesotrophic species seems unlikely because of the oligotrophic nature of the bottom peat. There is also an indication that merely small increases in mineral nutrients may give J. effusus some advantage over Eriophorum in colonizing the area.

The southern modern peat cuts were not examined. However from their geographical location on the western side of the peat bog it is predictable that at least part of the cuts are over richer fen peat deposits adjoining those of the canal region. It is known that this is an area of thick silty clay deposits (pers. comm. C.E.G.B. 1969) which would increase the likelihood that fen peat had originally developed here. It is possible therefore that if the water level was maintained at a reasonable height (sufficient to prevent drying out of the bottom peats in summer) then a community similar to that of the Canals may spread from there and become established in these new cuts.

RECOMMENDATIONS FOR FUTURE MANAGEMENT

The maintenance of a high water table is of obvious importance to the development of the mire. Great changes are constantly being made on the drainage pattern of the mire with, locally, great effect. It would therefore seem feasible to "manage" the level of water in the cuts to encourage the development of the favoured community.

Water flow appears to be of at least equal importance. The amount of flow would probably be related to the water level attained. To keep the water flow at a minimum in the northern cuts would encourage the growth of ombrophilous mire type communities especially Eriophorum and Sphagna with the possibility of the spread of a greater variety of species from the canal region. The effect of reduced water movement in the southern cuts is less predictable but by mimicking the present conditions in the Canals the spread of a similar community would be hopefully encouraged.

Peat cutting can be seen to be sometimes advantageous. However there is one region which should certainly not be cut; that is the Canal region. There are in fact plans for doing this in the very near future. It is extremely important to the ecological interest of Thorne Waste that these Canal communities are not obliterated. They provide a reservoir of species, some of which are now spreading to later cuts. Their value is enhanced by the fact that they extend right across the peat bog.

The Dutch left large baulks of peat as retaining banks for the Canals and the intervening areas (of some 200 yds) have had shallow depths of peat removed.

If economic considerations are overriding then it is suggested that at least the network richest in species, south of Cottage Dike, should remain untouched at the expense of the northern stretches. If necessary the feasibility of cutting up, between each Side Canal, without adversely affecting their water table should be examined. Observations on the proximity of the southern cuts to the ends of the side canals suggest this may be possible.

The diagram on page 47b shows what a small area the Canals occupy in relation to the total expanse of the peat bog. It is surely possible to avoid cutting them in the interest of maintaining and encouraging the varied flora of Thorne Waste.

SUMMARY

The plant ecology of a former raised bog at Thorne Waste was investigated. A mosaic of oligotrophic and mesotrophic communities was described. In accounting for the development of the unusual plant distribution the importance of historical factors is recognised including previous vegetation and man's activities. All parts of the mire have been modified to some extent by past and present anthropological influences.

The variety of habitats so created were shown to be further differentiated by the chemical characteristics of the mire water and surface peat. The relevance of stratigraphy and water movement was discussed.

A discussion of the possible future development of the mire based on these findings indicates the maintenance of a reservoir of species as being of vital importance to the conservation of the "richness" of Thorne Waste.

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APPENDIX

A further account of the drainage of Thorne Waste

As mentioned, large scale drainage of the Humberhead levels began in 1620 when Charles I commissioned Cornelius Vermuyden to drain Hatfield Chase. The Participants, as the group of Dutchmen were called, were rewarded with one-third of the reclaimed land. Altogether 75,000 acres of land to the south and east of Thorne were to be drained. Instead of utilizing the existing natural drainage system they considerably altered and artificially extended it. The course of the River Idle was diverted and the southern branch of the Don stopped. The remaining branch was widened and diverted along what is now called the Dutch River. Although enlarged, the Don proved insufficient to carry the excess water and much flooding of previously good land around Fishlake and Sykehouse occurred. (Their activities led to years of angry disputes with the local inhabitants.)

In 1792 the land between Thorne Waste and Hatfield Chase was so waterlogged as to be impassable to normal traffic. An Act of Parliament was passed at this time to allow a new Canal, the Stainforth and Keady, to be built to restore communications.

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Further considerations of the practice of warping

Cart warping had been practised around the Humber estuary for several centuries before the idea was extended by Creyke in the early eighteen hundreds. He was responsible for the construction of the Swinefleet Warping Drain which extends from the River Ouse on to Thorne Waste. The drains for carrying the warp ladened waters had to be well reinforced to withstand the force of the incoming tidal waters.

The land to be warped was first prepared by cutting the peat down to below sea level and enclosing it with an outer drain plus embankment to prevent the escape of the water. The Thousand Acre Drain on the Waste may well have served this purpose. A network of smaller drains inside this enclosure served to distribute the water and warp evenly. Spring tides were preferred as the strength of tide was then generally sufficient to force the water on to the land, where it stood and the sediment settled out. The spring ebb was strong enough to draw the water off again. Any excess water left behind might be drained off the land into a 'warping pond'. The remains of such a pond are found by Moorend Colliery.

In the final discussion the 'warping' of the Canals was discounted. There is a slight possibility that excess warp waters accidentally escaped on to the peat bog. However care would be taken to keep the silt ladened waters on the land and any left after the ebb tide would be comparatively free of sediment.

The process of warping was repeated several times so that in one season 1 to 3 ft. of alluvium might be deposited on the peat. The subsequent sinking of the peat often necessitated repeated warping several years later to raise the level of the land above the water table.

The Swinefleet Warping Drain does not appear to have extended as far as the southern area of warp. It is possible there is a different source of warp here. Edwards, in 1851, describes the practice of dry warping on Hatfield Chase and states that this method was to be used on Thorne Waste. By this method river alluvium from the old river beds of the Idle and Don were transported by rail and spread out on the land.

References. As in Bibliography.

APPENDIX TABLE

PRELIMINARY INVESTIGATION

Results of chemical analysis

Sample Site			pH	K	Na	Mg
WARP	A	ppm	6.8	5	29	60
	B		6.8	2	18	30
(Drain)	C		5.8	1	13	16.5
	D		6.8	5	20	30
Eriophorum area	A		3.4	.5	10	6
	B		3.6	1	11	10
	C		3.5	1	13	13
	D		3.5	1	12	7.5
New cut	A		3.6	1	18	13
Channel cut	A		3.8	2	14	18
Mill Drain	A		3.9	1	13	13
Juncus area			3.9	1	12	10

THE TIMES ... AUGUST 1971

A self-taught naturalist will fight again to save rich waste from jumbo jets

Regional notebook

Ronald Faux

The stretch of sour, waterlogged land lying low to the south of Goole seems magnetically attractive to planners of airports and to authorities with a lot of rubbish to tip. It stands out on the map as a bald patch of nothing in a featureless countryside.

But its name is really inapt. Thorne Waste suggests useless scrubland which no one would mourn if it disapeared beneath concrete, but to a growing number of universities and naturalists Thorne Waste is 10 square miles of laboratory, rich in rare animal and plant life of consuming interest to botanists, biologists and workers in several other branches of natural science.

The area has already escaped proposals that it should be the Stansted alternative in the third London airport saga, and that it should sink beneath layers of pulverized fuel ash from Drax power station. Now West Riding County Council is persisting with proposals that Thorne Waste should be the site of an international airport serving the region.

The council points out that the Waste lies close to the motorway that will link Hull to the industrial North. The main north-south railway line passes near by. Few people will be disturbed either by aircraft noise or through losing their homes. The main approach would be over the Humber estuary and the final approaches clear of high ground or built-up areas.

Eighteen million people live in the urban crescent stretching from Birkenhead to industrial Yorkshire, and both Birmingham and Manchester have little room to expand their airports. Chambers of commerce in the region, industrialists and several northern MPs support the county council's proposal, so with the conservation organizations now solidly ranked against changing the Waste at all the ground is set for a classic and irreconcilable clash—the jumbo versus a teeming wealth of beetles and butterflies; concrete or a rich tangle of wild plants growing.

The county council says the choices are not so stark, since not all the Waste need be taken over for the new airport, but it faces a dedicated and sceptical opponent in Mr William Bunting, of Thorne, who for over 15 years has been a true thorn to anyone who has interfered with the Waste. He prefers to call it by its alternative name, Thorne Moors, "but forget any other moor you have ever seen. This one is really different."

He strode along a narrow track, cutting back encroaching branches of birch scrub with a sharp machete. They might have been meddling bureaucratic fingers. "The airport idea is bunkum, absolute bunkum", he declared hotly. He pointed to the thick clusters of wild plants, pools choked with cushions of *Andromeda* and cotton grass, and wide stretches of peat bog lying thick an still. He went on: "It would cost many millions to build an airport here. There is 9ft of peat under this path. The moors are like a big sponge. They could build, but it would be costly and unnecessary."

Whitehall urged to look north for airport site

The Government is being urged to build a new international airport at Thorne Waste, Yorkshire, in the Humber estuary, and not ignore the problems of the rest of the country because of preoccupation with London's third airport.

Mr Brian Dixon, deputy county planning officer for the West Riding, writes in the journal of the Town and Country Planning Association: "There is a need for a major airport to be situated east of the Pennines." The West Riding had the ideal site in view of the need to site airports away from centres of population and near modern transport systems.

"Whitehall seems to be forgetting the needs of those other parts of England which include large industrial and residential complexes," he adds.

A new airport should be built at Thorne Waste, at the head of the Humber estuary. It was away from densely populated areas yet sufficiently close to the industrialised towns of the North and had excellent motorway and rail links. It covered 6,000 acres. There would be no noise problem.

A new airport would bring also a new economic stimulus to the flagging economy of the area. And would offer much-needed employment. Few sites in England presented such opportunities.

Mr Dixon goes on: "The South-east does not need any further economic stimulus whereas a major airport at Thorne would transform the economy of South Yorkshire and Humberside."

The Guardian March 26 1971

Thorne Waste: the case for a national policy

IF WE NEED another international airport, why not build it where it does least harm ? Mr Peter Walker, Secretary for the Environment, has ruled out the claims of Thorne Waste, in the West Riding of Yorkshire, to be London's third airport. But should the new airport be London's third or England's fourth ?

Thorne has a population of 4.25 million within 45 minutes by road. Its catchment would include not only industrial Yorkshire but future holiday and commercial traffic from across the Pennines and from the North-east. There are obstacles. There are also attractions. Our Regional Affairs and Yorkshire Correspondents examine them.